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Does Replication of Native Acetabular Anatomy Satisfy Recommended Hip-Spine Targets for Cup Orientation?

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Background: The aim of this study was to assess whether replication of native acetabular anatomy would satisfy cup orientation targets using 3 commonly described hip-spine algorithms. Whether spinopelvic characteristics influence ability to achieve cup orientation targets when replicating native anatomy and the agreement between algorithm recommendations was tested.

Methods: A prospective database was queried to identify patients with adverse (n = 70) spinopelvic characteristics. These were matched for age and sex with patients without adverse characteristics (n = 70). Spinopelvic characteristics were obtained from radiographs and computed tomography (CT) scans. CT scans were segmented to determine native acetabular anatomy, particularly anteversion. Three hip-spine planning algorithms were evaluated for each patient (Optimized Positioning System [OPS], Combined-Sagittal Index [CSI], Hip-Spine Classification). Differences between target orientations and native anatomy were determined. Agreement between algorithms was tested.

Results: OPS plan had significantly reduced inclination compared with native (39° vs. 52°, $p < 0.001$). No significant difference between OPS and native anteversions was seen (18° vs. 18°, $p = 0.1$) for the adverse group. OPS-planned anteversion was greater than native (23° vs. 16°, $p < 0.001$) in the nonadverse group. Most native orientations met published CSI targets (90% nonadverse, 59% adverse). Most native acetabular orientations (61% adverse and 58% nonadverse) failed to meet Hip-Spine Classification targets. Overall, in 88% of cases, replication of native acetabular version and 40° of inclination satisfied at least one suggested target. Agreement of all 3 algorithms was 31%; greater agreement was seen between Hip-Spine Classification and OPS (64%).

Conclusions: Native acetabular anteversion and radiographic inclination of 40° are reliable targets, satisfying at least one hip-spine algorithm and thus justifying such practice, when advanced hip-spine analysis is not performed. The discrepancy between suggested orientations by the various published techniques, despite their validated low dislocation rates, emphasizes that although achieving a target cup orientation is important, the nature of hip stability is multifactorial and merits a holistic approach.

Introduction

Instability following total hip arthroplasty (THA)[1-3] is associated with significant morbidity and cost[4-6]. Acetabular (cup) orientation is an important determinant of instability risk[7]. Previously described "safe zones"[8] for cup orientation are not universally "safe"[9-11]. Patient-specific cup orientations accounting for hip-spine characteristics have gained popularity, since the hip-spine relationship influences functional cup orientation and is associated with instability[7,12,13].

Methods to determine target cup orientation accounting for spinopelvic characteristics are based on categorization[14-16] or impingement modeling[17,18] strategies. The Hip-Spine

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Classification system[16] delineates patients into one of 4 groups based on spinal alignment and mobility and provides group-specific targets. Others propose a target combined sagittal index (CSI)[13,19]. Proprietary software examining hip-spine dynamics with individualized impingement modeling studies provide alternative options to identify optimum cup orientation target[7,18,20].

Without advanced technology intraoperatively, surgeons rely on anatomical landmarks such as the acetabular rim and transverse acetabular ligament (TAL) for cup orientation[21-23]. Replication of native acetabular anteversion, while reducing native inclination, increases the ability to achieve traditional orientation targets[23]. However, whether following native acetabular anatomy aids in achieving optimum cup orientation as per spinopelvic characteristics is unknown.

The primary objective of this study was to assess whether replication of native acetabular anatomy would satisfy cup orientation targets using three commonly described hip-spine algorithms (Optimized Positioning System [OPS] [Corin Group][24], CSI targets[13] and the Hip-Spine Classification[16]). We tested whether the presence or absence of adverse spinopelvic characteristics influences ability to achieve cup orientation targets when replicating native anatomy and what the agreement between different algorithms is.

Methods

Study Design

This is an IRB-approved, retrospective, case-control study from a prospective registry (CorinRegistry, Bellberry Limited 2020-08-764, WCG-Clinical IRB No.: 120190312).

Study Power

An a priori power calculation was performed based on the studies of Vigdorchik that reported on target cup orientations as per different spinopelvic characteristics (5° difference in inclination/anteversion)[16] and Grammatopoulos that reported on range of cup inclination/anteversion post-THA (7°)[11]. At least 41 hips per group would be required to provide sufficient study power ($1-\beta = 0.80$, $\alpha = 0.05$) to test between group differences.

Cohort

A commercial database of preoperative hip arthroplasty imaging (CorinRegistry database; Corin Group) was queried. All patients had comprehensive imaging (supine and standing anteroposterior pelvic radiographs, standing and deep-seated lateral spinopelvic views, and pelvic computed tomography [CT] scans). All patients underwent primary THA using the OPS 3D planning system (Corin Group). Surgical and demographic details are provided in Table I. Choice of implant and approach reflect individual preferences of surgeons not involved in this study.

