Effect of Labral Tear Size on Acetabular Suction Seal

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Disclosures:

INTRODUCTION: The labrum's primary function is to deepen the hip joint and dissipate the hip joint compressive forces through the establishment of a ring-shaped suction seal around the joint. This seal creates an improved fit for the acetabular head while helping maintain synovial fluid within the hip capsule, regulating fluid pressurization and stress distribution during weight-bearing activities. While research is abundant on labral tears in literature, most studies focus on clinical functional outcomes and biomechanical behaviors before and after repairs or reconstructions. The objective of this study was to determine how varying sizes of labral tears affect the sealing function of the labrum by quantifying the peak distraction force during controlled pullout tests to dislocate the hip joint.

METHODS: Four labral tears sizes were studied based on the most common location and sizes for tears. These tears consisted of progressively increasing sizes, described by the number of clockface hours of 1, 2, 3, and 4 hours, located at the 12-1, 12-2, 12-3, and 11-3 o'clock positions, respectively. The native labrum was used as a control. The specimen was isolated from the pelvis with an adequate portion of the proximal femur and the acetabulum to preserve the hip joint and its capsule. The femur was transected at approximately 2 inches from the lesser trochanter. A threaded rod (½ inch) was drilled through the proximal femur centered at the intertrochanter in the anteroposterior direction. The rod was coupled with a pair of eyebolts connected to the actuator of a servo-hydraulic testing system (Landmark 370, MTS Systems, Eden Prairies, MN) to apply axial loads to the proximal femur. The acetabulum side of the specimens was mounted on the base of the testing system potted in dental cement with the hip joint held in 10º abduction and 15º flexion position to avoid impingement of the labrum during distraction (Figure 1). The joint capsule was cut right before loading. Approximately 1 ml of J&J baby gel was squirted in the joint space to mimic intraarticular synovial fluid lost, and the specimen was wrapped in a saline-soaked paper towel. Testing was initiated by applying a compressive load up to 500 N to the acetabulum at a rate of 3.0 mm/s followed by decompression and extraction at a rate of 1.0 mm/s to a maximum distance of 12 mm. Force and displacement were recorded to capture the failure point of the suction seal identified as a rapid drop in force. Following each round of distraction tests, the labrum was progressively released off the bony acetabular rim using a No.15 scalpel, and the tests were repeated with each newly enlarged tear. Peak distraction force was identified on the force-displacement plot of each trial. The work needed to break the acetabular suction was identified as the area under the curve from the onset of distraction to the maximum displacement of 12 mm. Following trial completion, labrum height was measured at each hour mark of the tear (11 o'clock to 3 o'clock) and this value was averaged across all five sites. Non-parametric analyses were conducted to account for the small sample size. Repeated measure one-way analysis of variance (ANOVA Friedman test) of the peak distraction force and work to failure across all five groups was conducted. Post-hoc comparisons (Dunn's test) were used to compare varying tear sizes to native labrum baseline data. Spearman correlation between peak force and labral size was also performed. The significance level was set at 5% for all tests.

RESULTS: Six pairs of hemipelvis were available for the study. After screening for pre-existing tears (n=2) and extremely small labrum (< 2 mm, n=2), eight hemipelves from five donors (mean age 45.5 yrs, range 20-69 yrs, 3 males and 2 females) were included. The peak distraction force was averaged (SD) at 121±38 N for the intact and decreased to 101±34 N, 82±40 N, 69±35 N, and 57±27 N for the 1-hour, 2-hour, 3-hour, and 4-hour tears respectively (Figure 2). The reductions from the Intact were significant for 3-hour (by 43%, $p<0.02$) and 4-hour (by 53%, $p<0.001$) groups (Figure 2). The work required to break the suction when the labrum was intact was averaged (SD) at 620±187 mJ and decreased to 482±230 mJ, 337±188 mJ, 241±175 mJ, and 179±127 mJ for the 1-hour, 2-hour, 3-hour, and 4-hour tears respectively (Figure 3). The reduction in work reached statistically significant levels in the 3-hour (by 61%, $p<0.006$) and 4-hour (by 71%, $p<0.001$) groups. The average labrum height across the eight hips was 5.2 ± 2.2 mm (range 2.7 – 8.8 mm). The correlation was not significant between the labral size and the peak distraction ($r=0.52$, $p=0.20$) nor with the work ($r=0.68$, $p=0.07$).

DISCUSSION: Sequential distraction tests from our study demonstrated the progressive weakening of the labral sealing function, as measured by peak distraction force and the work required, with the increase in labral tear size. Labral tears of 3 hours or larger significantly reduced both distraction and work needed to break the suction. The reduction in work with increased labral tears occurred more rapidly than the reduction in peak distraction force. Observation of the force-displacement curves noticed that in the native labrum, the force initiated at a faster rate and maintained over a longer distraction distance than all the cases of tears. Labral size has been shown to influence the sealing function of the hip; however, the present study did not find a strong relationship given our limited sample size. Besides the small sample size, another limitation that should be noted of the study is that the distraction of the femur at a quasistatic rate provides a consistent loading environment for comparison, but it is not readily related to any specific activities of daily living.

SIGNIFICANCE/CLINICAL RELEVANCE: Acetabular labrum has increasingly been recognized as playing an important role in maintaining joint stability and improving the subchondral loading environment of the joint through its suction sealing function. The present study provides quantitative biomechanics evidence of the labral tear impact on sealing function in terms of tear size, knowledge useful in selecting treatment options, and timing.

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Figure 1. Testing setup.

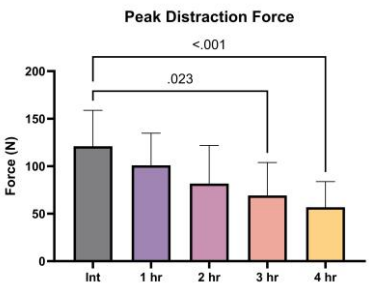

Figure 2. Mean (SD) Peak distraction force.

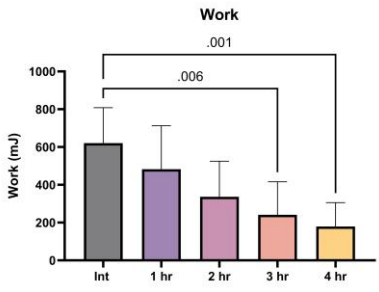

Figure 3. Mean (SD) work to failure.