SAFE ZONE FOR THE ACETABULAR COMPONENT IN THE CONCEPT OF SPINOPELVIC RELATIONSHIPS

A.V. Peleganchuk, E.N. Turgunov, E.A. Mushkachev, B.R. Tashtanov, V.V. Pavlov, A.A. Korytkin
Novosibirsk Research Institute of Traumatology and Orthopaedics, Novosibirsk, Russia

Objective. To analyze the correlation of the acetabular component (AC) position criteria with the sagittal balance criteria in pelvic translation associated with body posture change from a standing to a sitting position and vice versa.

Material and Methods. A prospective study of 20 patients who underwent hip arthroplasty for unilateral coxarthrosis, in the absence of signs of arthrosis and dysfunction of the contralateral joint was conducted. A the 20th week after surgery, an X-ray examination of the spine and hip joints was performed with an analysis of anteversion, inclination, AC ante-tilt, PT, SS, PTsit. A search for correlations between the indicators was carried out using the Spearman correlation method. Numerical associations were identified by calculating the Pearson correlation coefficients. Statistical hypotheses were tested at a critical significance level of 0.05, i.e. the difference was considered statistically significant when the level of $p < 0.05$ was achieved.

Results. A direct correlation was found between the changes in the sagittal balance parameters (SS, PT) and the AC position. Comparison of the mean values and medians of the studied parameters measured in the standing and sitting positions showed the high correlation between them. The same dynamics of changes in the values between the AC ante-tilt and pelvic PT parameters was noted. A high direct correlation of the difference (Δ) in the AC ante-tilt values with PT in standing position, and a strong correlation of Δ in the AC ante-tilt values with PT in sitting position indicates an indirect relationship between the sagittal balance parameters and the AC position parameters through the AC ante-tilt parameter. This is confirmed by the strong direct correlation of Δ (sitting/standing) PT with Δ (sitting/standing) AC inclination (0.67) and Δ (sitting/standing) AC ante-tilt (0.82), and by an inverse correlation of Δ (sitting/standing) SS with Δ (sitting/standing) AC inclination and Δ (sitting/standing) AC ante-tilt (−0.7).

Conclusion. Comparison of sagittal balance parameters (SS, PT) measured in standing and sitting positions with the position of the AC showed their direct high correlation with each other. Acetabular ante-tilt serves as a connecting criterion between sagittal balance parameters and the spatial position of the acetabular cup.

Keywords: coxarthrosis; total hip arthroplasty; dislocation of the femoral head; sagittal balance; anteversion; ante-tilt; safe zone; pelvic tilt; hip-spine syndrome.

Please cite this paper as: *Peleganchuk AV, Turgunov EN, Mushkachev EA, Tashtanov BR, Pavlov VV, Korytkin AA. Safe zone for the acetabular component in the concept of spinopelvic relationships. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2025;22(2):23–31. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2025.2.23-31

For a long time, lumbar spine and hip joint abnormalities have been studied separately. Pathological or postoperative stiffness and concomitant pelvic tilt degression were not considered, as well as decrease in lumbar lordosis compensated by increasing PT when changing sitting to standing position [1, 2]. Researches on the relationship between spine types and the incidence of prosthetic hip joint dislocations are described in the Russian literature sources; however, they are few in number [3].

Prosthetic dislocations in patients were often associated with concomitant spinal abnormality, with the dislocation incidence of 7.4% in patients with lumbar stiffness (history of ankylosing spondylitis, or single-level or multilevel lumbar fusion) vs 4.8% in patients with mobile lumbar spine [2, 4]. This combined abnormality of the lumbar spine and hip joint, known as hip-spine syndrome, placed in question the perfect idea of the “safe zone” proposed earlier by Lewinnek.

The interrelation between the spatial orientation of the pelvis and the spine is analyzed as part of spinopelvic relationships [4, 5]. Meanwhile, the correlation of the criteria of spinopelvic relationships with the values of inclination and anteversion angles as knowledge-based criteria for the position of the acetabular component (AC) is not analyzed sufficiently to clarify the patterns of interrelation between these parameters.

To describe the AC position in the sagittal plane (sagittal orientation), the concept of the AC anterior tilt (acetabular tilt, ante-tilt) was implemented [6]. It was observed that the AC sagittal orientation (AC anterior tilt, acetabular tilt) changed consistently with this movement of the pelvis and correlated with PT [7, 8].

Accumulation of knowledge on the spinopelvic relationships contributes to the understanding of the regularity of the pelvic position transformation [7]. A change in the spatial position of the pelvis when changing body posture from a standing position to a sitting position and vice versa unavoidably leads to a change in the spatial position of the AC [1, 9]. These changes require analysis of the correlation of the AC position criteria with the sagittal balance criteria, and it was the objective of our research.

