The Effect of 3-Column Spinal Osteotomy on Anterior Pelvic Plane and Acetabulum Position

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Abstract

Because the spine and pelvis are integrated, changes in spine sagittal balance affect relative acetabulum position. A 1° change of the anterior pelvic plane changes acetabulum anteversion by 0.8°. Three-column spine osteotomies correct fixed sagittal plane deformity.

Twenty patients with kyphotic deformity and associated sagittal imbalance underwent corrective 3-column osteotomy. We reviewed upright pelvic and spine radiographs preoperatively and postoperatively and documented the changes in angles. The average sagittal vertical axis was 11.07 cm preoperatively and 4.8 cm postoperatively. Lumbar lordosis changed (on average) from 39° preoperatively to 55° postoperatively ($P < .05$). Sacral slope increased an average of 6.7° ($P = .015$). Pelvic tilt decreased by 5.4° ($P = .001$). The anterior pelvic plane increased by 8.23° ($P < .0001$). This correction of the sagittal balance is associated with a concomitant increase in sacral slope, pelvic tilt, and the anterior pelvic plane angles. These changes will increase acetabulum anteversion by a predicted 6.54°. This increase will change acetabular cup position and must be considered in patients with spine and pelvic osteoarthritis that requires hip surgery.

Osteoarthritis, which is a growing problem in the Western world, most commonly presents in knees, hips, and the joints in the hands and in the spine.[1] More than 10% of people older than 55 years suffer from symptomatic osteoarthritis that requires care.[2] In the spine, disc degeneration starts in the second decade of life,[3] advancing over the years to spinal deformity in 60% of the population. Although this disc degeneration is often asymptomatic, symptomatic spinal deformity is present in 6% of the population in the seventh decade of life.[4]

Often, patients develop a combined degenerative disease affecting the spine and the hip, described by Offierski and MacNab[5] as "hip-spine" syndrome. Afflicted patients often present with low back pain, pain in the groin and lateral hip related to the hip joint, or diffuse general pain radiating down the affected extremity. Patients may complain of back pain, neurogenic claudication, and joint-related pain, during a physical examination that is not joint-specific.[6] The priority that a surgeon assigns to hip or spine pathology remains a topic of debate.

In total hip replacement, proper orientation of the acetabular component is critical for the stability and the longevity of the implanted hip prosthesis. Malposition of the acetabular component has been linked to an increased rate of dislocation, liner fracture, and wear. Although Sir John Charnley originally recommended 0° of anteversion,[7] subsequent authors, such as Lewinnek,[8] have described the optimal acetabular component position as 40° ± 10° of abduction and 15° ± 10° of acetabular anteversion. Most surgeons would agree that these absolute descriptions of acetabular component position are inadequate because the optimal position should be tailored to each patient's anatomy. Relative femoral anteversion or retroversion, femoral offset, body habitus, sex, and flexibility can influence the optimal acetabular position. Extremes of abduction or version of the acetabulum may decrease the contact area between the head and the liner or may cause impingement, and both can result in untoward clinical sequelae, such as increased dislocation, wear, and liner fracture rates.[9]

Computer navigation of the acetabular component is a powerful tool that can improve the accuracy and the precision of the implant position.[10] The anterior pelvic plane (APP) is an important reference during navigation.[11] Once the APP is registered, computer algorithms can calculate the acetabular abduction angle and anteversion. In navigated hip replacement surgery, pelvic tilt is the deviation of the APP in either the anterior or the posterior direction. For every degree of pelvic tilt, acetabular version changes by 0.7° to 0.8°.[12,13] Thus, pelvic tilt can have a significant effect on the acetabular component position.

