

Dynamic Coverage Following Periacetabular Osteotomy Surgery for Dysplastic Hips

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INTRODUCTION: Developmental dysplasia of the hip (DDH) is an arthritis-causing disorder that involves reduced hip stability due to insufficient coverage of the femoral head. [1,2] Current treatment for DDH focuses on reorienting the acetabulum (pelvis socket) using periacetabular osteotomy (PAO) surgery to improve femoral head coverage. [3] Coverage before, during, and after surgery is most often measured using 2D radiographs. Two key limitations with 2D radiographic measures are that they cannot capture 3D femoral anatomy and are limited to static hip positions. To fully assess how PAO surgery changes femoral coverage, it is important to quantify coverage in 3D and during dynamic activities, like gait and squat that are cited by patients with DDH as being painful. [4,5] The first objective of this study was to calculate 3D femoral coverage changes after PAO in the regions targeted during PAO. The second objective was to compare 3D coverage in a neutral position to dynamic coverage during the stance phase of gait and throughout the squat cycle. We hypothesized lateral femoral coverage will increase after PAO in neutral position and during gait and squat. We also hypothesized that femoral coverage measured in a neutral position would not match coverage during functional gait and squat tasks after surgery.

METHODS: Using pre- and post-PAO computed tomography scans (0.74 x 0.74 x 0.6 mm voxels), femur and pelvis bones from patients with DDH (N=15) who underwent PAO were segmented with IRB approval. The femurs and pelvises were aligned to a neutral anatomical position and segment coordinate systems were established. The femoral head was objectively isolated and split into four anatomic regions: anteromedial (AM), anterolateral (AL), posteromedial (PM), and posterolateral (PL). [6] Coverage was determined by projecting the lunate surface of the acetabulum to the nearest points on the femoral head. To isolate the effects of anatomy, gait and squat activities in each subject were simulated by rotating the femur in the acetabulum using hip joint angles averaged from 20 previous patients with DDH. [7,8] Coverage was calculated pre- and post-PAO in the neutral position, and dynamically during the stance phase of the gait cycle (0-55% gait), and throughout the entire squat cycle. In the current study, the percent of coverage in the anterior and lateral head sections was reported because these regions are a focus during PAO. The lateral head sections were compared during gait and the anterior head sections were compared during squat since the activity requires deep flexion. Neutral position coverage pre- and post-PAO was compared using paired samples t-tests. Statistical parametric mapping was used to compare dynamic coverage before and after PAO and analyze coverage in the neutral position versus dynamic activities.

RESULTS: Lateral coverage in the neutral position increased following surgery. Neutral AL coverage increased from $4.9 \pm 3.1\%$ pre-PAO to $13.2 \pm 4.5\%$ post-PAO ($p=0.05$); neutral PL coverage increased from $21.4 \pm 9.5\%$ pre-PAO to $38.9 \pm 13.4\%$ post-PAO ($p=0.05$). Dynamic coverage during gait also increased pre- to post-PAO, with significant increases to AL and PL coverage during the whole stance phase (Fig 1). Compared to the neutral position, dynamic coverage post-PAO was significantly different in the AL region during 0-10% and 30-55% of the gait cycle and in the PL region from 0-30% of gait (Fig 1). Dynamic coverage of the AL region significantly increased throughout the squat cycle after PAO, while the AM region did not significantly change (Fig 2). During the entire squat cycle, dynamic AM coverage was significantly greater compared to the neutral position. AL region coverage during the squat cycle was not different when compared to neutral (Fig 2).

DISCUSSION: Our results are similar to previous research that found significantly greater 3D coverage in the lateral and anterior regions following surgery. [9] As hypothesized, dynamic lateral coverage increased pre- to post-PAO during the stance phase of gait and during squatting. Importantly, measurements of coverage in a neutral position, the position most often reported, did not reflect coverage or post-surgical change in coverage during dynamic activities. This finding was true for the AL and PL regions during stance of gait, and for the AM, but not the AL, region during squat. Understanding the relationship between neutral position coverage and dynamic coverage could be clinically useful as surgeons could estimate how changes due to PAO affect the stability of the joint during activities of daily life. Also, changes in regional dynamic coverage with PAO could have important implications for joint loading. For example, it is known that lateral acetabular edge loading is high during gait before PAO [7], and in pilot data we have found that edge loads are reduced after PAO. Future work will quantify the relationships between the magnitude of regional coverage changes and edge loading responses. Patient-specific differences in kinematics such as pelvic tilt and hip joint angles could also affect coverage, and possibly loading. In this study, we applied the same initial pelvic tilt and an averaged set of hip angles to all subjects in order to isolate the coverage effects of anatomy. Future work will determine how coverage changes due to kinematic variability and if post-PAO dynamic coverage is comparable to healthy hips.

SIGNIFICANCE/CLINICAL RELEVANCE: Understanding the relationship between neutral coverage and dynamic coverage can potentially aid optimized surgical planning to comprehensively improve coverage during different activities of daily life. While anterior and lateral coverage increase after PAO, neutral position coverage does not match and is not indicative of dynamic coverage during daily tasks.

REFERENCES: [1]Wyles Clin Orthop 2017. [2]Ganz Clin Orthop 2008. [3]Clohisy JBJS 2005. [4]Hampton Bone Jt J 2019. [5]Reddy BMC Musculoskelet Disord 2020. [6]Harris Ann Biomed Eng 2013. [7]Song Front Sports Act Living 2021. [8]Song J Orthop Res 2022. [9]Neppe 2017 Clin Orthop Relat Res.

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IMAGES AND TABLES:

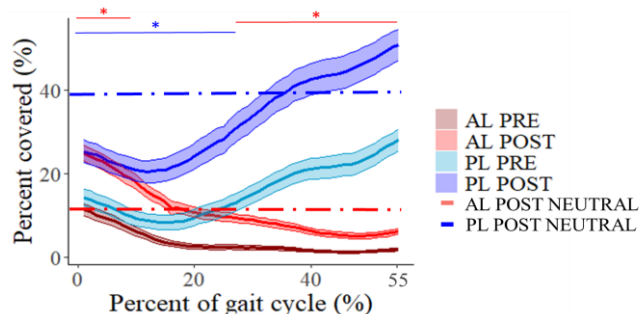


Figure 1: Coverage during the stance phase of the gait cycle in the AL and PL regions. The dashed lines represent coverage in neutral position. Asterisks indicate significant differences between post-PAO dynamic and neutral coverage.

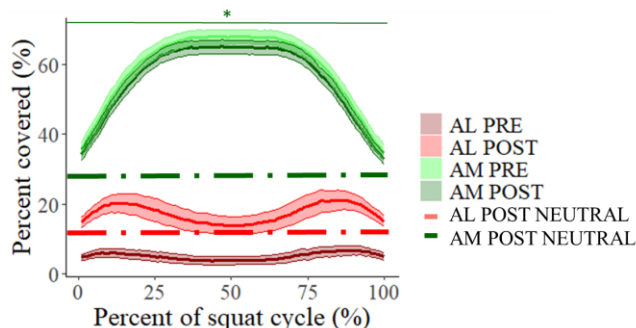


Figure 2: Coverage during squat cycle in the AL and AM regions. The dashed lines represent coverage in neutral position. Asterisks indicate significant differences between post-PAO dynamic and neutral coverage.