Material and Methods

A single-center prospective study was conducted as part of the postoperative control and involved 20 patients who underwent hip arthroplasty for unilateral coxarthrosis with no signs of arthrosis and dysfunction of the contralateral hip joint.

Inclusion criteria were the following:

- patients who underwent unilateral cementless total hip arthroplasty;
- contralateral hip joint which was not involved in surgery with no signs of arthrosis or joint dysfunction;
- the AC prosthesis was placed in the Lewinnek safe zone;
- the study was conducted during week 20 after hip arthroplasty.

Non-inclusion criteria were the following:

- patients with bilateral total hip arthroplasty;
- patients with unilateral hip arthroplasty, contralateral hip joint which was not involved in surgery with the signs of arthrosis and joint dysfunction;
- the AC prosthesis was placed outside the Lewinnek safe zone;
- the study was conducted earlier than 20 weeks after hip arthroplasty;
- history of revision surgical intervention in the hip joint;
- the patient does not want to participate in the study.

Radiological examination of the pelvic area in two planes was performed 5 months after surgery, when the hip joint function is restored (no pain, walking without walking aids) and the period of incapacity to work ends. Radiography was performed in a frontal plane with the patient standing and sitting, involving the lumbar spine in a lateral plane while standing (as a part of the radiological examination of the sagittal balance). Radiography of the pelvis was also performed in a lateral plane with the patient sitting on a "backless stool" with arms crossed or palms (hands) placed crosswise in the clavicle area. Thus, each patient had four radiological images: a radiological image in the anteroposterior plane while standing (Fig. 1), a radiological image in the anteroposterior plane while sitting (Fig. 2), a radiological image in the lateral plane while standing (Fig. 3), and a radiological image in the lateral plane while sitting (Fig. 4). A frontal radiography of the pelvis in a sitting position was performed using the Rippstein position [10].

The frontal anteroposterior radiological images of the pelvis were used to analyze the AC anteversion and inclination parameters using conventional techniques. The measurements were performed in K-PACS software, version 1.5.0.29 (Image Information Systems Ltd). The anteversion of the acetabular component was measured using the method proposed by Lewinnek et al. [11].

The following parameters were determined using the lateral radiological images of the pelvis in the standing and sitting positions: the AC ante-tilt, sagittal balance parameters (PT and SS; PTsit that is measured as the angle between the line connecting the middle of the upper endplate of the S1 with the projection point of the ischial tuberosity axis and the vertical line drawn through the projection point of the ischial tuberosity axis).

The AC ante-tilt was calculated by measuring the angle formed by a horizontal line drawn through the lower edge of the AC and a line drawn along the AC plane, or a line drawn through the most prominent points of the AC contour [12].

The correlation of the AC ante-tilt angles with the AC inclination and anteversion was analyzed, as well as with the sagittal balance parameters.

Statistical analysis. The search for correlations between the parameters in the standing and sitting positions, between the parameters of the acetabular inclination, acetabular anteversion and ante-tilt in the standing and sitting positions and other parameters, as well as between the difference in the values in the standing and sitting positions and other parameters was carried out using the Spearman's correlation coefficient. Numerical associations were found by calculating the Pearson correlation coefficients. Statistical hypotheses were tested at a critical significance value of 0.05, i.e. differences were considered statistically significant at the achieved $p < 0.05$. Statistical calculations were performed in the IDE RStudio software (version 2023.09.1 Build 494 © 2009-2009-2023 Posit Software, PBC) using the R language (version 4.0.2, URL: https://www.Rproject. org).

Results

Measurement results obtained during radiological examinations 5 months after hip arthroplasty in the standing and sitting positions are provided in Table 1.

Differences in the values of the AC inclination and anteversion angles in the standing and sitting positions are associated with the pelvic retroversion when the patient sits with support on the ischial tuberosities. These data correlate with changes in the PT and SS parameters in the standing and sitting positions that are used to describe the sagittal balance, in particular, the spinopelvic relationships. The values of PT standing and sitting, PTsit standing and sitting, and SS standing provided in Table 1 correspond to the conventional values and patterns and indicate the measure of the pelvic inclination angle (retroversion) when changing from a standing to a sitting position. A direct correlation of the sagittal balance parameters (SS, PT) with the AC position can also be observed when analyzing the values of the AC ante-tilt that varied in the same ranges.