Seventy patients with spinopelvic characteristics known to be associated with increased dislocation risk[13]–(pelvic incidence [PI]—lumbar lordosis [LL] >10°), high standing spinopelvic tilt ($sPT_{standing}$ >19°), and lumbar stiffness–lumbar flexion between standing and seated (ΔLL <20°)–were randomly selected from the CorinRegistry database, forming the study group (“adverse” group) (Table I). Patients were then propensity score matched for age, sex, native femoral anteversion, and PI-nearest neighbor, to a group of 70 patients who did not exhibit any abnormal spinopelvic characteristics, thus forming the controls (“nonadverse” group).

Following exclusion of patients with CT scans wherein severe arthritis precluded reliable landmark identification (n = 29), 111 patients remained for analysis (54 in adverse and 57 in nonadverse).

Radiological Evaluation

Spinopelvic Characteristics

Spinopelvic characteristics were determined from lateral spinopelvic radiographs in both standing and deep-seated positions[7,25,26]. Parameters of interest included LL, sPT, PI, sacral slope (SS), anterior pelvic plane angle (APPA), and pelvic femoral angle (PFA) (Fig. 1).

Acetabular morphology

Acetabular morphology was determined from point selection of CT scans of each patient's pelvis using validated software (ITK-snap[27]). Coordinates were defined along the acetabular rim and at the insertion and attachment of the TAL. The TAL and acetabular rim have demonstrable utility in setting version intraoperatively[21-23], hence both were determined in this study. A brief overview of rim-defined acetabular version and inclination is outlined here, though available in more detail[28,29]. The anterior pelvic plane (APP) was defined by fitting the pubic symphysis and anterior-superior iliac spines onto a plane. The APPA was calculated as the angle between an axis perpendicular to the APP and the horizontal (CT y-axis). Points were selected along the entirety of the acetabular rim's clock face (at every slice—ranging from 0.25 to 2 mm) and a best fit plane determined by the least-squares method[30] defined the acetabular rim plane (ARP). The angle between the ARP and the sagittal/coronal plane or APP defined inclination/anteversion in functional and morphological contexts, respectively (Fig. 2). To determine point selection of TAL, we used a described method of segmentation and 3D rendering to visualize the acetabulum[29]. Points were selected on the 3D model corresponding to the origin and insertion of the TAL (Fig. 3).

Targets as per Spinopelvic Algorithms

OPS-defined targets

Corin OPS uses pelvic CT scans to develop 3D reconstructions of pelvis and femur[20]. A proprietary algorithm is implemented that takes the segmented pelvis and femur through range of motion, with varying component sizes and orientations. In doing so, a range of theoretical impingement-free orientations are defined. These are then visually depicted and reported in reference to supine and standing radiographs. Using Murray radiographic definition[31], options are supplied to surgeons, who then proceed to select their preferred orientation for transfer to the intraoperative delivery system[20]. Planned OPS

TABLE I Demographic, Surgical, and Anatomic Characteristics of Study Cohort

Demographic, Surgical, and Anatomic Details	Group (n = 111)	Nonadverse (n = 57)	Adverse (n = 54)	p (Where Applicable)
Mean age (yrs-old)	73 ± 9.4	72 ± 11	71 ± 2.4	0.69
Sex (male/female)	53/58	31/26	22/32	0.15
Surgical approach				
Anterior	27	18	9	0.1683
Posterior	81	38	43	
Lateral	3	1	2	
Acetabular liner				
Ceramic	82	45	37	0.0375*
Polyethylene	17	10	7	
Dual Mobility	12	2	10	
Femoral stem				
TriFit TS	5	3	2	0.614
Paragon	19	11	8	
Metafix	59	31	28	
TaperFit	27	11	16	
MiniHip	1	1	0	
Median/mean femoral head size	36 mm/37 mm ± 3.0 mm	36 mm/36 mm ± 1.9 mm	36 mm/37 mm ± 3.8 mm	0.1013
Mean spinopelvic parameters				
Supine APPA	0.14° (7.0°)	3.86° (6.1°)	−3.78° (5.6°)	<0.001*
Pelvic incidence	58° (11°)	58° (9.4°)	59° (12°)	0.52
Lumbar flexion	29° (18°)	44° (12°)	12° (5.1°)	<0.001*
PI-LL	8.1° (17°)	−6.1° (9.0°)	23° (9.0°)	<0.001*
Standing APPA	−6.7° (8.9°)	−0.73° (6.5°)	−13° (6.4°)	<0.001*
Seated APPA	1.1° (14°)	0.84° (13°)	1.4° (15°)	0.91
Standing SS	39° (11°)	45° (7.7°)	32° (10°)	<0.001*
Seated SS	47° (14°)	47° (13°)	46° (15°)	0.56
Standing LL	50° (18°)	64° (9.7°)	36° (14°)	<0.001*
Seated LL	22° (14°)	20° (13°)	24° (14°)	0.097
Standing PFA	190° (9.6°)	190 (5.1)	200 (8.3)	<0.001*
Standing PT	20° (9.6°)	12 (5.2)	28 (6.3)	<0.001*
Mean femoral parameter				
Native femoral version	10° (10°)	10° (9.4°)	11° (11°)	0.684