Spinal osteotomies can correct spinal sagittal alignment. Pontine and Smith-Petersen osteotomies can correct (on average) 10° of misalignment. Spinal 3-column osteotomy is a

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Table. **Osteotomy Patient Demographics and Operative Data**

Patient	Age	Gender	Diagnosis	Prior Spine Surgery	Osteotomy Level(s) and Type	Instrumentation Levels	Change in APP (degrees)
1	73	F	Fixed kyphosis	Laminectomy L4-L5 and PSF L3-S1	L2 PSO	T10-S1	12.05
2	66	M	Flat back	PSF T3-pelvis, PLIF L5-S1	L3 PSO	L1-pelvis	4.1
3	60	F	Flat back	PSF T5-S1, PLIF L5-S1, XLIF L4-L5	L3 PSO	T5-sacrum	2.6
4	72	M	Flat back	PSF L2-S1, PLIF L4-L5	L3 PSO	T9-sacrum	3.85
5	49	F	Flat back	PSF L3-S1, ALIF L3-S1	L3 PSO	T9-sacrum	3.85
6	56	F	Fixed kyphosis	PSF T12-sacrum, PLIF L2-L3, L3-L4	T12 PSO	T3-pelvis	7.6
7	58	M	Flat back	PSF T10-sacrum, ALIF T12-L1, L5, S1	L2 PSO	T9-pelvis	15.3
8	43	F	Flat back	PSF T4-S1	L4 PSO	T2-pelvis	16.6
9	73	M	Fixed kyphosis	PSF L2-S1	L2 PSO	T9-pelvis	5.8
10	69	M	Flat back	PSF L2-S1	L3 PSO	T5-pelvis	18.15
11	43	F	Flat back	PSF T10-S1	L3 PSO	T10-S1	2.8
12	84	M	Fixed kyphosis	PSF T10-S1	L3 PSO	T10-pelvis	14.4
13	63	M	Flat back	PSF T10-L3	L3 PSO	T10-pelvis	5.75
14	51	F	Flat back	PSF T10-L3	L3 PSO	T10-L4	3.7
15	40	F	Flat back	PSF T12-S1	L3 PSO	T10-L4	4.6
16	72	F	Posttraumatic fixed kyphosis	None	L2 PSO	T11-pelvis	5.6
17	47	M	Flat back	PSF L1-S1	L3 PSO	T10-S1	9.7
18	75	F	Flat back	None	L3 PSO	T10-S1	7.25
19	70	F	Flat back	None	L3 PSO	T3-S1	9.95
20	70	M	Flat back	PSF T3-S1	T8-T11 pontine	T12-S1	3.95

Abbreviations: APP, anterior pelvic plane; ALIF, anterior interbody fusion; PLIF, posterior lateral interbody fusion; PSF, posterior spine fusion; PSO, pedicle subtraction osteotomy; XLIF, extreme lateral interbody fusion.

more powerful tool that can change spinal sagittal alignment of the lumbar spine by 30° to 60°.[14] We hypothesized that 3-column osteotomy will influence the APP and affect the anteversion of the acetabulum.

Materials and Methods

We performed a retrospective chart and image review in all patients who underwent a 3-column osteotomy to fix spinal deformity at 1 academic center from 2004 to 2011. Patients who did not have a preoperative and postoperative anteroposterior and lateral 36-in cassette, full-spine film, and a lateral standing pelvis view were excluded from the study. All patients chose surgery when a conservative period of care failed.

We evaluated patients' preoperative and postoperative images for sagittal alignment, pelvic tilt, sacral slope, pelvic incidence, C7 plumb line, and APP. We assessed sagittal alignment with a 36-in lateral film of the entire spine and both femoral heads, with the patient free-standing and hands on clavicles and shoulders at 45°, and knees fully extended.[15] A view of overlapping femoral heads and the entire bony pelvic structure, including the spine from C7 to the sacral endplate, could be seen in all images. The angles measured in this study were described extensively in previous publications,[16] but are described here briefly as well.

