Biomechanical Validation of Medial Pie Crusting for TKA Soft Tissue Balancing

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Introduction: Soft tissue balancing is an important part of every total knee arthroplasty (TKA) surgery. Traditionally, balancing the varus knee has been approached by releasing portions of the medial soft tissue sleeve in a sub-periosteal nature off of the proximal tibia, but this may lead to undue laxity or residual pain about the area where the release was performed. More recently, “pie crusting” of the medial soft tissue sleeve has been used to balance the varus knee without compromising the structural integrity of the ligament and without sub-periosteal release (Ranawat et al 2012). This technique may provide advantages over a sub-periosteal release by targeting only medial tight bands that can be palpated with the capsule distracted by a laminar spreader in 90 degrees of flexion and full extension. This study aims to biomechanically validate the pie crusting technique of the medial soft tissue sleeve and compare the results to those of standard medial releases that have been previously reported. Our hypothesis is that pie crusting will be as effective as complete subperiosteal release and that targeting the anterior and posterior aspects of the medial soft tissue sleeve will have more effect on the flexion and extension gaps respectively. These hypotheses are based on previous reports where the anterior portion of the superficial medial collateral ligament released in a standard fashion has more effect on the flexion gap compared to the posterior aspect of the SMCL and posterior oblique ligament which has more effect on the extension space (Whiteside 2001).

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. Ten knee specimens (4 Left, 6 Right, including 2 bilateral cadavers) 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, while the proximal tibiofibular joint was left intact and the fibular shaft transected 100mm from the joint line. 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. Specimens were then placed with the tibia mounted vertically in the machine, and the femoral coupling locked in a neutral position as defined by the tibia being placed vertically. Specimens were tested with the knee joint at full extension and at 30, 60, and 90 degrees of flexion. An upward vertical force of 30N 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 free to rotate about the joint center in the coronal plane. A 10Nm varus and valgus torque was also applied to the tibia, while internal-external rotation was unconstrained. A fellowship trained board-certified orthopedic surgeon then performed a standard arthrotomy to gain access into the knee capsule. Using a number 11 scalpel, alternating stab patterns of 4-5mm known as “pie crusting” were made into the anterior aspect of the superficial medial collateral ligament (SMCL) from the medial epicondyle to the tibial insertion on 5 TKA specimens (figure 1). The other 5 specimens were subjected to pie crusting in a similar manner on the posterior aspect of the SMCL. Pie crusting was then performed on the opposite portion of the SMCL on all specimens, resulting in a “complete” pie crusting. After the total pie crusting, the SMCL was released from its attachment in a subperiosteal manner on the proximal tibia down to 5cm below the joint line. After each alteration, the specimen was subjected to the same loads and positions as the native specimen. The angular deflection in degrees at ±10Nm of valgus torque in the coronal plane referenced from normal neutral position was recorded to determine the 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. Paired t-tests were used to detect statistical differences in data from the 5 anterior pie crusting specimens to the matching data from complete pie crusting and ligament release, and likewise for the posterior pie crusting data. A Holms-Sidak correction was used for these analyses. A single paired t-test was used to compare all pie crusting and ligament release data, and anterior and posterior pie crusting were analyzed using a Student’s t-test. All statistical analyses were performed using SPSS version 21.0 (IBM-SPSS, Armonk, New York) software. A p-value less than 0.05 was considered significant at the 95% confidence level.

Results: No significant changes from normal TKA knees were found in varus laxity for any of the surgical procedures. Posterior pie crusting had a greater effect on valgus laxity at all flexion angles compared to anterior pie crusting. Anterior pie crusting increased valgus laxity by 0.9±0.2 degrees in full extension and 1.6±0.9 degrees at 90 degrees of flexion. In comparison, posterior pie crusting increased valgus laxity by 3.4±1.4 degrees in extension and 4.1±1.0 degrees in flexion. Complete pie crusting and a standard ligament release produced essentially the same changes in valgus laxity at full extension, but ligament...
release had a significantly greater effect at 90 degrees of flexion, increasing laxity by 3.3 degrees over pie crusting (figure 2). No significant changes occurred between pie crusting and ligament release in external rotation (figure 3), but they were significantly different at flexion angles of 30, 60, and 90 degrees in internal rotation (figure 4).

**Discussion:** As with previously reported studies concerning subperiosteal release of the anterior and posterior portions of the SMCL and posterior oblique ligament, anterior pie crusting produced a greater change in laxity from normal conditions in flexion. Likewise, pie crusting the posterior aspect of the medial soft tissue sleeve (SMCL and posterior oblique ligament) produced greater laxity changes at full extension and 30 degrees of flexion, where these aspects of the medial sleeve are tightest. Overall, pie crusting and ligament release produced increasingly greater changes in laxity as the flexion angle increased, but the subperiosteal release did effect a greater change overall. This suggests that ligament release may compromise stability compared to pie crusting but in severe deformity cases pie crusting may not afford enough release to balance the medial joint gap. Limitations of this study include a small sample size and variation in the age and implant type, leading to large differences in normal laxity among the specimens.

**Significance:** Knowledge of how different pie crusting techniques affect laxity through a range of knee flexion could help surgeons better target the necessary structures to balance ligaments during TKA surgery.

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**References:**

![Figure 1: Images of pie crusting technique. Left: scalpel used to indicate posterior pie crusting region of SMCL on left knee. Right: anterior pie crusting performed on right knee.](image1)

![Figure 2: Valgus laxity of different surgical procedures performed. Values are average changes from normal laxity. Anterior and posterior pie crusting are averages of 5 TKA specimens, and complete pie crusting and ligament release are averages of 10 specimens. Error bars indicate standard error of the mean (SEM). Symbols indicate statistical difference. * indicates difference from anterior pie crusting, + indicates difference from complete pie crusting.](image2)
Figure 3: External rotational laxity changes from normal of different surgical procedures performed. Values are average changes from normal laxity.

* difference from anterior pie crusting

Figure 4: Internal laxity changes of different surgical procedures. Values are changes from normal laxity.

* difference from anterior pie crusting  + difference from complete pie crusting