*Indicates statistically significant difference. APPA = anterior pelvic plane angle, PFA = proximal femoral angle, PI = pelvic incidence, PT = pelvic tilt, SS = sacral slope, and LL = lumbar lordosis.

orientation is as per functional plane when supine. The difference between planned and native, functional anteversion was calculated:

$$\Delta\text{Anteversion} = \text{Planned anteversion (i.e., Corin OPS)} - \text{Native anteversion (i.e., TAL)}$$

Combined Sagittal Index Targets

CSI was calculated as the sum of standing PFA and cup anteinclination. Cup anteinclination was determined using standing native functional acetabular anteversion and a simulated radiographic inclination of 40°, as native inclination has been shown to be unacceptably high for arthroplasty targets[23,32]. Previously defined equations were used to convert radiographic inclination/anteversion to anteinclination[31,33]. These are detailed below for convenience here:

$$Tan(anteinclination) = Tan(anteversion) \div Cos(inclination)$$

CSI targets were 205° to 245° for nonadverse spinopelvic characteristics and 215° to 235° for adverse spinopelvic characteristics[13].

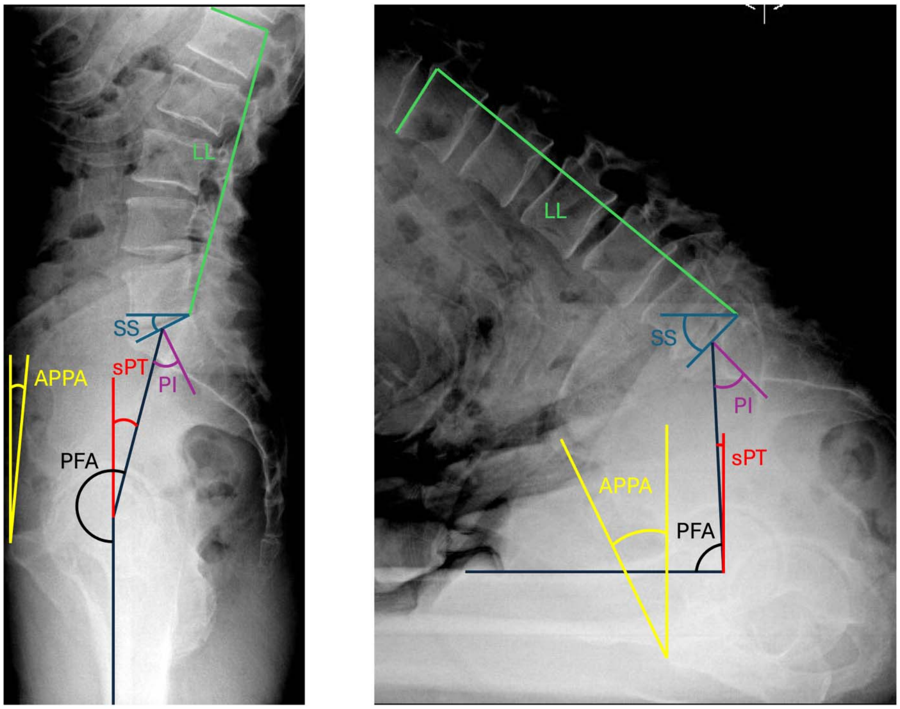

Fig. 1

Radiographic measurements of spinopelvic alignment and mobility. Left is standing, right is deep seated. Note that the APPA illustrated above is numerically the same value as the APPA described in the text. APPA = anterior pelvic plane angle, PFA = proximal femoral angle, PI = pelvic incidence, sPT = spinopelvic tilt, SS = sacral slope, and LL = lumbar lordosis.

