# 5.2 Hip-Spine Relationships: A New Concept to Analyse THP Dysfunction and Instability

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## Introduction

Dislocation is one of the most common complications of total hip replacement [25, 26]. The period of greatest risk for dislocation has been reported to be within the first few months after surgery, but, even if a hip is stable initially, a first dislocation still can occurs years after surgery.

The concept of cumulative risk factors is widely developed in the literature (type of T.H.P., operative approach, malposition, neurologic impairment, cognitive dysfunction) [2,7,16,18].

For late dislocation, the analysis is often very difficult, and several new mechanical problems are pointed out (muscular deconditioning with time, proximal or rotational migration of the socket and subsidence of the femoral stem reducing soft-tissue tension and increasing osseous impingement) [24].

Repetitive subluxation can be associated with dislocation (early or late) in some patients: subluxation leads to cold flow of the polyethylene of the socket rim and less containment of the femoral head.

In case of early or late dislocation, implant malposition has been reported This risk has been widely documented, using measures of femoral or acetabular anteversion [1,11,21]. But the analysis remains very elementary and especially focused on A.P. views of the pelvis (measuring acetabular frontal inclination) or conventional CT scan datas in patients in supine position.

Lumbosacral pelvic orientation is of outmost importance, as it plays a critical role in the sagittal orientation of the spine and of the hip joints. The trunk equilibrium influences the tridimensionnal orientation of each acetabulum and the functional range of motion of the hips.

The "sagittal spine profile" has been mainly studied by spine surgeons [8,9,11, 12,13].

They observed the side effects of long fusions for scoliosis treatement, without correct adjustment of sagittal plane, leading to more kyphosis and severe disequilibrium.

For a long time, the analysis was mainly focused on lumbar lordosis. The recent studies are more sophisticated, measuring new parameters: they demonstrate that this sagittal equilibrium is the consequence of a postural strategy, specific to each subject.

Duval-Beaupere's studies provided a new dimension to those radiological observations [3]. Each patient is characterized by a "morphological" parameter: the incidence angle (pelvic incidence is the angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the midpoint of a line connecting the femoral heads: it represents the thickness of the pelvis). The adaptation of other factors, as "pelvic version" (pelvic tilt) and spinal parameters (sacral tilt, lumbar lordosis, thoracic kyphosis) provides the general conditions for the best adapted posture of the spino-pelvic complex (minimal muscles activity for this "economical" postural situation).

Other studies demonstrated relationship between pelvic and spinal parameters (with a strong correlation between pelvic incidence and sacral slope, pelvic tilt, and lumbar lordosis in a normal population)[5,10,15 ,17,20,23].

## Hip-spine relationships

The understanding of this functional anatomy is necessary to explain the strange consequences of some lumbosacral arthrodesis on hip joints and to avoid some difficult adjustments of T.H.P. in patients with a fused or stiff spine.

In the normal subject standing, sitting or lying positions are "instantaneous" situations in a more complex adjustment including spinal movements, sacral tilt and hips flexion [6,19,22]. We often analyse the adaptation for sitting as hip flexion alone, but the lumbosacral movements may create until 30% of the global adjustment. On the contrary, trunk extension is achieved through simultaneous but nonlinear contributions from both the pelvis and lumbar spine throughout the range of motion. (The lumbar spine accounts for 70% of the total, with increased pelvic contributions in initial flexed postures).

Lumbar-pelvic rythm depends on whether the trunk was flexing or extending. During trunk flexion (down lift) there is a greater tendency for lumbar and pelvic rotations to occur simultaneously; during extension (up life) they normally occur more sequentially.

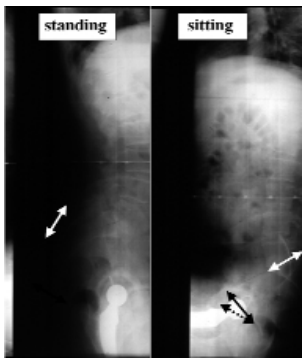


**Figure 1:**
Lateral views standing and sitting
Modifications of sagittal orientation of the acetabular cups can be observed as well as variation for sacral sagittal tilt.
- In standing position , sacral tilt (ST) is important.
- In sitting position, sacral tilt is low.

