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CASE REPORT

Sacroiliac joint luxation after pedicle subtraction osteotomy: report of two cases and analysis of failure mechanism

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Abstract
Background Sagittal decompensation after pedicle subtraction osteotomy (PSO) is considered as late onset complication. Several mechanisms have been suggested, but little attention has been paid to the caudal end of lumbar instrumented fusion, especially sacral iliac joint (SIJ) deterioration.
Methods Clinical histories and radiographic sagittal parameters of two patients with SIJ luxation after PSO are presented. The biomechanical failure mechanism and risk factors are analysed.
Results Two patients underwent correction of fixed anterior sagittal imbalance by PSO, followed by pseudarthrosis revision surgery. Both of them sustained persistent sacroiliac pain, progressive recurrence of anterior imbalance and progressive pelvic incidence (PI) increase around 10°. An acute bilateral SIJ luxation occurred in both patients leading to sharp increase or PI around 20°. One patient was treated by SIJ fusion and the other patient was placed on non-weight-bearing crutch ambulation for 1 year. Both patients had a high preoperative PI (95° and 78°). A theoretical match between lumbar lordosis (LL) and PI was not achieved by PSO. Osteopenia was present in both patients. Computed tomography evidenced L5–S1 pseudarthrosis and sacroiliac joint violation by pelvic or sacral ala screws.
Conclusion Patients with high PI might seek for further compensation at their SIJ when lacking LL after PSO. Chronic anterior imbalance might lead to progressive weakening of sacroiliac ligaments. Initial circumferential lumbosacral fusion and accurate iliac screw fixation might reduce stress on implants, risk for pseudarthrosis, implant failure and finally SIJ deterioration. Bone mineral density should further be investigated preoperatively.

Keywords Sagittal imbalance · Pedicle subtraction osteotomy · Complications · Sacroiliac joint luxation · Pelvic incidence

Introduction

Correction of sagittal imbalance gained popularity with surgical techniques such as pedicle subtraction osteotomy (PSO). This technique may improve spinal sagittal alignment and health-related quality of life [1]. However, PSO does not always ensure optimal realignment, and recurrence of sagittal imbalance has been described [2–5]. Sagittal decompensation may be related to loss of lordosis with pseudarthrosis at the osteotomy or to proximal kyphosis above the instrumentation. Little attention has been paid to caudal failure at the sacroiliac level.

The sacroiliac joint (SIJ) forms the lowest segment of the axial skeleton. Pelvic incidence (PI) is recognized as constant anatomical parameter in adults, independent of the pelvic position, as long as the SIJ remains stable [6, 7]. SIJ degeneration and pain may develop after lumbosacral fusion [8, 9]. Sacral and pelvic insufficiency fractures have been described after multilevel lumbosacral fusion [10, 11]. Severe SIJ destruction or luxation after sagittal

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imbalance correction has not yet been reported to our knowledge.

We present the cases of two patients who developed bilateral SIJ luxation after PSO, characterized by a progressive increase of PI. An attempted was made to elucidate factors that might predict this failure mode, in order to prevent these catastrophic scenarios.

Case 1

A 46-year-old female underwent posterior instrumentation and fusion T1-L4 for congenital scoliosis in 1998. She had a Fallot tetralogy and was an active smoker. A revision has been performed in 2004 because of pseudarthrosis and rod fracture at L3–L4. She presented at our institution in 2008 with chronic low back pain and anterior sagittal imbalance with a large pelvic incidence and horizontal orientation of her sacrum: lumbar lordosis (LL) 43°, pelvic incidence (PI) 95°, sacral slope (SS) 52°, pelvic tilt (PT) 43° and sagittal vertical axis (SVA) 13 cm (Fig. 1). She was treated by PSO at L3 with posterior hybrid instrumentation T1–S1 using thoracic hooks, lumbar pedicle screws and a TLIF at L2–L3: LL 69°, PI 95°, SS 56°, PT 40°, SVA 6 cm (Fig. 2). In 2010, a pseudarthrosis at L5–S1 and sacral screw loosening were evidenced on CT (Fig. 3). This led to a recurrence of anterior imbalance by progressive loss of lordosis and increase of PI of 10°: LL 56°, PI 105°, SS 56°, PT 50°, SVA 22 cm (Fig. 4). The posterior instrumentation was revised from L2 to the pelvis using a rod connector system. L4 and L5 pedicles were not instrumented as screw holes were distant from frontal plane alignments of new rods, and posterior bone graft was solid above L5. Iliac screws measured 8.5 mm in diameter and 80 mm in length. Segmental lordosis was increased at L5–S1 by a Ponte osteotomy and completed by an ALIF using iliac crest (Fig. 5). After 1 year, pain increased progressively at the left iliac crest. CT evidenced left iliac screw loosening and a trajectory through the SIJ, while L5–S1 was fused