Hip-Spine Classification

This classification determines spinal alignment based on PI-LL and spinal mobility using the SS change, ΔSS, from standing and relaxed-seated radiographs[16]. However, ΔLL from deep-seated to standing is a more reliable marker of spinal mobility[34]. Thus, ΔLL ≤20° was used to define a stiff spine[34] and PI–LL ≥10° was used to define flatback deformity. There were 57 patients (51%) in group 1A, 3 (3%) in group 2A, and 51 (46%) in group 2B. Those in 2A and 2B accounted for all patients in the adverse group. A range of ±5° centered on the recommended target values, rather than target value itself, was used (Table II). Inclination of 40° meets target ranges in all cases. Native morphological version was used for comparison with the Hip-Spine Classification.

Statistics

Kolmogorov-Smirnov tests were used to assess normality (range: 0.045-0.20). All parameters but PI-LL, lumbar flexion, planned inclination, and functional inclination were normally distributed. For comprehensiveness, differences

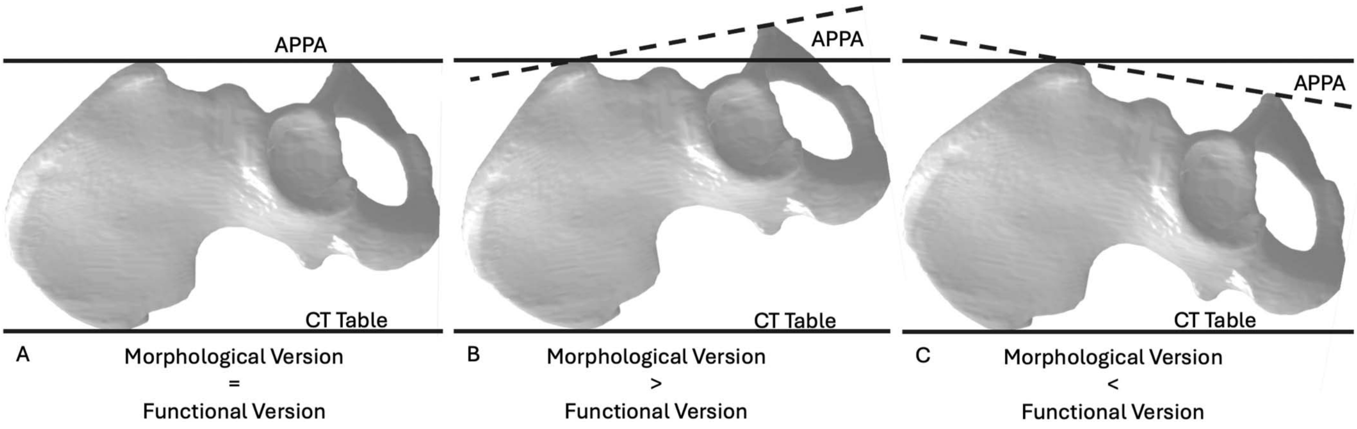

Fig. 2

Visual representation of morphological vs. functional version definitions. Functional version uses the horizontal plane as a reference and changes with patient positioning whereas morphological version uses the APP as a reference and is thus unaffected by changing pelvic position[29].

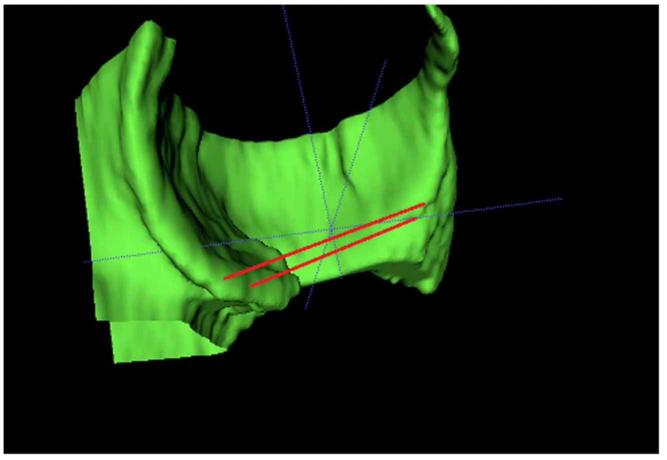

Fig. 3

Representative TAL points selected on axial CT cuts shown on a portion of a 3D rendered acetabulum. Anterior oriented to the right and superior above. CT = computed tomography, and TAL = transverse acetabular ligament.

between groups were assessed with nonparametric tests (Mann-Whitney U test) for continuous variables. Categorical differences between groups were assessed with χ^2 tests. Analysis was performed using SPSS Statistics, Version 26 (IBM). Significance level was set at $p < 0.05$.

Results

Whole cohort anatomical characteristics and group differences are detailed in Table I. There were no postoperative dislocations to date. No difference was detected between ARP version and TAL version (p = 0.32) (Table III).