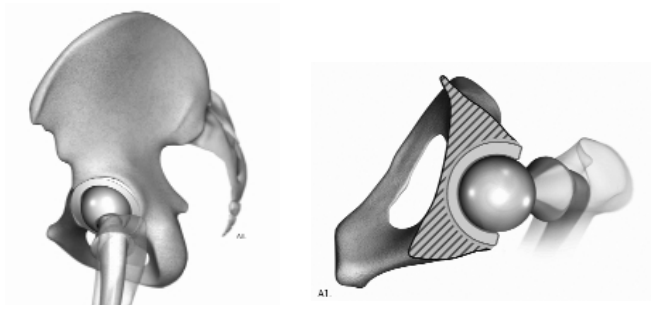

**Figure 2:**
Standing position.

- On the lateral view, the pelvis is anteverted (forward tilt of the pelvis); the sacrum is relatively horizontal with approximatively 40° sacral tilt (ST).
- On the CT scan, functional acetabular anteversion is low.

Standing position is linked to pelvic anteversion which means anterior tilt of the whole pelvis including the sacrum.

In this situation, the superior endplate of the sacrum on a lateral view creates with the horizontal line the sacral tilt angle ST (mean value 40°).

The acetabulum is oriented in a specific position: we call it "functional anteversion". This "functional anteversion" is the consequence of the "anterior opening" of the acetabulum in the standing position. The "functional anteversion" is not the "morphological anteversion" or "anatomical anteversion" (angle between the margin of the acetabulum and the sagittal plane): this value is a fixed parameter, specific to each subject.

In the standing position, the "functional acetabular anteversion is low" in normal subjects, despite some variations due to different postural patterns.

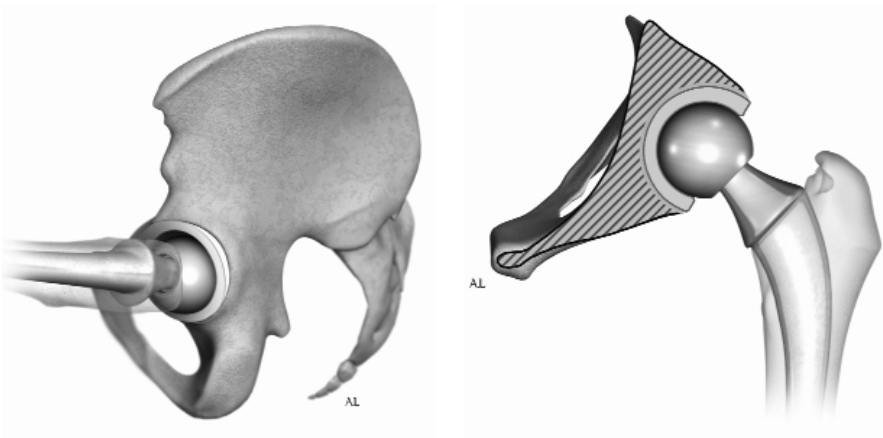

**Figure 3:**
Sitting position.
- On the lateral view, the pelvis is more retroverted (backward pelvic tilt); the sacrum is more vertical with a low sacral tilting angle (ST).
- On the CT scan, the functional acetabular anteversion is more important.

In sitting position, the situation is the opposite. The pelvis tilts posteriorly according to the progression to the sitting position. The sacral tilt angle (ST) decreases. In a series of more than 350 subjects studied in La Pitié, the ST values were either slightly positive (5° - 10°) or negative.

Sitting position creates a pelvic retroversion which means that the pelvis tilts backwards with a more vertical position of the sacrum. In this situation, the "functional" acetabular anteversion increases (the anterior opening of the acetabulum is greater due to this new posture).

Some subjects have a low sacral tilt angle, even in standing position, which means that the pelvic anteversion is low: we call it "paradoxal pelvic retroversion" and the sacrum seems more vertical on the lateral view of the pelvis. (Fig. 4)

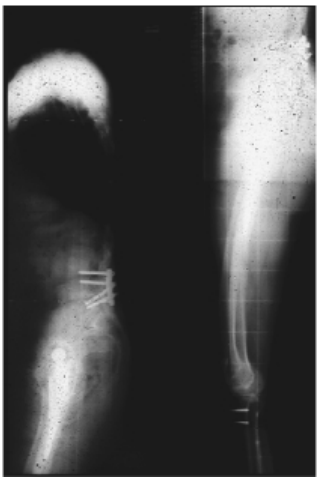

**Figure 4:**
Lumbosacral arthrodesis with inadequate adjustment (flat back, vertical sacrum, hips flexion).
On the right view, the patient was asked to correct is posture as much as possible:
residual hips flexion as the hips don't have sufficient adaptation possibilities.

