DEA-computed contact stress as computational biomarker for OA development in the untreated contralateral hip of individuals that underwent unilateral PAO to treat hip dysplasia

Dominic Joseph Lupe Rivas[1], Jessica Goetz, Holly D Aitken, Ashley Suzanne Kochuyt, Taylor Matthew Murray, Todd Owen McKinley, Michael C Willey
[1]Orthopedics and Sports Medicine

INTRODUCTION:

Hip dysplasia is the most common cause of early onset hip osteoarthritis (OA), yet there are dysplastic hips that function into old age without developing OA. Elevated joint contact stresses calculated using a technique called discrete element analysis (DEA) are associated with cartilage degeneration in dysplastic hips treated with periacetabular osteotomy (PAO), but the association between elevated joint contact stress and joint failure in untreated dysplastic hips has not been characterized. Therefore, the aim of this study was to use DEA modeling of the surgically untreated contralateral hip in individuals that underwent unilateral PAO for hip dysplasia to determine a level of contact stress that may serve as a computational biomarker for future development of OA in the untreated contralateral hip.

METHODS: Patients who underwent a unilateral periacetabular osteotomy (PAO) at our institution between January 9, 2003, and July 22, 2010 were retrospectively identified. Patients were contacted to document surgeries since their unilateral PAO and to complete the following patient reported outcomes for each hip individually: International Hip Outcomes Tool (iHOT-12), modified Harris Hip Score (mHHS), PROMIS Bank v2.0 – Physical Function (PROMIS-PF), and PROMIS Bank v1.1 – Pain Interference (PROMIS-PI). Lateral center edge angle (LCEA), Tönnis Angle, and Tönnis grade were assessed on pre-operative anteroposterior radiographs of the non-operated, contralateral hip, or on immediate post-operative radiographs when pre-operative images were unavailable. Contralateral hips were considered dysplastic if they had LCEA < 20° and/or Tönnis Angle > 11°. Patient-specific DEA models were constructed from the pre-operative CT scan and used to calculate hip joint contact stress and contact area. Patient age at follow-up or age at total hip arthroplasty (THA) were used in calculation of contact stress-time exposure, a metric of cumulative exposure to contact stresses over time. Primary comparative analyses were performed between preserved and failed non-operative contralateral hips, with failure defined by either THA or reported mHHS < 70. Secondary analyses were conducted between modes of failure. Spearman's correlation was performed to relate articular contact mechanics to either (1) the time between unilateral PAO and THA in the contralateral failed hip or (2) to patient-reported outcomes for the non-operative contralateral hip in all hips that did not have a THA. Statistical testing between failure groups was performed in Prism (GraphPad 10.4.2) using Mann-Whitney non-parametric tests. Statistical significance was defined as $p < 0.05$.

RESULTS:

54 patients consented to participate in our study or had joint failure defined by conversion to THA. Among those 54 participants, 10 hips had failed by THA and 7 were defined as failed by mHHS<70, with the remaining 37 hips in the preserved group. Length of follow-up was 18.1 ± 2.3 years post unilateral PAO for preserved contralateral hips, 16.9 ± 3.0 years for hips that failed by mHHS<70, and 13.4 ± 6.4 years for hips that failed by THA.

35/54 (64.8%) participants had radiographically dysplastic untreated contralateral hips, with 21/35 (60%) in the preserved group and 14/35 (40%) in the failed hips. Of the 37 preserved hips, 3/37 (8.1%) had a Tönnis grade ≥ 2 at the time of their PAO on the opposite side, as did 4/17 of the failed hips (23.5%). Failed hips had lower LCEA (16.9° vs 19.9°; p=0.0550) and greater Tönnis angle (16.9° vs 9.5°; p=0.0575) than preserved hips. iHOT (89.0 vs 41.0; p<0.0001), mHHS (96.0 vs 63.0; p<0.0001), and PROMIS-PF (48.0 vs 45.0; p=0.1442) were greater in the preserved hips compared to hips failing by mHHS, while PROMIS-PI (52.0 vs 62.0; p=0.0105) was greater in hips that failed by mHHS.

Preserved hips had greater contact area (755 vs 665 mm^2; p=0.1151), lower mean contact stress (3.3 vs 3.8 MPa; p=0.0312), and lower peak contact stress (16.2 vs 18.4 MPa; p=0.0308) than failed hips (Figure 1). Preserved hips also tended to have lower mean (7.4 vs 8.6 MPa-years; p=0.0562) and peak (35.0 vs 44.8 MPa-years; p=0.0273) contact stress time exposures. Further examination of the failed hips revealed that those failing by mHHS<70 had lower mean (3.7 vs 3.9; p=0.4883) and peak (17.9 vs 20.7; p=0.0553) contact stresses and greater contact area (734 vs 653; p = 0.6009) than hips that failed by THA.

No strong relationships were determined between any of our contact mechanic metrics (r=-0.1636-0.2; p=0.5837-0.7772) and time from unilateral PAO to contralateral THA in failed hips. Moderate correlations were found with increasing peak stress and increasing PROMIS-PI (r=0.3619; p=0.0217) along with increasing peak stress and decreasing mHHS (r=-0.2645; p=0.0991).

DISCUSSION AND CONCLUSION:

Pathologic contact mechanics and smaller contact area was associated with joint failure in untreated contralateral hips at over 17-year average follow-up. These associations were stronger when considering THA as the only failure mechanism. Additionally, moderate correlations were found between patient reported outcomes and articular mechanics. These findings highlight the potential of computational techniques to predict future joint failure in untreated contralateral hips in

patients that underwent unilateral PAO for hip dysplasia and may serve as a tool to appropriately indicate patients for additional surgical treatment on the contralateral side.