Does Replication of Native Acetabular Anatomy Satisfy Cup Orientation Targets?

For the whole cohort, the mean planned OPS inclination was 13° ± 8° less than native inclination and planned OPS anteversion was 4° ± 7° greater than native anteversion. OPS-planned inclination and version were within ±5° of native values in 19% and 42% of cases, respectively. CSI following native version (cup inclination of 40°) resulted in mean CSI of 224° ± 13. 88% of all cases were within CSI target range of 205° to 245°, while only 56% were within CSI target range of 215° to 235°. Thirty hips (27%) had morphological acetabular version within ±5° of recommended Hip-Spine targets.

Does Distinction Between Adverse and Nonadverse Spinopelvic Characteristics Influence Ability of Achieving Cup Orientation Targets When Replicating Native Anatomy?

Native anatomy vs. OPS

In patients with nonadverse spinopelvic characteristics, native anteversion was smaller (16° ± 5.8°) than planned (23° ± 2.8°, p < 0.001) (Table III). In patients with adverse spinopelvic characteristics, there was no difference between native (18° ± 6.8°) and planned (20° ± 3.6°, p = 0.111) anteversion (Fig. 4). Inclination was higher for native (nonadverse: 53° ± 6.9°, adverse: 51° ± 7.1°) compared with planned (nonadverse: 39° ± 1.3°, adverse: 39° ± 2.0°, p < 0.001) for both groups.

Native Anatomy vs. CSI

Average CSI for native anatomy was 216° ± 10° for the nonadverse and 232° ± 12° for the adverse groups. Ninety percent (51 hips) of the nonadverse group met CSI targets; hips outside CSI targets had CSIs smaller than the lower limit (<205°), and 5 of 6 were men (Fig. 5). Fifty-nine percent (32 hips) of the adverse group met CSI target. Most hips (18 of 22) outside target in the adverse group had native CSI greater than the upper limit (>235°), and most were women (13/18); all with low native CSI were men (n = 4).

Native Anatomy vs. Hip-Spine Classification

Average native anteversion distributed between Hip-Spine Classification groups are listed in Table IV. Most native anteversions fell outside Hip-Spine Classification recommended targets, and there were no differences between groups (61% in the adverse group and 58% in the nonadverse group). Nearly all hips outside of target ranges had lower native anteversion than recommended, regardless of spinopelvic characteristics (Fig. 6).

Agreement Between Recommended Targets

The degree to which native anteversion satisfied targets for planned OPS, CSI, and Hip-Spine Classification is presented in Table V. Only 15 patients (26%) of the nonadverse group and 6 (11%) of the adverse group met targets for all 3 recommendations. A total of 88% of all patients met at least one target recommendation, with only 6 of the nonadverse and 7 of the adverse group not meeting any recommended targets. Greater agreement was seen between the Hip-Spine Classification and OPS compared with CSI.

TABLE II Target Ranges of Anteversion Based on the Target Values of the Hip-Spine Classification Target Value[16], to Allow Statistical Comparison

Hip-Spine Classification	Anteversion	Inclination
Group 1A–Non-adverse alignment, normal mobility	22.5° ± 5°	42.5° ± 5°
Group 2A–Flatback deformity, normal mobility	22.5° ± 5°	45° ± 5°
Group 2B–Flatback deformity, stiff mobility	25.0° ± 5°	40° ± 5°
	30.0° ± 5° (if posterior pelvic tilt was ≥13°)	45° ± 5° (if posterior pelvic tilt was ≥13°)

TABLE III Planned Acetabular Cup Orientations as Determined by a Patient-Specific Positioning Software (Corin OPS); Native Acetabular Anteversion and Inclination as Determined by Referencing TAL and the ARP; Difference Between Planned and Native (Per TAL) Anteversion and (Per ARP) Inclination*

	Group	Nonadverse Spinopelvic Characteristics (±SD)	Adverse Spinopelvic Characteristics (±SD)	p
Planned (Corin OPS) anteversion	22° (3.8°)	23° (2.8°)	20° (3.6°)	<0.001*
Planned (Corin OPS) inclination	39° (1.8°)	39° (1.3°)	39° (2.0°)	0.009*
Morphological anteversion per TAL	18° (6.4°)	17° (5.8°)	18° (6.9°)	0.67
Morphological anteversion per ARP	18° (6.3°)	18° (5.3°)	18° (7.2°)	0.69
Morphological inclination per ARP	52° (7.4°)	53° (7.5°)	50° (7.1°)	0.044*
Functional anteversion per TAL	17° (6.4°)	16° (5.8°)	18° (6.8°)	0.024*
Functional anteversion per ARP	18° (7.1°)	15° (5.6°)	21° (7.1°)	<0.001*
Functional inclination per ARP	52° (7.0°)	53° (6.9°)	51° (7.0°)	0.11
Delta Anteversion	4.4° (7.4°)	8.6° (6.3°)	−1.1° (6.5°)	<0.001*
Delta inclination	−13° (7.4)°	−14° (7.7°)	−12° (7.7°)	0.11

*Indicates statistically significant difference. ARP = acetabular rim plane, OPS = optimized positioning system, and TAL = transverse acetabular ligament.

