Patient-Specific Acetabular Safe Zones in Total Hip Arthroplasty: External Validation of a Quantitative Approach to Preoperatively Templating Spinopelvic Parameters

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INTRODUCTION:

Consideration of spinopelvic mechanics are critical in total hip arthroplasty (THA). However, there is no established consensus for acetabular component positioning. This study aimed to 1) externally validate a recently developed Patient-Specific acetabular safe zone calculator that factors in spinopelvic parameters and 2) characterize differences between patient-specific acetabular targets and Hip-Spine Classification targets.

METHODS:

A total of 3,750 consecutive patients underwent primary THA across three academic referral centers, a total of 33 (0.88%) required revision due to instability, 22 for initial internal validation from the first 2,457 patients (Group 1) and 11 for subsequent external validation (Group 2) from the last 1,293 patients. Spinopelvic parameters were measured before initial THA, and acetabular position was measured following the index and revision procedure. Utilizing our recently developed open-source Patient-Specific Safe Zone tool, theoretical intraoperative positions were calculated. Patient-Specific Safe Zone targets were compared to actual component positions before and after revision. Additionally, Hip-Spine classification targets were compared to calculated Patient-Specific Safe Zone targets.

RESULTS:

Of the pooled 33 patients who underwent revision, none dislocated at follow up (5.1 years), and the internal and external validation cohorts were not statistically different. Differences between Patient-Specific Safe Zones and the median and extreme recommendations of the Hip-Spine Classification targets were 3.8°±2.1° inclination / 5.0°±3.2° version and 5.4°±3.1° inclination / 7.5°±3.2° version, respectively, for the external validation cohort. Patient-Specific Safe Zone targets for the pooled cohort differed from prerevision acetabular component position by 7.9°±5.1° inclination / 11.4°±6.9° version; after revision, the mean difference was 3.6°±3.1° inclination / 5.8°±3.5° version ($p<0.001$).

DISCUSSION AND CONCLUSION:

A Patient-Specific approach for acetabular component positioning improved the accuracy and tolerance of clinically relevant targets within 6° of version and 4° of inclination of stable, revised hips with both internal and external validity. By incorporating patient-specific biomechanics, Patient-Specific Safe Zones provide quantitative targets for nuanced spinopelvic preoperative planning that may mitigate the risk of instability regardless of supplementation with navigation and robotic-assisted technologies.

Hip-Spine Classification	Pre-Revision Position *Inclination/ Anteversion*	Post-Revision Position *Inclination/ Anteversion*	Predicted Patient-Specific Safe Zone *Inclination/ Anteversion*
Group 1 (n=22)			
1A (n=6)	40.8°±9.9°/ 18.5°±12.0°	42.2°±2.2°/ 29.0°±4.4°	45.2°±3.4°/ 24.5°±5.6°
1B (n=11)	37.6°±4.0°/ 14.1°±8.6°	43.4°±2.3°/ 30.7°±2.9°	44.0°±2.0°/ 22.2°±4.4°
2A (n=3)	60.3°±6.7°/ 39.3°±3.1°	48.0°±10.4°/ 31.3°±1.5°	42.0°±0.2°/ 16.5°±0.9°
2B (n=2)	53.5°±2.1°/ 19.0°±24.0°	39.5°±0.7°/ 27.0°±2.8°	37.2°±0.5°/ 15.6°±2.3°
Group 2 (n=11)			
1A (n=7)	44.0°±4.0° / 35.1°±5.1°	47.0°±5.4°/ 31.4°±5.0°	47.2°±1.6°/ 28.9°±2.6°
1B (n=4)	54.3°±8.9° / 27.0°±4.8°	43.4°±4.7°/ 32.0°±6.3°	47.2°±1.6°/ 29.0°±2.6°
Pooled (n=33)			
1A (n=13)	44.1°±7.8°/ 28.5°±15.1°	46.1°±5.8°/ 32.0°±5.9°	46.3°±2.7°/ 26.9°±4.8°
1B (n=15)	42.2°±10.2°/ 16.2°±10.8°	43.4°±4.6°/ 30.0°±7.3°	44.9°±2.3°/ 24.0°±5.0°
2A (n=3)	54.8°±2.4°/ 35.3°±1.3°	36.7°±9.9°/ 23.2°±1.9°	42.0°±0.2°/ 16.5°±0.9°
2B (n=2)	44.6°±9.1°/ 11.7°±25.8°	36.5°±0.4°/ 17.5°±5.0°	37.2°±0.5°/ 15.6°±2.3°

Table 1

Measurement	Difference Relative to Patient-Specific Safe Zone		
	Pre-revision	Post-Revision	p-value
Group 1 (n=22)			
Inclination	9.1°±4.3°	3.2°±3.0°	<0.001
Anteversion	13.3°±6.8°	5.3°±2.7°	<0.001
Group 2 (n=11)			
Inclination	5.5°±5.9°	4.2°±3.3°	0.52
Anteversion	7.7°±5.7°	6.9°±4.7°	0.71
Pooled (n=33)			
Inclination	7.9°±5.1°	3.6°±3.1°	<0.001
Anteversion	11.4°±6.9°	5.8°±3.5°	<0.001

Table 2

Measurement	Differences between Patient-Specific Target and Hip-Spine Targets	
	Median	Acceptable Extreme
Group 1 (n=22)		
Inclination	2.2°±1.9°	3.0°±2.8°
Anteversion	5.6°±3.7°	7.9°±3.5°
Group 2 (n=11)		
Inclination	3.8°±2.1°	5.4°±3.1°
Anteversion	5.0°±3.2°	7.5°±3.2°
Pooled (n=33)		
Inclination	2.7°±2.1°	3.8°±2.8°
Anteversion	5.4°±3.5°	7.8°±3.4°

Table 3