Comparison of the means and medians of the analyzed parameters in the standing and sitting positions demonstrated their high correlation with each other (Table 2). However, the most significant are the same-type changes over time between the AC ante-tilt and pelvic PT values.

Being an integrating parameter for the AC inclination and anteversion measured on frontal pelvic radiological images in the anteroposterior plane, the AC ante-tilt measured on lateral pelvic radiological images can be used as a linking criterion between the parameters of the sagittal balance and of the AC spatial position.

The high direct correlation (0.025) of the difference (Δ) of the AC ante-tilt values with the pelvic tilt values in the standing position, as well as the strong correlation of the Δ ante-tilt values (0.058) with the pelvic tilt values in the sitting position indicate an indirect relationship between the sagittal balance parameters and the AC position parameters via the ante-tilt. This is confirmed by the strong direct correlation of Δ PT in the sitting/standing position with Δ AC inclination (r (p) = 0.67 (0.001)) in the sitting/standing position and Δ AC ante-tilt (r (p) = 0.82 (<0.001)) in the sitting/standing position, as well as the inverse correlation of Δ SS in the sitting/standing with Δ acetabular inclination (r (p) = 0.48 (0.031)) in the sitting/standing position and Δ AC ante-tilt in the sitting/standing position (r (p) = –0.7 (<0.001)).

The inverse correlations of the sitting sacral slope (SS) angle and Δ standing/sitting SS angle values with the values of the AC ante-tilt correspond to the pelvic back rotation in regard to the sciatic axis which is formed with support on the ischial tuberosities.

Pelvic rotations in regard to the rotation axes (the rotation axis in regard to the femoral heads in the standing position, and the rotation axis in regard to the ischial tuberosities in the sitting position) are estimated using anatomical landmarks with relatively conventional "zeros": vertical (Y) and horizontal (X) (2D coordinate system). If the values of the ante-tilt while standing correlate with the sitting values and the values of the SS angle, then the AC anteversion and inclination angles have the same reliable direct correlation with the same correlation of the values of the acetabular inclination angle while standing and sitting. Thus, it can be assumed that the change in the AC angles will correlate with the values of the sacral slope angles, so it corresponds to the incidence principle.

When changing to a sitting position, the pelvis is supported by the tuberosities of the ischial bones, and the values of the pelvic tilt (PT) angle measured in regard to the centers of rotation of the femoral heads highly correlate with the values of the ante-tilt; and it is a natural result, since the measurement of the pelvic tilt angles and ante-tilt is carried out in the same X/Y coordinate system, which corresponds to their common "zero" point.

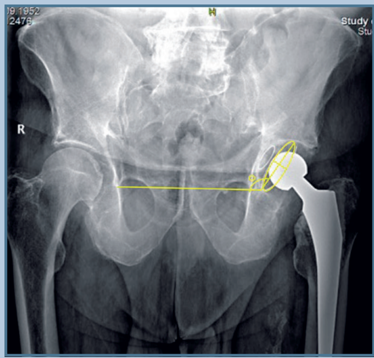

Fig. 1
Radiograph of the pelvis in the anteroposterior plane in a standing position with an angle of inclination and anteversion

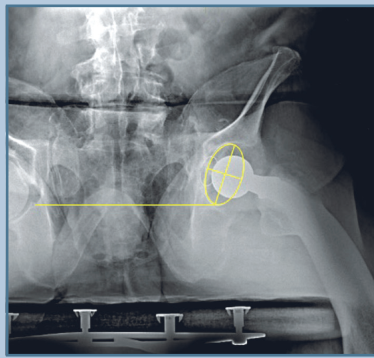

Fig. 2
Radiograph of the pelvis in the anteroposterior plane in a sitting position with an angle of inclination and anteversion

Discussion

Hip joint prosthesis dislocation as a clinical manifestation of instability is a significant complication [2, 4]. To prevent hip joint instability, in particular, femoral component dislocations, Lewinnek et al. [11] proposed implanting the AC of the hip joint prosthesis in acceptable angle ranges.