Discussion

Identification of optimal, acetabular component orientation for patients undergoing THA is a subject that has received great attention as patient-specific orientation targets likely exist[7,14,20]. Each patient's anatomy varies greatly[29,30], and it is unknown whether replicating native anatomy is ideal for biomechanical THA behavior. It has been suggested that replicating TAL for cup anteversion, while aiming for cup inclination of 35° to 40°, significantly reduces dislocation risk post-THA[21]. In this study, we compared native anatomy with target cup orientations as recommended by 3 algorithms that consider hip-spine characteristics[13,16,20]. We did not determine any difference in TAL and ARP-defined anteversion and, thus, consider both to be representative of native anatomy.

Replication of native anatomical acetabular version would not consistently achieve targets for each algorithm. Native anatomy did not differ from OPS-prescribed orientations in patients with adverse spinopelvic characteristics, and most native orientations met CSI targets. However, native anatomy did not meet prescribed target orientations by the Hip-Spine Classification[16]. Target orientations defined by the 3 algorithms,

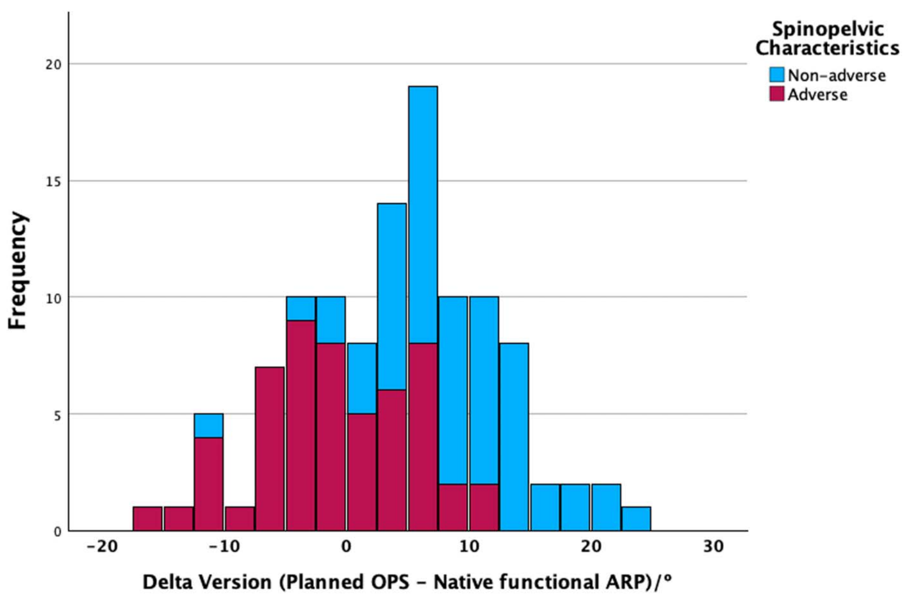

Fig. 4
Differences between planned and native anteversions for both the nonadverse and adverse groups.

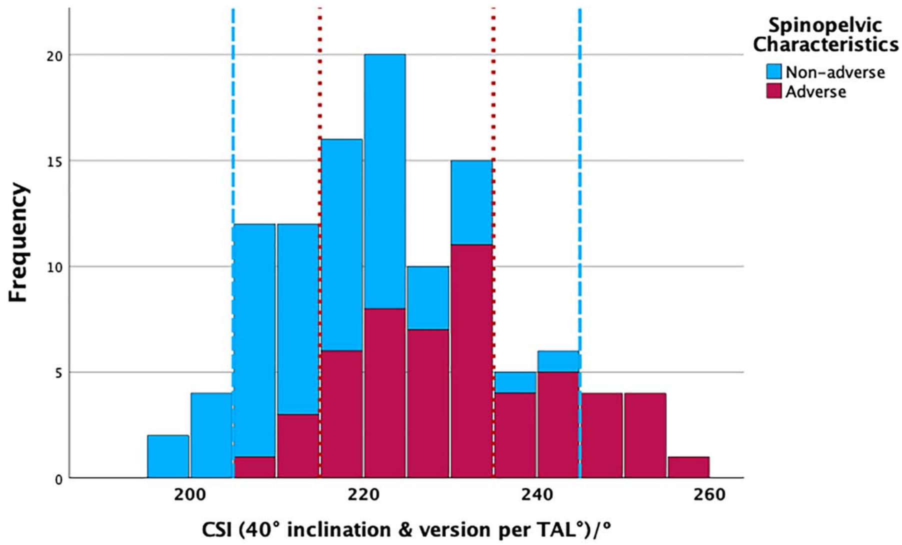

Fig. 5
Differences of CSI for both the nonadverse and adverse groups. Dashed lines indicate target ranges: blue dash for nonadverse and red dash for adverse. CSI = combined sagittal index.

