INTRODUCTION: Fluoroscopy studies show the hip subluxes during the swing phase of gait in subjects with total hip arthroplasty [1], demonstrating distraction forces act on the hip with gait. The periarticular soft tissues, including the labrum and capsule with its associated ligaments and zona orbicularis provide hip stability in distraction [2]. We hypothesize that the zona orbicularis is the most important contributor to hip stability in distraction.

METHODS: Experimental Setup: Seven fresh frozen cadaveric hip specimens from 7 male donors were subjected to distraction of the femur from the acetabulum in a direction parallel to the femoral shaft with the hip in the neutral position using a testing machine (MTS Bionix 858). After ten cycles of preconditioning from 20 to 100 N distraction, each specimen was loaded in tension by distracting the femur longitudinally from the acetabulum at a constant rate of 0.4 mm/sec to a maximum displacement of 5 mm [3].

Experimental Sequences: Each specimen was distracted under 8 sequential different conditions. (1) Normal condition All muscles and skin were removed, but the capsule was left intact. (2) Venting the capsule To evaluate the effect of disruption of the capsular seal, the anteroinferior part of the capsule was vented by placing an 18-gauge needle. (3) Incised iliofemoral ligament The distal part of the greater iliofemoral ligament was transversely cut without excising the capsule. (4) Circumferentially incised capsule The capsular insertion on the femur was circumferentially detached from the femur at the intertrochanteric line to evaluate the effect of having complete discontinuity of the capsule and all of its ligaments. (5) Partially resected capsule The distal 1 cm of the capsule was circumferentially resected. The main thickest part of the zona orbicularis was maintained in all specimens. (6) Completely resected capsule The entire capsule was completely excised. The labrum was kept intact in experiments (1) through (6). We assessed the stabilizing function of the intact labrum itself without the surrounding capsule in this experiment. (7) Incised labrum We created an anterior radial labral tear by cutting the anterior labrum with a scalpel to the bony edge of the acetabulum. (8) Completely resected labrum The labrum was completely removed.

Histologic Analysis: To evaluate the morphology and histology of the zona orbicularis, an embalmed specimen from a 76-year-old male cadaveric donor (not included in distraction experiments) was evaluated. The posterior part of the zona orbicularis was histologically analyzed.

RESULTS: The greatest reduction of distraction load was observed between the partially resected capsule phase and completely resected capsule phase at 1 mm, 3 mm and 5 mm joint displacements. (Table 1, Fig. 1; p-values in Table 2). The distraction load reduced in the vented capsule at 1 mm and 3 mm displacements. The distraction load did not significantly decrease after the iliofemoral ligament was incised. Circumferentially incising the capsule and removing the distal 1 cm of capsule (the partially resected capsule phase) did not significantly reduce the load necessary to distract the hip joint at 3 mm and 5 mm displacements. The distraction load reduced in the torn labrum phase at 3 mm displacement. The distraction load was still further decreased when the labrum was cut at 3 mm displacement. The distraction load was also reduced after the labrum was completely resected at 1 mm and 3 mm displacements, however, no significant difference was found at 5 mm displacement. Grossly the capsule is internally shaped like an hourglass with the narrowest part being the zona orbicularis and located at the level of the femoral neck (Fig. 2). Histologically, the zona orbicularis consisted of densely packed collagen fibers oriented in a circumferential direction.

Discussion: The zona orbicularis appears grossly, histologically, and biomechanically to act as a locking ring around the neck of the femur. Based on our sequential cutting, the zona orbicularis was the most important structure contributing to biomechanical hip stability in distraction. The isolated acetabular labrum contributes to stability when the joint is distracted smaller distances (1 mm and 3 mm). However, the contribution of the labrum without the surrounding capsule is much less than that of the zona orbicularis. In the tested position, the contribution of the iliofemoral ligament is less than that of the zona orbicularis. The sealed environment of the joint enhances joint stability, but its effect is less than that of the zona orbicularis. To our knowledge, this is the first study that evaluated to what degree each joint structure contributes to the hip stability in distraction, advancing our understanding of biomechanical hip stability. Hip stability in distraction is determined in large part by the integrity of the proximal capsule including the zona orbicularis, implying that abnormality of this structure would affect joint stability.