The accepted values are 40–45° for the AC inclination angle and 5–15° for the AC anteversion. These ranges of AC inclination and anteversion are associated with the lowest amount of dislocations of the femoral component of the hip joint prosthesis; due to that, Lewinnek et al. [11] described the above ranges as the safe zone. Using these recommendations, the incidence of dislocations during standard primary hip arthroplasty significantly reduced; however, they still occurred, amounting to 4.8–7.4%,

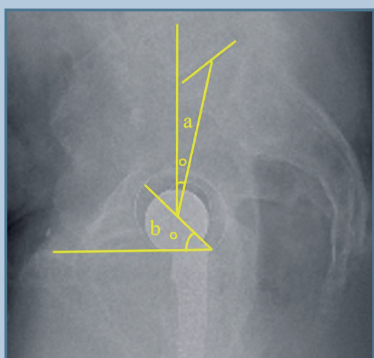

Fig. 3
Radiograph of the pelvis in the lateral plane in a standing position with an angle of acetabular component ante-tilt and PT

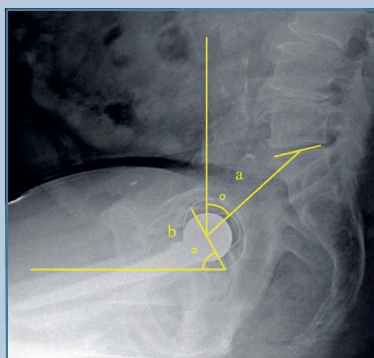

Fig. 4
Radiograph of the pelvis in the lateral plane in a sitting position with an angle of acetabular component ante-tilt and PT

Table 1

Indicators of sagittal balance and orientation of the acetabular component (AC) in the patient's standing and sitting positions 5 months after surgery, degrees

Indicator	MED [Q1; Q3]	M ± SD	MIN–MAX
PT standing	14.0 [8.25; 19.00]	13.80 ± 8.97	1–33
SS standing	39.0 [33.75; 48.25]	41.15 ± 9.01	28–56
Anteversion angle of AC standing	21.0 [16.25; 25.75]	20.70 ± 8.44	5–34
Inclination angle of AC standing	44.0 [37.50; 45.50]	42.80 ± 8.08	30–61
Ante-tilt angle of AC standing in sagittal plane	39.5 [30.00; 48.50]	39.50 ± 11.36	18–59
PTsit standing	–0.5 [–5.25; 2.50]	0.15 ± 9.48	–5–27
PT sitting	36.5 [30.25; 42.25]	35.60 ± 7.42	23–48
SS sitting	18.5 [9.75; 27.00]	18.40 ± 11.03	1–40
Anteversion angle of AC sitting	29.0 [22.75; 33.25]	27.65 ± 8.53	7–39
Inclination angle of AC sitting	50.0 [47.50; 59.00]	53.15 ± 10.06	37–77
Ante-tilt angle of AC sitting in sagittal plane	61.0 [51.75; 68.00]	60.20 ± 12.15	38–83
PTsit sitting	15.0 [10.00; 22.25]	15.20 ± 8.10	–13–18

despite the fact that the AC position was in the target safe zone [2]. When studying the hip-spine syndrome, it was found that a spinal pathology leads to not only the pelvic tilt in the frontal plane that is often considered during hip arthroplasty, but also to the limited movement (retro- and anteversion) of the pelvis that is often ignored by orthopedists in routine practice when planning hip arthroplasty [1, 2, 13]. Placed in a certain spatial position considering the "safe zone" and according to the manufacturers' technologies in the patient's lying position with orientation to the pelvic anterior plane, the prosthetic AC is usually analyzed using frontal radiological images of the pelvis in the anteroposterior plane in a standing or lying position, when the spatial position of the pelvis differs. Due to the actual kinetics of the pelvis, in accordance with the incidence principle, the AC, like the pelvis, will change its position in natural everyday postures (standing or sitting) in a greater range than the safe zone [2, 5, 14].

The pelvic kinetics and its interrelation with the spine are analyzed in the context of spinopelvic relationships and are described using specific criteria, features, values, and patterns of correlation relationships [1].

The criteria for assessing spinopelvic relationships were developed as follows. Legaye et al. [15] proposed a parameter to measure the pelvic incidence (PI). The pelvis is a rigid structure, with certain defined points (vertices) and lines (edges) forming the common pelvic parameters (PI, PT, SS, etc.). These vertices and edges form an interconnection that can be described using graph theory [12] and incidence as a fundamental feature that characterizes all systems with rigidly interconnected landmarks that have stable connections; it explains the interrelations of the sagittal balance parameters. The pelvic tilt (PT) parameter was proposed to measure the dynamic parameters of the pelvic tilt. Sacral slope (SS) and lumbar lordosis (LL) are also the parameters required to evaluate the sagittal balance. PT, PI, SS, and LL are the most valid parameters of the spinopelvic relationships in the sagittal plane. It is recognized that LL directly depends on the SS and has a positive correlation with it. The LL parameter describes the compensation of the pelvic tilt variation which results in the achievement of trunk balance. This compensation mechanism also has a reverse trend: in degenerative diseases of the lumbar spine, with the flattening of the lumbar lordosis, the pelvis tilts dorsally for compensation and acquires a posteriorly open SS angle [1, 2, 11].