Standing with the torso bent forward is inefficient and unstable. The hips and knees flex to compensate and to maintain an upright posture, producing a crouched posture and gait.

This posture puts extra demand on the back extensors, causing fatigue pain. Hip extensor weakness is frequent and the flexion of the hip may serve to place the extensors at a more mechanically advantageous muscle length.

In sitting position, this pelvic retroversion remains or increases. In this case, "functional" acetabular anteversion is abnormally increased and the "Functional Range of Motion" of the hip joint is modified with more internal rotation. This phenomenon has been observed in clinical practice, when studying the gait of patients with spinal fusion inducing a flatback with pelvic retroversion.

On the contrary, some subjects have a very horizontal sacrum in standing position, with a sacral tilt angle more than 50°. In sitting position,the pelvic anteversion remains or slightly reduces. In this case, functional acetabular anteversion is decreased and the "Functional Range of Motion" of the hip joint is deviated to the external rotation.

## Lying position (supine)

When the lower limbs are lying in full extension, the anterior pelvic tilt is greater than in standing position. This specific posture can be observed when doing lateral X rays on patients in a dorsal decubitus for a T.H.P. via an anterior approach. This adaptation occurs if the lumbosacral junction is mobile, but, if it is fused or stiff the spatial orientation of the acetabulum can be dramatically modified: this can creates problems for the adaptation of an acetabular implant.

## Correlations between lumbo-pelvic sagittal position and acetabular orientation:

Lumbosacral posture influences acetabulum anteversion. Understanding sacral tilt (ST) variations is essential to analyse standing and sitting positions acetabular positions [14].

- For the evaluation of each patient, precise radiological criteria are mandatory. We use full-length lateral radiographs centered on T12 in the standing and sitting positions with a focal film distance of 2 m. The radiographs show the entire trunk, the external acoustic meati, and the upper third of the femurs.

The standing position is standardized as follows: the subject stands in a relaxed position, with the arms folded across the chest to minimize variation due to the effects of trunk posture on the lumbosacral junction. Standardization of the sitting position involves placing the subject with the axes of the thighs perpendicular to the axis of the trunk and no pressure of the trunk against the back of the chair. The subject is asked to remain as relaxed as possible.

Those Xrays allow to measure Sacral Tilt angle (ST); the same measure can be done on classical lateral Xrays, but the same and precise rules must be followed. A classical lateral Xray can be done to appreciate de lying ST angle; this angle can also be measured on CT scan lateral scout view.

The measures of "real" or "functional" acetabular anteversion are realized on CT scan cuts replicating the horizontal planes for the subjects in standing or sitting positions. (Fig. 5 )

Conventionnal CT scan evaluation may be inefficient especially when ST standing and ST lying are very different [4] and for the evaluation of sitting position.

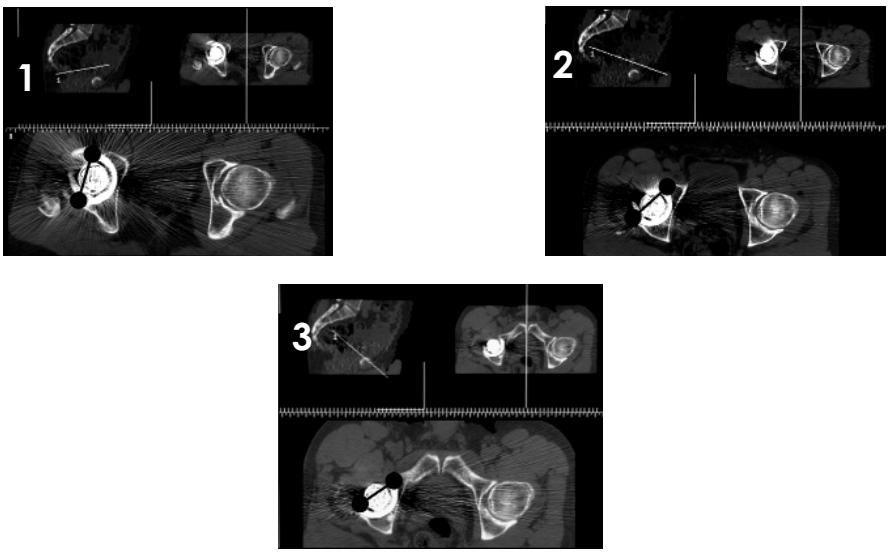


**Figure 5:**
CT scan measures of « real » or « functional » acetabular anteversion from standing to sitting position. Acetabular anteversion progressively increases.