varied greatly between them with absolute agreement in only 31% of cases and superior agreement between OPS and the Hip-Spine Classification (64%). Despite the lack of agreement for target orientations, use of these 3 algorithms has illustrated low dislocation rates (0.3%-0.8%) post-THA[13,16,24]. In view of their cup target differences, it is plausible that the reduced dislocation rates reported stem from a multitude of reasons associated with advanced planning (e.g., muscle sparing approach, accuracy of coronal reconstruction, bearing diameter, femoral version) and not solely cup orientation. Until high-level evidence exists on optimal patient-specific target orientation, replication of native anteversion, with 40° of inclination will satisfy spinopelvic orientation target in 88% of patients according to at least one hip-spine algorithm and is of clinical use for surgeons not using additional technologies.

Reconciling static preoperative imaging studies to dynamic hip-spine relationships and then to intraoperative component positioning is complex. Computer modeling is an attractive solution, as it allows kinematic hip and spine analysis to theoretically mitigate impingement risks and dislocation risks postoperatively. Use of OPS is associated with a 0.4% dislocation rate[24] and has demonstrated improved accuracy in achieving preset cup orientation targets relative to traditional intraoperative methods (i.e. landmarking)[26]. OPS creates plans and intraoperative delivery systems for all aspects of hip reconstruction, and it is thus impossible to uncouple the effect of cup orientation from other reconstruction parameters. In this study, OPS-planned cup anteversion as did not differ from native anatomy for patients with adverse spinopelvic characteristics. Inclination was expectedly different between planned and native anatomy, as this has previously been reported and a target of about 40° remains universally accepted[23]. Anteversion differed for the nonadverse group, being relatively higher for planned orientations. This is probably reflective of corrections made to mitigate dislocation risk in a subset of subjects with low anteversion, knowing that lack of abnormal spinopelvic characteristics implies that patients do not hyperextend their hip, thus are not at risk of posterior impingement and anterior dislocation when standing. Furthermore, most patients were operated with a posterior approach and surgeons might have opted for increased version to mitigate posterior instability risk.

Replicating native anatomy in patients without adverse characteristics satisfied CSI zone for most patients. In a small subset, this was not satisfied due to low CSI values (low acetabular anteversion). This finding aligns with the OPS analysis that a small cohort of patients, likely male, with nonadverse spinopelvic characteristics might benefit from an increase in cup version. In patients with adverse spinopelvic characteristics, replicating native anatomy might increase CSI beyond the narrow target in 33% (18/54) of patients. Thus, replicating native anteversion is advocated but should be followed by a detailed intraoperative assessment of posterior impingement as not all hips with high CSI would impinge posteriorly, due to other factors at play (offset, femoral version, pelvic morphology[35]).

TABLE IV Average Native Anteversion Per TAL, Distributed According to the Hip-Spine Classification[16],*

Hip-Spine Classification	Native Anteversion (±SD)
Group 1A–normal alignment, normal mobility	17.3° ± 5.8° (n = 57)
Group 2A–flatback deformity, normal mobility	15.2° ± 3.9° (n = 3)
Group 2B–flatback deformity, stiff mobility	17.9° ± 7.0° (n = 51)

*TAL = transverse acetabular ligament.