In 2014, Kanawade et al. [8] studied the changes in the AC position in the sagittal (lateral) plane, with simultaneous evaluation of the sagittal balance parameters. When analyzing the AC position on lateral pelvic radiological images, to describe it and considering the orientation in the sagittal plane, they introduced the concept of "acetabular tilt" that can be described as the acetabular ante-tilt, in a manner similar to the SS and PT criteria. The authors proposed to define the ante-tilt angle as the angle between the line drawn through the most prominent points of the contours of the AC anterior and posterior edges and the horizontal line drawn through the point of the AC lower edge [8]. Differences between the ante-tilt angles measured in the standing and sitting positions represent a change in the AC inclination and anteversion caused by the dynamic movement of the pelvis.

During the study of the correlation of the AC inclination and anteversion angles when changing the standing/sitting position, Lazennec et al. [6, 7] demonstrated that the AC anteversion angle measured on standing and sitting survey radiological images of the pelvis in anteroposterior plane is directly proportional to the magnitude of the pelvis version angle. Thus, when changing the trunk position from standing to sitting,

Table 2

Indicators of sagittal balance (PT, SS) and spatial orientation (inclination, anteversion) of the acetabular component (AC) in the patient's sitting and standing positions

Indicators	Standing position	Sitting position	Δ, difference in the values in standing/sitting position	Wilcoxon test, p value
	p value	MED [Q1; Q3]	pMED [95 % CI]	
	M ± SD	M ± SD	SMD [95 % CI]	
	MIN–MAX	MIN–MAX		
PT	14.00 [8.25; 19.00]	36.50 [30.25; 42.25]	−21.50 [−22.50; −20.50]	<0.001*
	13.80 ± 8.97	35.60 ± 7.42	−2.65 [−3.51; −1.79]	
	1–33	23–48		
SS	39.00 [33.75; 48.25]	18.50 [9.75; 27.00]	22.25 [21.50; 23.00]	<0.001*
	41.15 ± 9.01	18.40 ± 11.03	2.26 [1.46; 3.06]	
	28–56	1–40		
AC inclination	44.00 [37.50; 45.50]	50 [47.50; 59.00]	−10.50 [−11.50; −9.50]	<0.001*
	42.80 ± 8.08	53.15 ± 10.06	−1.13 [−1.80; −0.46]	
	30–61	37–77		
AC anteversion	21.00 [16.25; 25.75]	29 [22.75; 33.25]	−7.00 [−7.50; −6.50]	<0.001*
	20.70 ± 8.44	27.65 ± 8.53	−0.82 [−1.47; −0.17]	
	5–34	7–39		
AC ante-tilt	39.50 [30; 48.50]	61 [51.75; 68.00]	−20.50 [−21.50; −20.00]	<0.001*
	39.50 ± 11.36	60.20 ± 12.15	−1.76 [−2.50; −1.02]	
	18–59	38–83		
PTsit	−0.50 [−5.25; 2.50]	15.00 [10.00; 22.25]	−16.50 [−17.50; −15.00]	0.001*
	0.15 ± 9.48	15.20 ± 8.10	−1.71 [−2.44; −0.98]	
		−5–27		

* $p < 0.05$.

with a mean retroversion of the pelvis by 14.5°, there is an increase in the AC frontal anteversion by 7.1° [6]. The similar relationship is observed in the Bordeaux classification that considers the features of the spinopelvic relationship and assumes a change in the AC anteversion in one or another direction during its implantation [17].

The experiment on modeling various combinations of AC inclination and anteversion angles compared with the AC ante-tilt angles during a sagittal examination conducted by Kanawade et al. [8] revealed their effect on the actual values of the ante-tilt angle; this emphasizes the importance of the ante-tilt parameter as an additional reference criterion for the functional position of the AC.

Based on this experiment and the earlier described features of pelvic biomechanics [18], one can state with confidence that the spatial positions of the placed ACs with a certain combination of inclinations and anteversions during surgery in the lying position will differ from the effective spatial position of the AC while standing and sitting. At that, as we have demonstrated, the correlation of the AC position angles depending on the standing and sitting position with the sagittal balance parameters (PT and SS) measured under the same conditions is quite strong. These data values correspond to the results obtained by Lazennec et al. [6, 7] who stated that the position of the AC implanted with certain angles of anteversion and frontal inclination in the lying position will subsequently change when taking a sitting and standing position.