A CT section plane that goes through femoral head centers and forms with the upper S1 endplate an angle equal to standing ST (measured on the standing film) replicates the horizontal transverse plane in the standing position: it can be used to calculate standing "functional anteversion" of the acetabulum. If an angle equal to sitting ST is used, the plane shows sitting "functional" anteversion of the acetabulum (Sitting ST is usually smaller than standing ST).

- This CT scan technique provides very interesting datas about the real anteversion in usual standing or sitting postures. Additional cuts for different ST angles values (for example every 10°) can also be realized to obtain the global anteversion variations, even in hyperextension or hyperflexion of the lumbosacral area.
- When the range of motion of the spine is normal in the sagittal plane, rotation of the pelvis around a transverse axis gives some room for adjustment during movements of the hip as the normal value for variation of sacral tilt is about 30° between standing and sitting position in our series of control patients. In the standing position, forward rotation of the pelvis uncovers the femoral head posteriorly and improves anterior coverage (marked ST). In the sitting position, the relatively vertical position of the sacrum with backward rotation of the pelvis uncovers the femoral head anteriorly (small ST). Those modifications of sagittal orientation are associated with variations of anatomical anteversion (less cup anteversion in standing position and more cup anteversion in sitting position).
- Diseases affecting the spine or lumbosacral junction (aging spine) and adjustments during prior surgical procedures (lumbosacral fusion) can affect the ST angle. A permanent decrease in ST results in marked anterior uncovering and can cause posterior impingement in the standing position. This situation can occur in patients with degenerative lumbar spine lesions that fix the sacrum in a vertical position in both the sitting and the standing positions. Lumbosacral fusion with a small degree of ST replicating the sitting position can have the same effect.

In patients with limited spinal motion and, in many cases, permanent backward rotation of the pelvis (closed and fixed ST angle), changes in anteversion between the sitting and standing position may be very small. This explains the possible catastrophic consequences of selecting an inappropriate anteversion angle during hip replacement in case of stiff lumbosacral junctions.In such situation, we could observe anterior THP dislocation during hyperextension of the hip in standing position, even in patients implanted via a posterior approach. (Fig. 6)

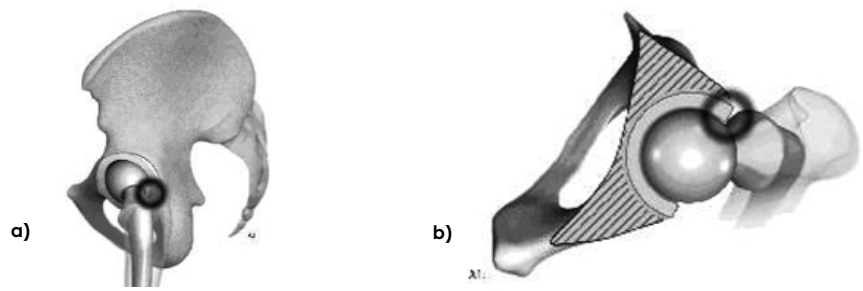


**Figure 6:**
**a)** Lateral standing view in a patient with T.H.P. and permanent pelvic retroversion. The potential posterior conflict can be seen. **b)** Idem on a CT scan cut replicating standing position.

On the contrary, we can observe some cases with excessive lumbar lordosis and avery horizontal sacrum. The "functional" acetabular anteversion is low; this particular situation can cause severe problems for T.H.P. acetabular implantation. Actual THP cannot reproduce the real mechanical characteristics and tolerances of normal hip joint. If the only reference is bone architecture and not the dynamic positions of the pelvis, is possible, Low "functional" acetabular anteversion in standing and sitting positions can induce T.H.P. instability.

Walking is associated with changes in the relative anteversion of the acetabular and femoral components. According to the phase in the walking cycle, these changes can result in 5 – 10° of anteversion or retroversion of the femoral component relative to the acetabular cup. When there is little or no femoral component anteversion, relative retroversion can occur if the functional acetabular anteversion in the standing position is inadequate; this can result in impingement or even in dislocation.

