Effectiveness of Labral and Capsular Management Towards Hip Stability Before and After Cam Over-Resection: An In Vitro Imaging Study

Mohammadreza Kheshti[1], Luke Beaton[1], Peter Doan[1], Louis Ferreira[1], Ryan M. Degen[1], K.C. Geoffrey Ng[1]
[1] Western University, London, ON, Canada

Disclosures: None

INTRODUCTION: Cam-type femoroacetabular impingement (FAI) is a leading cause of early hip osteoarthritis, where an enlarged femoral head restricts motion and damages the labrum. Femoral head incongruency leads to loss of a concentric center of rotation and labral damage, disrupting the suction seal and ultimately increasing translation and compromising joint stability [1]. Surgical treatment of cam FAI often involves capsulotomy, labral repair, and cam resection, yet the biomechanical impact on intraarticular joint mechanics and stability remains unclear. This in vitro cadaveric study aimed to quantify femoral head translations across successive surgical stages—intact hip, capsular and labral management, cam over-resection—using CT imaging and an imaging-compatible mechanical hip testing fixture.

METHOD: Six fresh-frozen cadaveric hips (n = 6, 3M:3F; age = 52 ± 7 years; IRB# 120409) were denuded to the bone and capsule. Each truncated hip was potted and mounted onto our novel, 3D-printed fixture compatible with clinical imaging [2]. The custom fixture was printed from tough polylactic acid for its rigidity and radiolucency, enabling imaging in a conventional CT scanner (Aquilion ONE PRISM; Canon Medical, 512×512 resolution, 0.5 mm slice, 135 kVp, 0.587 mm pixel spacing). Specimens were tested at 0°, 60°, and 90° flexion with neutral rotation, internal rotation, and external rotation. Each hip underwent two protocols across nine testing stages, with cam over-resection performed either before or after labral management. After the intact hips and capsulotomy stages were tested: Protocol A then examined cam over-resection (5 mm beyond physeal scar) before labral tear, repair, reconstruction with capsular management; while Protocol B then examined labral tear, repair, reconstruction, and then cam over-resection with capsular management. After each stage, the capsule was closed using simple, interrupted sutures. Three specimens were assigned to each of the two protocols randomly. The 3D bone and soft tissue models were reconstructed from the CT data using segmentation software (Simpleware, Synopsys) and joint translations were calculated as the distances between the femoral head and acetabular centers. Statistical analysis was performed using the Friedman test to compare translation across surgical stages ($\alpha = 0.05$).

RESULTS: In Protocol A, translations progressively increased with each surgical stage, where capsular closure was able to slightly reduce translations (Figure 1.B1). This pattern was consistent across other tested positions, including 90° flexion and internal rotation. In Protocol B, 0° flexion with external rotation demonstrated a significant difference compared to other positions ($p = 0.02$; Figure 1.B2). Translation increased after capsulotomy (MD = 1.2 mm [IQR 1.2–1.6]), labral tear with capsulotomy (2.9 mm [IQR 2–4.2]), and labral repair with capsulotomy (3.7 mm [IQR 2.5–4.1]) compared to the intact state (0.9 mm [IQR 0.7–1]). Capsular closure after labral repair reduced translation to 1.1 mm [IQR 0.5–2.2] compared to labral repair. Labral reconstruction with capsulotomy increased translation to 2.9 mm [IQR 2.6–5.4] compared to intact hip. After capsular closure, translation decreased to 1.9 mm [IQR 1.4–3.1] compared to labral reconstruction with capsulotomy. Capsulotomy with an over-resection caused the largest increase (4.8 mm [IQR 2.6–7.2]), while subsequent capsular closure decreased translation to 0.6 mm [IQR 0.5–1.5], which would be below the intact state. At 60° flexion with external rotation, joint translation progressively increased following capsulotomy, labral tear, labral repair, labral reconstruction, and over-resection, but consistently decreased after capsule closure.

DISCUSSION: The most important finding was that the capsular closure was crucial in reducing joint translation closer to the intact hip. Our testing protocol isolated the cam over-resection to assess its effects before and after soft tissue management. Moreover, this enabled us to visualize intraarticular joint in various positions and evaluate how different surgical stages affect joint stability. Although cam over-resection increased translation, joint stability was still safely maintained when the labrum was intact. In addition to the labrum acting synergistically to preserve the suction seal and resist translation, the capsule plays a predominant role in restricting hip instability at higher amplitudes of hip mobility [3]. Following cam over-resection, focusing on capsular management is key, as it controls instability more effectively than labral management. Proper capsular management improves stability and restores native hip joint mechanics, helping to reduce pain and lower the risk of revision surgery.

SIGNIFICANCE: Although adequate cam resection and labral management are necessary to restore native joint mechanics, capsular repair is essential to reduce postoperative instability.

ACKNOWLEDGEMENTS: The study was funded by the Arthritis Society Canada Ignite Innovation Grant (Ng, Degen). Thank you to Tom Chmiel for his help with 3D printing and fabrication; and Brittany Sinclair for her help with CT imaging.

REFERENCES:
[1] A. J. Hoffer, et al., Arthroscopy: The Journal of Arthroscopic & Related Surgery, vol. 41, no. 5, pp. 1390–1399, May 2025.
[2] Mohammadreza Kheshti, et al., Canadian Society for Biomechanics, Aug. 2024.
[3] K. C. G. Ng, et al., Arthroscopy, vol. 37, no. 1, pp. 159–170, Jan. 2021.

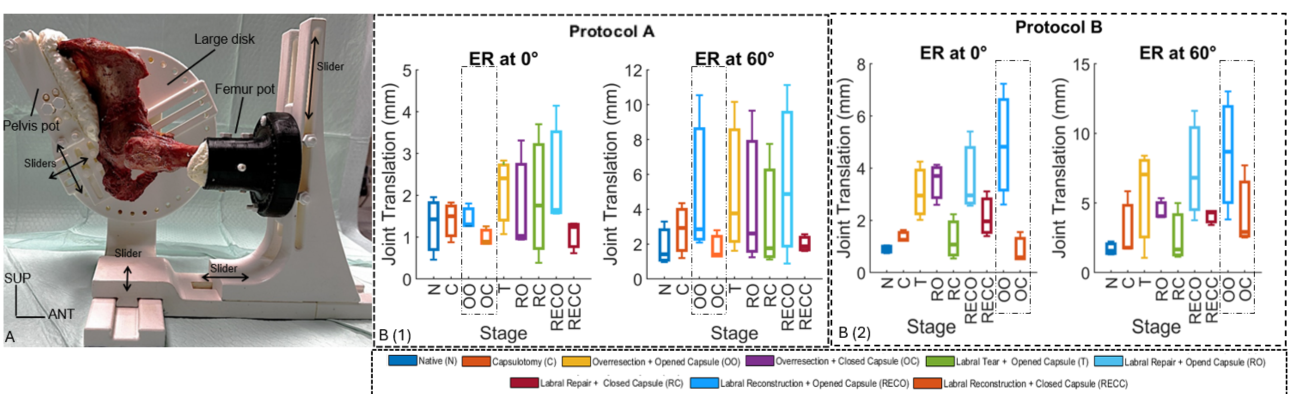

Fig 1. (A) Testing device compatible with clinical imaging with mounted cadaveric hip specimen in sagittal view (60° flexion and neutral rotation). (B) Box-and-whisker plots of joint translation (mm) under external rotation (ER) at 0° and 60° for Protocol A (B(1)) and Protocol B (B(2)). Different colors represent the tested conditions.