Accumulated data resulted in clear understanding that the AC position in the safe zone does not guarantee the absence of dislocations in the postoperative period. This is associated with either excessive retroversion of the pelvis and, accordingly, of the AC in the sitting position, or, conversely, with a fixed position of the pelvis when it becomes static and an unchanged AC position. Ignoring this fact may result in unavoidable impingement of the femoral component with the AC and the prosthesis dislocation [2, 19].

Being one of the significant reference parameter for hip arthroplasty, the AC anteversion has an effect not only on the prosthesis dislocation, but also on its survival. Increasing AC anteversion leads to the contact patch shifts and, as a result, to the increasing pressure on the edge of the liner [20]. The correct position of the contact patch and regular load distribution on the liner have an effect on the wear rate of the latter [1], and this is extremely important for assessing the quality of surgical intervention.

One of the current issues of hip arthroplasty is noise in hard-on-hard bearing surfaces. It is established that the assessment of the AC position can be a noise predictor vs static measurements in the lying position [20–23]. The authors of the researches associated this phenome-

Table 3

Comparative assessment of the difference (Δ) in the values of sagittal balance (PT, SS) and spatial orientation (inclination and anteversion, ante-tilt) of the acetabular component when changing the sitting and standing position 5 months after surgery

Показатель	Δ cup inclination, sitting/ standing, r (p)	Δ cup anterversion, siting/ standing, r (p)	Δ ante-tilt, sitting/ standing, r (p)
PT standing	–0.34 (0.145)	–0.05 (0.822)	–0.50 (0.025*)
SS standing	0.07 (0.756)	–0.31 (0.181)	–0.03 (0.913)
PT sitting	0.47 (0.039*)	0.44 (0.051)	0.43 (0.058)
SS sitting	–0.28 (0.231)	–0.50 (0.023*)	–0.61 (0.004*)
Δ PT standing	0.67 (0.001*)	0.20 (0.405)	0.82 (<0.001*)
Δ SS sitting/standing	–0.48 (0.031*)	–0.33 (0.152)	–0.70 (<0.001*)
PTsit standing	0.01 (0.968)	0.09 (0.718)	–0.21 (0.377)
PTsit sitting	0.25 (0.281)	0.42 (0.062)	0.39 (0.087)
Δ PTsit sitting/standing	0.22 (0.347)	0.22 (0.354)	0.38 (0.099)

* $p < 0.05$.

non with the pelvic displacement during movement corresponding to the disorientation of the acetabular component angles in the sitting and standing positions, and during moving [22, 24].

In an experiment with mathematical simulation, Pierrepont et al. [24] evaluated and clearly demonstrated the significance of the sagittal balance in relation to the anteversion of the acetabular component in various positions and its effect on the displacement of the contact patch. The experiment demonstrated that an increase in the PT angle of more than 10° when the patient assumes a sitting position leads to a displacement of the head of the prosthetic femoral component to the AC edge (edge loading), regardless of the size of the femoral component head (32 mm, 36 mm, and 40 mm). As a result of the displacement of the contact patch between the femoral head and the acetabulum, the contact patch area was reduced, thereby increasing the contact pressure of the head on the liner that contributes to its premature wear in case of, for example, a polyethylene liner. With a ceramic liner, friction under dry conditions develops (with no lubricated zones because of high pressure which leads to noise/creaking). The maximum pressure of 500 MPa was identified by the authors for a 40 mm liner and 30° PT displacement in the sitting position [24].

In our research, a very high positive correlation was found at the critical significance value ($p < 0.001$) between the variable values of PT, acetabular anteversion, as well as a high correlation with the acetabular ante-tilt, and a significant correlation of SS values and acetabular inclination between the standing and sitting positions. These data indicate one-way changes in the measured parameters within one object (pelvis) in accordance with graph theory and represent their interrelation by the type of an incidence matrix. These changes correspond to the concept of pelvic rotation with support on the femoral heads and are well described in the literature [18].

Generally accepted criteria of sagittal balance to assess the pelvic version (SS, PT) allow for an accurate determination of the extreme positions of pelvic anteversion and retroversion, therefore, providing an indirect preoperative idea of the difference in the AC position when moving from a standing position to a sitting position and vice versa as a part of preoperative planning. This helps to make adequate decisions on the target position of the AC imposed by the pelvic kinetics [1].

Thus, the ante-tilt is the crossover point for the areas of interest of spinal surgeons and orthopedic prosthetists. The latter have increasingly start paying attention to individual parameters and patient requirements, as well as to kinematic technique for arthroplasty, rather than remaining within the standardized range of certain patient parameters, and all this has a beneficial effect on long-term results.