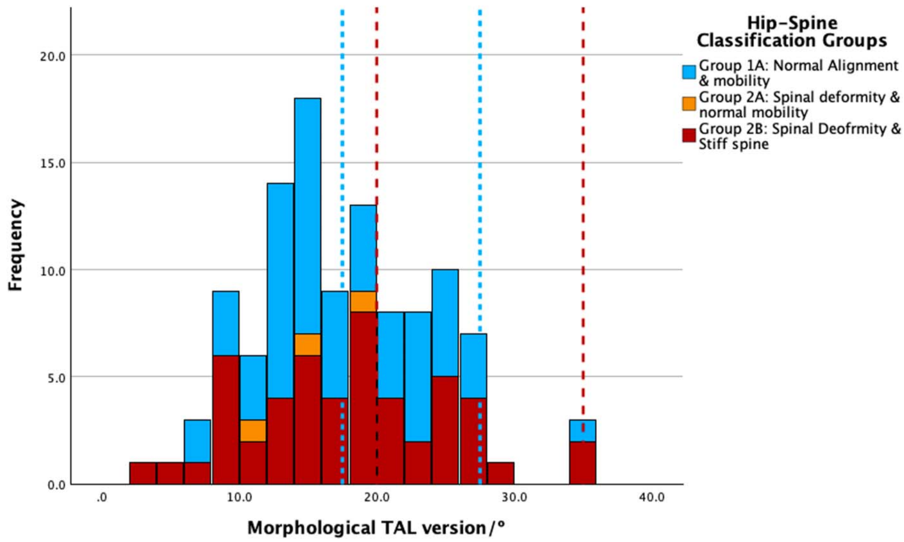

Fig. 6
Differences in anteversion for Hip-Spine Classification groups based on TAL anteversion. Dashed lines indicate target ranges: red for Group 2B and blue for Group 1A and 2A. TAL = transverse acetabular ligament.

Contrary to OPS and CSI, replicating native acetabular version would only satisfy Hip-Spine Classification[16] recommendations in 40% of cases. In most cases, native version was below Hip-Spine algorithm recommendations. The Hip-Spine algorithm[16] is simple to use and interpret but has certain limitations[7]. Furthermore, its description has been in posterior approach THAs with navigation/robotics and use of dual mobility in patients with abnormal spinopelvic characteristics[16]. To date, there has been no external validation without additional technology and, thus, the low dislocation reported[16] cannot solely be attributed to cup orientations achieved.

There was low agreement between all 3 hip-spine algorithms, which further contributes to the complexity on how best to incorporate hip-spine analysis into practice. Replicating native version (as per TAL) and reducing inclination to 40° would satisfy at least one validated hip-spine algorithm in most cases and should be advocated. Surgeons should focus on how best to achieve this as reliably as possible. This can be done visually and with simple tools (e.g., inclinometer)[22,32]. Considering that surgeons may display poor ability to achieve target orientations[36] and the potentially narrower safe orientation windows, advanced technology with proven ability to improve intraoperative accuracy[20,24,26,37], is likely to improve outcomes as such tools can improve overall reconstruction accuracy. Furthermore, as dislocation rates reduce, optimal reconstructions should aim at improving outcome by reducing (sub)clinical impingement.

This study suffers from certain limitations. First, it suffers from inherent limitations associated with a retrospective study design. Second, we focused on the contribution of acetabular orientation toward outcome/instability. Numerous additional variables contribute, including femoral version, head size, offset, soft tissue repair, and surgical approach. However, the primary aim of this study was to uncouple cup orientation, native acetabular anatomy, and spinopelvic characteristics. Third, TAL, besides not always being visible intraoperatively, was not directly visible on CT scans and was instead inferred from anatomical landmarks.

TABLE V Algorithm Agreement Between Corin OPS[24], CSI[13], and the Hip-Spine Classification[16]*

Hip-Spine Planning Algorithms	Algorithm agreement, Within Target	Algorithm Agreement, Outside Target	Overall Algorithm Agreement
OPS and Hip-Spine Classification	26 (15/11)	45 (28/17)	71 (43/28)
Hip-Spine Classification and CSI	35 (24/11)	18 (6/12)	53 (30/23)
CSI and OPS	37 (20/17)	18 (6/12)	55 (26/29)
All 3 algorithms	21 (15/6)	13 (6/7)	34 (21/13)

*Calculated as sum of all hips with native anatomy that met or did not meet the listed combinations of planning algorithms. The greatest agreement was between OPS and the Hip-Spine Classification. When tallied, native anatomy for 98 of 111 hips satisfied at least one target range. Table values represented as: Total cases (Nonadverse/Adverse). CSI = combined sagittal index, and OPS = optimized positioning system.

Both the TAL and ARP were determined using similar methods, and TAL anteversion was in close proximity to that defined by ARP, which has been validated previously[28,29].

Conclusion

Replication of native acetabular version and 40° of inclination (±5°) would satisfy at least one hip-spine algorithm target in 88% of cases and is a reasonable target if no advanced hip-spine algorithms are used for preoperative planning or intraoperative execution. Consideration of increasing acetabular version should be given in men without adverse spinopelvic characteristics. The lack of agreement between algorithms, yet low dislocation rates reported with their use, indicates that although achieving "optimal" cup orientation is of value, other parameters are of importance too that probably contribute to the outcomes reported, emphasizing the holistic approach necessary for improved outcome. ■

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