We used the sagittal vertical axis (the horizontal offset from the posterior superior corner of S1 to the C7 vertebral

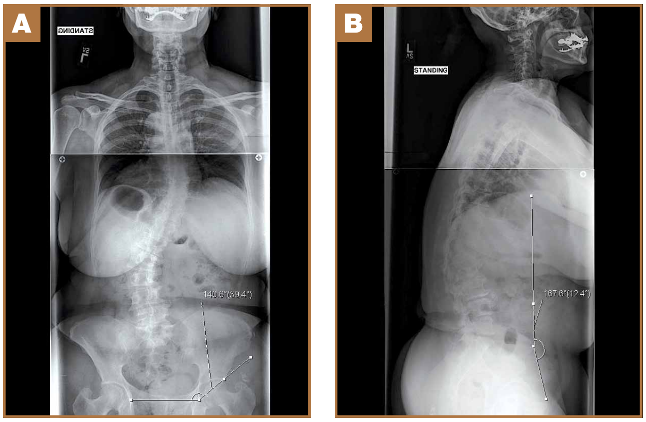

Figure 1. (A) Presurgical anteroposterior standing scoliosis image of the spine shows a left thoracolumbar scoliotic deformity with apex at L2. (B) Lateral scoliosis image shows a focal kyphosis at L2 with flattening of her lumbar lordosis with an anterior pelvic angle of 168.3°.

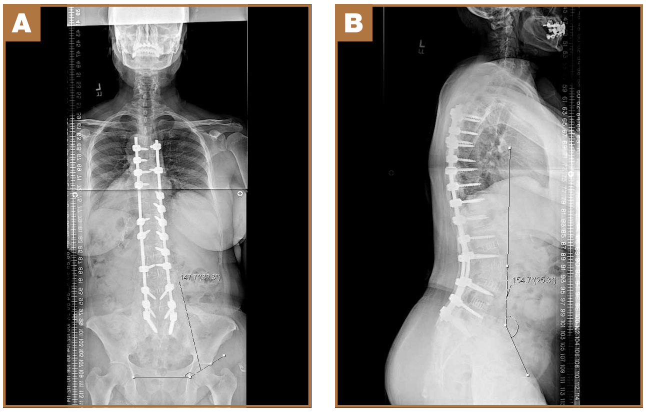

Figure 2. The patient underwent correction of the deformity with extreme lateral interbody fusion (XLIF; NuVasive Inc, San Diego, California) at T12-L1, L1-L2, L2-L3, and L4-L5. Posterior spine fusion was performed at the L3 levels, and pontine osteotomies were performed at the T12-L1 and L1-L2 levels. Posterior fixation was achieved with pedicle screws and rods (Expedium; DePuy Orthopaedics Inc, Warsaw, Indiana) at T5-S1. (A) Anteroposterior standing scoliosis image of the spine shows correction of the scoliotic deformity with well-balanced lumbar spine at 2-year follow-up. (B) Lateral scoliosis image shows restoration of the lumbar lordosis with the surgical construct, a pedicle subtraction osteotomy at the L3 level, and an anterior pelvic angle of 154.7°.

angle) and a combination of the thoracic kyphosis (T4-T12) and lumbar lordosis (L1-S1) to measure sagittal alignment of the spine. Pelvic parameters were calculated as following: Pelvic incidence is the angle between the lines joining the middle of the sacral endplate to the middle axis of the femoral heads. The sacral slope is the value of the angle between the superior plate of S1 and a horizontal line. Pelvic tilt is defined as the angle between the vertical and the line through the midpoint of the sacral plate to the axis of the femoral heads. The sum of sacral slope and pelvic tilt is the pelvic incidence. The APP connects the anterior superior iliac spines and the anterior aspect of the pubic tubercles. The pelvic tilt is defined as the angle between the APP and a vertical line in the standing position. Acetabular cup anteversion changes were calculated according to the formula that a change of the APP leads to a change of 0.8° in the acetabular anterversion.[12,13]

Two orthopedic surgeons performed all measurements on 2 different occasions to determine intraobserver reliability and error. Data were evaluated with the unpaired Student t test (Microsoft Excel; Microsoft, Redmond, Washington), and significance was defined as $P < .05$. The study was approved by the Hospital for Special Surgery Institutional Review Board.