To comply with the principles of kinematic arthroplasty, it is recommended to perform a preoperative evaluation of the position of the lumbar spine, pelvis and hip in the sagittal plane in functional positions (sitting/standing) and to consider the specific features of the sagittal balance, thereby reducing the possibility of dislocation, early wear of polyethylene liner, loosening of components, or destruction of certain contacting surfaces.

Our study brings new data that may reveal the pathogenesis of type VI hip prosthesis instability (of unclear origin) according to the Classification System for the Unstable THA. Standard treatment for this type of instability using a constrained liner, without considering the kinematics of the pelvis, leads to a high failure rate; therefore, a change in treatment strategy is required for this type of instability. With this background, the implementation of robot-assisted hip arthroplasty technologies is becoming increasingly reasonable.

Further studies with a high level of evidence are needed for more detailed analysis of this issue.

Conclusion

Comparison of sagittal balance parameters (SS, PT) measured in the standing and sitting positions with the AC position demonstrated their high direct correlation with each other.

The ante-tilt may be used as a linking criterion between the sagittal balance parameters and the spatial position of the acetabulum.

The study had no sponsors. The authors declare that they have no conflict of interest.

The study was approved by the local ethics committees of the institutions.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

References

1. **Yang G, Li Y, Zhang H.** The influence of pelvic tilt on the anteversion angle of the acetabular prosthesis. Orthop Surg. 2019;11:762–769. DOI: 10.1111/os.12543
2. **Haffer H, Amini DA, Perka C, Pumberger M.** The impact of spinopelvic mobility on arthroplasty: Implications for hip and spine surgeons. J Clin Med. 2020;9:2569. DOI: 10.3390/jcm9082569
3. **Peleganchuk AV, Turgunov EN, Mushkachev EA, Sanginov AJ, Simonovich AE, Pavlov VV.** The influence of spinopelvic relationships on late dislocation of the prosthetic femoral head after total hip arthroplasty. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2022;19(1):63–70. DOI: 10.14531/ss2022.1.63-70
4. **Heckmann N, McKnight B, Stefl M, Trasolini NA, Ike H, Dorr LD.** Late dislocation following total hip arthroplasty: spinopelvic imbalance as a causative factor. J Bone Joint Surg Am. 2018;100:1845–1853. DOI: 10.2106/JBJS.18.00078
5. **Morimoto T, Kobayashi T, Tsukamoto M, Hirata H, Yoshihara T, Toda Y, Mawatari M.** Hip–spine syndrome: a focus on the pelvic incidence in hip disorders. J Clin Med. 2023;12:2034. DOI: 10.3390/jcm12052034
6. **Lazennec JY, Thauront F, Robbins CB, Pour AE.** Acetabular and femoral anteversions in standing position are outside the proposed safe zone after total hip arthroplasty. J Arthroplasty. 2017;32:3550–3556. DOI: 10.1016/j.arth.2017.06.023
7. **Lazennec JY, Charlot N, Gorin M, Roger B, Arafati N, Bissery A, Saillant G.** Hip-spine relationship: a radio-anatomical study for optimization in acetabular cup positioning. Surg Radiol Anat. 2004;26:136–144. DOI: 10.1007/s00276-003-0195-x
8. **Kanawade V, Dorr LD, Wan Z.** Predictability of acetabular component angular change with postural shift from standing to sitting position. J Bone Joint Surg Am. 2014;96:978–986. DOI: 10.2106/JBJS.M.00765
9. **Buckland AJ, Vigdorchik J, Schwab FJ, Errico TJ, Lafage R, Ames C, Bess S, Smith J, Mundis GM, Lafage V.** Acetabular anteversion changes due to spinal deformity correction: bridging the gap between hip and spine surgeons. J Bone Joint Surg Am. 2015;97:1913–1920. DOI: 10.2106/JBJS.O.00276
10. **Moeller TB, Reif E.** Pocket Atlas of Radiographic Positioning. Including Positioning for Conventional Angiography, CT, and MRI. 2nd ed. Thieme Verlagsgruppe, 2000.
11. **Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR.** Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60:217–220.
12. **Zaripova ER, Kokotchikova MG**. Discrete Mathematics. Part III. Graph Theory. Moscow, 2013].
13. **McKnight BM, Trasolini NA., Dorr LD.** Spinopelvic motion and impingement in total hip arthroplasty. J Arthroplasty. 2019;34:S53–S56. DOI: 10.1016/j.arth.2019.01.033
14. **Lazennec JY, Boyer P, Gorin M, Catonne Y, Rousseau MA.** Acetabular anteversion with CT in supine, simulated standing, and sitting positions in a THA patient population. Clin Orthop Relat Res. 2011;469:1103–1109. DOI: 10.1007/s11999-010-1732-7
15. **Legaye J, Duval-Beaupere G, Hecquet J, Marty C.** Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J. 1998;7:99–103. DOI: 10.1007/s005860050038
16. **Wera GD, Ting NT, Moric M, Paprosky WG, Sporer SM, Della Valle CJ.** Classification and management of the unstable total hip arthroplasty. J Arthroplasty. 2012;27:710–715. DOI: 10.1016/j.arth.2011.09.010
17. **Riviere C, Harman C, Parsons T, Villet L, Cobb J, Maillot C.** Kinematic alignment versus conventional techniques for total hip arthroplasty: A retrospective case control study. Orthop Traumatol Surg Res. 2019;105:895–905. DOI: 10.1016/j.otsr.2019.02.012
18. **Peleganchuk AV, Turgunov EN, Mushkachev EA, Fedorova NV, Danilov MN, Korytkin AA, Pavlov VV.** Modeling the behavior of the acetabular axis and the axis of the ischial tuberosities during the transition from a standing to a sitting position. Genij Ortopedii. 2023;29(4):410–418. DOI: 10.18019/1028-4427-2023-29-4-410-418
19. **Riviere C, Lazennec JY, Van Der Straeten C, Auvinet E, Cobb J, Muirhead-Allwood S.** The influence of spine-hip relations on total hip replacement: A systematic review. Orthop Traumatol Surg Res. 2017;103:559–568. DOI: 10.1016/j.otsr.2017.02.014
20. **Taylor S, Manley MT, Sutton K.** The role of stripe wear in causing acoustic emissions from alumina ceramic-on-ceramic bearings. J Arthroplasty. 2007;22(7 Suppl 3):47–51. DOI: 10.1016/j.arth.2007.05.038
21. **Shah SM, Deep K, Siramanakul C, Mahajan V, Picard F, Allen DJ.** Computer navigation helps reduce the incidence of noise after ceramic-on-ceramic total hip arthroplasty. J Arthroplasty. 2017;32:2783–2787. DOI: 10.1016/j.arth.2017.04.019
22. **Pierrepont JW, Feyen H, Miles BP, Young DA, Bare JV, Shimmin AJ.** Functional orientation86 of the acetabular component in ceramic-on-ceramic total hip arthroplasty and its relevance to squeaking. Bone Joint J. 2016;98B:910–916. DOI: 10.1302/0301-620X.98B7.37062
23. **Tashtanov BR, Kirilova IA, Pavlova DV, Pavlov VV.** Ceramic-related noise as an adverse outcome in total hip arthroplasty. Genij Ortopedii. 2023;29(5):565–573. DOI: 10.18019/1028-4427-2023-29-5-565-573
24. **Pierrepont J, Yang L, Arulampalam J, Stambouzou C, Miles B, Li Q.** The effect of seated pelvic tilt on posterior edge-loading in total hip arthroplasty: A finite element investigation. Proc Inst Mech Eng H. 2018;232:241–248. DOI: 10.1177/0954411917752028