But the main instable situation occurs in sitting position, due to anterior impingement. In such cases, we could observe posterior THP dislocations, even in patients implanted via an anterior approach. (Fig. 7)

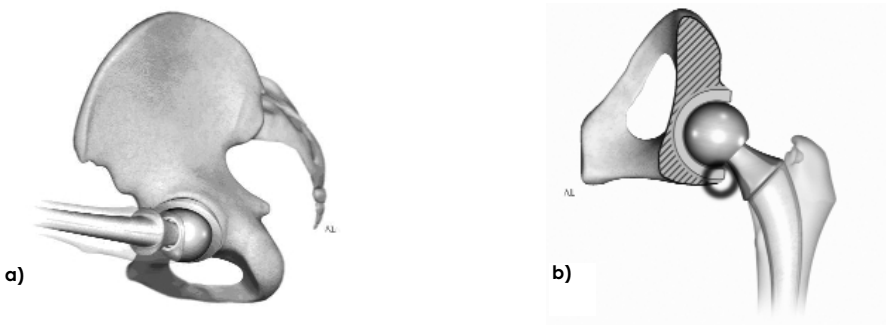


**Figure 7:**
Patient with T.H.P. and permanent pelvic hyperanteversion.
**a)** Lateral view in sitting position.
**b)** On the CT scan cut replicating the sitting position, acetabular anteversion is very low with a potential anterior conflict.

## Conclusion

The analysis of sagittal equilibrium of the trunk cannot be limited to the study of spine on lateral Xrays. Hips position and lower limbs adaptation are essential.

Sitting Xrays show very important variations in sagittal equilibrium. All of these Xrays only show "instantaneous" images of complex postural situations.

In-depth knowledge of the mechanics of the lumbosacral junction is essential both for spinal surgeons and for surgeons who perform hip replacements in elderly patients with abnormal sagittal spinal posture and/or a marked reduction in the functional range of motion.

The "pelvic vertebra" adapts the orientation of the each acetabulum, and then, the functional range of motion of the hip joints.

Sagittal sacral tilt is a functional parameter that illustrates the importance of the relationship between pelvis and spine.

It takes into account the extent to which the pelvis can rotate to improve joint motion within the useful range.

In normal subjects ST angle variations are about 30° between standing and sitting position. There is less functional acetabular anteversion in the standing than in the sitting position.

This evaluation of lumbo-pelvic alignment is mandatory for optimization in THP implantation or spinal fusion. (Fig. 8) But those adjustments can be questionable in the future due to progressive changes in postural adaptation of our patients.

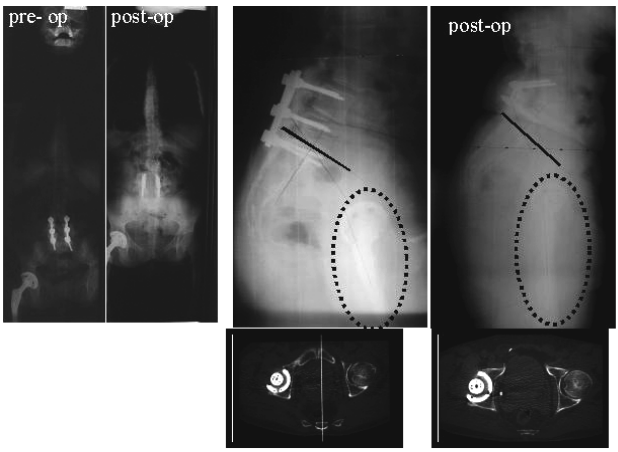


**Figure 8: pre-op**
Failure of lumbar fusion with major sagittal desequilibrium
- right T.H.P. with permanent adaptative hip flexion
- lumbar pain due to abnormal torse bent posture
- recurrent subluxation of the right T.H.P. due to lack of adaptation possibility in extension (the excessive functional acetabular anteversion in standing position induces an inadapted Functional Range of Motion; posterior impingement in standing position)

**post-op**
- consequences after lumbosacral fusion correction (wedge osteotomy): permanent hip flexion is reduced and functional acetabular anteversion is corrected in standing position

Pelvic retroversion has decreased and each acetabulum is less anteverted.

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