Results

Thirty-one patients (16 men, 15 women) at a mean (SD) age of 61.7 (5.6) years underwent 3-column osteotomies for symptomatic sagittal imbalance. Twenty patients had complete spine and pelvis preoperative and postoperative radiographs that could be analyzed (**Table**). Eleven patients, who did not have these complete radiographs, were excluded. The average osteotomy angle was 31.9° (range, 15° to 44°). The mean follow-up was 26.4 months.

The average sagittal vertical axis was 11.07 cm preoperatively and 4.8 cm postoperatively. Lumbar lordosis changed from 39° preoperatively to 55° postoperatively ($P < .05$), but thoracic kyphosis did not change and remained 40°. Sacral slope increased by an average of 6.7° ($P = .015$). Pelvic tilt decreased by 5.4° ($P = .001$). The APP increased by 8.64° ($P < .0001$) (**Figures 1A, 1B, and 2A, 2B; Table**). The effect of this change on the acetabulum anteversion is a predicted 6.54°, depending on a calculation of 0.8° change in hip anteversion for every degree in spinal slope.[12,13] The interobserver correlation coefficient ranged from $r = 0.96$ to $r = 0.82$ for the different measurements.

Discussion

In the standing person, the pelvic inclination is determined by the attachment at the lumbosacral juncture.[17] Because the pelvis girdle is 1 innominate bone, this inclination affects the acetabular orientation. The APP is a common reference for the standing pelvic plane; it indicates the sagittal position of the pelvis. This landmark is commonly used in computer-navigated total hip replacements in order to determine the relative position of the pelvis. Once the APP is registered, computer algorithms calculate the abduction and the anteversion of the acetabular component.[18] This calculation has reproducible clinical results.[19] In this study, we showed that 3-column spinal osteotomies affect the APP, which, in turn, changes acetabular orientation by increasing the anteversion of the hip by more than 5° on average. The larger the osteotomy, the larger the change in pelvic tilt will be. In cases in which a hip replacement was performed, this change, which increased anteversion, decreased joint stability and raised the risk for dislocation.[9]

Patients with hip-spine syndrome have complex conditions that result in pain and disability involving multiple joints. It is difficult to identify which joint is creating pain and often requires multiple images and injections. The prime consideration is to target the patients at the predominant pain generator. Computed tomography, magnetic resonance imaging of the spine, and other diagnostic modalities can help delineate the primary pathology and guide surgical management.[20] In a study by Ben-Galim and colleagues,[6] the hip joint was treated first in patients with hip-spine syndrome, reducing their back pain and often alleviating the need for spinal surgery. This effect was prevalent despite the lack of change in spine alignment.[6] It is questionable if a severe sagittal misalignment would respond similarly, and the study did not determine each patient's primary pain generator. A recent review by Devin and colleagues[20] recommended treating the spine first in cases of a severe deformity. In cases with a rigid spinal deformity, spine surgery, especially a procedure that includes a major osteotomy, will change the pelvic inclination and may cause increased hip dislocations. In such cases, the spine surgery should be performed first.

In this study, we showed that every degree of change in spinal sagittal balance created by the 3-column osteotomy changes the anteversion by 0.25°. Therefore, if an osteotomy of more than 20° is planned, the acetabulum anteversion will change by more than 5°. In most spine fusion cases, especially those with degenerative changes of the spine, the degree of change is less than 20°. Osteotomies can change the sagittal alignment of the spine by a greater degree. For example, the correction is 10° to 15° per level and up to 30° in a Smith-Petersen pedicle subtraction osteotomy.[14] The limitations of the study are its retrospective nature, small size, and the exclusion from the study of 11 patients who did not have high-quality images.

Conclusion

We have shown that a 3-column osteotomy of the spine may affect the stability of the hip implant, especially if correction of the sagittal balance of the spine is greater than 20°. In hip replacement, therefore, it is important to consider the future change in pelvic parameters and plan the acetabulum orientation accordingly or perform the spine procedure prior to hip replacement.

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