Address correspondence to:
Mushkachev Evgeniy Andreevich
Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan,
17 Frunze str., Novosibirsk, 630091, Russia,
mushkachevi@gmail.com

Received 13.05.2025
Review completed 03.06.2025
Passed for printing 10.06.2025

Aleksey Vladimirovich Peleganchuk, MD, PhD, researcher, Research Department of Neurovertebrology, neurosurgeon, head of the Department of Neurosurgery No.2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 2663-9450, ORCID 0000-0002-4588-428X, apeleganchuk@mail.ru;

Eminjon Nematovich Turgunov, postgraduate student of Chair of traumatology and orthopaedics, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 7962-5060, ORCID 0000-0002-9381-7460, travma83@mail.ru;

Evgeniy Andreevich Mushkachev, junior researcher, Research Department of Neurovertebrology, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 4250-4886, ORCID 0000-0003-0346-3898, mushkachevi@gmail.com;

Baikozho Rustamovich Tashtanov, postgraduate student, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia. eLibrary SPIN: 6814-8599, ORCID: 0000-0002-8553-9712, b.tashtanov95@gmail.com;

Vitaly Viktorovich Pavlov, DMSc, head of the Research Department of endoprosthetics and endoscopic joint surgery, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 7596-2960, ORCID 0000-0002-8997-7330, pavlovdoc@mail.ru;

Andrey Aleksandrovich Korytkin, MD, PhD, Director, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 2273-2241, ORCID: 0000-0001-9231-5891, andrey.korytkin@gmail.com.