Combined Version Strongly Predicts Femoral Head Coverage Greater Than Femoral or Acetabular Version Alone in Hip Dysplasia

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INTRODUCTION: Periacetabular osteotomy (PAO) remains the mainstay treatment for surgical treatment of hip dysplasia, with emphasis placed on improving lateral and anterior femoral head coverage. However, femoral-sided morphology, particularly femoral version, can be overlooked regarding its effect on femoral head coverage. We hypothesized that while femoral and acetabular version each significantly contributes to femoral head coverage, a combined model of femoral and acetabular version would better predict coverage than either alone.

METHODS: A retrospective analysis was performed on 326 hips in patients with symptomatic hip dysplasia undergoing PAO. Preoperative CT scans that included the pelvis and femur were obtained for each patient. A custom-developed and validated program (VirtualHip, Boston Children's Hospital) was used to automatically segment bones, identify landmarks, define anatomical coordinate system based on ISB recommendations, and then measure anatomical features of the hip joint. Femoral version, acetabular version (proximal and central), and femoral head coverage were measured. We evaluated whether acetabular version, femoral version, or their combination better predicted femoral head coverage. Three linear regression models were constructed: (1) femoral head coverage regressed on acetabular version, (2) femoral head coverage regressed on femoral version, and (3) femoral head coverage regressed on both acetabular and femoral version. To assess model performance and reduce the risk of overfitting, we used 10-fold cross-validation repeated 100 times. Performance was summarized using three metrics. The coefficient of determination (R^2) reflects the proportion of variance in femoral head coverage explained by the predictors, with higher values indicating better fit. The root mean square error (RMSE) measures the average magnitude of prediction error, placing greater weight on larger errors, while the mean absolute error (MAE) represents the average absolute difference between observed and predicted values. For RMSE and MAE, lower values indicate more accurate predictions.

RESULTS: Femoral version demonstrated the strongest individual correlation with femoral head coverage ($r = -0.48$, $p < 0.001$), followed by central acetabular version ($r = -0.36$, $p < 0.001$) and proximal acetabular version ($r = -0.29$, $p < 0.001$) (Figure 1). When analyzed separately, femoral version accounted for more variance in femoral head coverage than acetabular version ($R^2 = 0.24$ vs. 0.16) and demonstrated lower prediction error (RMSE 10.7, MAE 8.4 vs. RMSE 11.4, MAE 8.8). The model including both acetabular and femoral version provided the best fit, explaining 32% of the variance in femoral head coverage ($R^2 = 0.32$) and yielding the lowest error values (RMSE 10.1, MAE 7.9). Together, these results indicate that while femoral version alone is a stronger predictor than acetabular version, the combined model offers the most accurate estimate of femoral head coverage (Table 1).

DISCUSSION: While lateral and anterior coverage remain the main focus of PAO, our findings highlight the effect of combined acetabular and femoral version on femoral head coverage. For patients undergoing PAO alone without femoral osteotomy, acetabular version should be optimized to each patient's unique femoral version, without sacrificing impingement-free range of motion. While the spatial relationship of the projected anterior and posterior walls gives some insight on acetabular version during intraoperative fluoroscopy, precise re-orientation in the axial plane is challenging with present two-dimensional imaging modalities. The use of navigation or CT-based planning should be explored to allow for precise acetabular fragment re-orientation, accounting for unique patient anatomy.

SIGNIFICANCE: Incorporating femoral version into preoperative planning enhances prediction of femoral head coverage. Precise acetabular reorientation in the axial plane with respect to the patient's unique femoral version may optimize correction and improve outcomes following PAO for hip dysplasia.

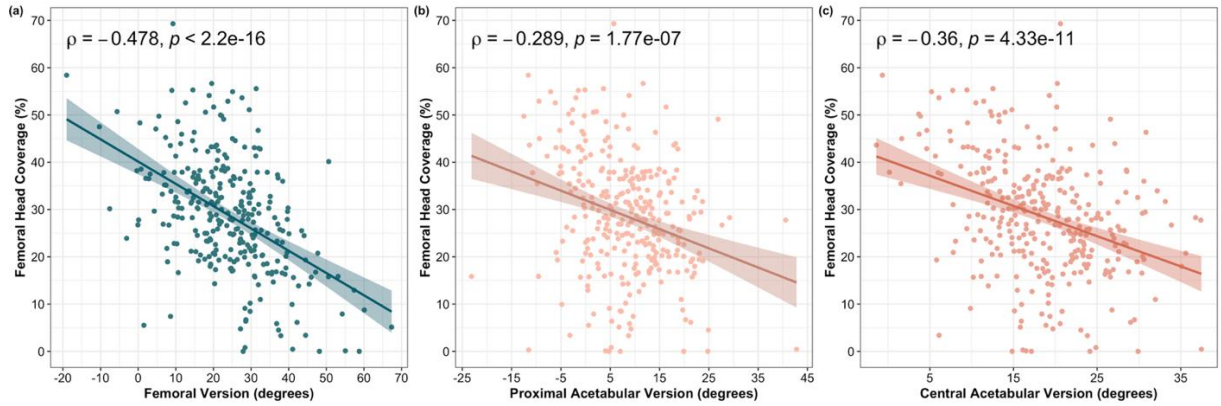

Figure 1. Correlation of femoral head coverage comparing femoral version, proximal acetabular version, and central acetabular version.

Model	R2	RMSE	MAE
Acetabular Version	0.16	11.4	8.8
Femoral Version	0.24	10.7	8.4
Acetabular Version + Femoral Version	0.32	10.1	7.9

Table 1: Model performance for predicting femoral head coverage using acetabular version, femoral version, or both. Values represent coefficient of determination (R^2), root mean square error (RMSE), and mean absolute error (MAE).