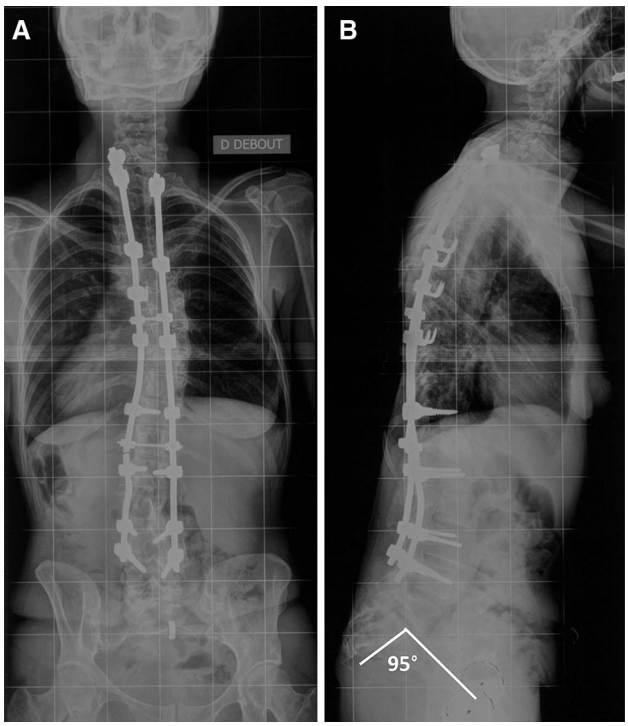

Fig. 1 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after posterior instrumentation T1–L4 for congenital scoliosis showing a rod fracture at L3–L4 due to pseudarthrosis and anterior sagittal imbalance

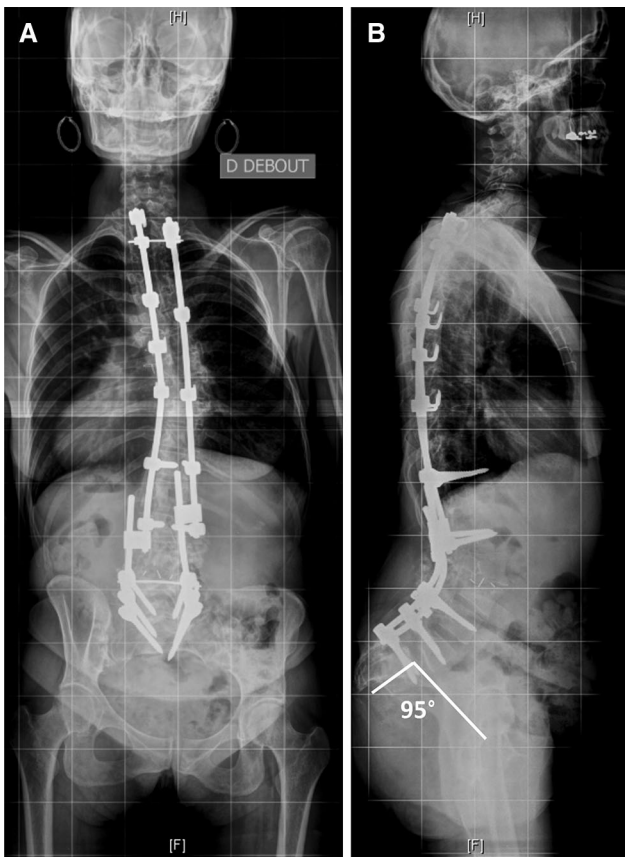

Fig. 2 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after PSO at L3 with posterior instrumentation T1–S1 and satisfactory restoration of sagittal alignment

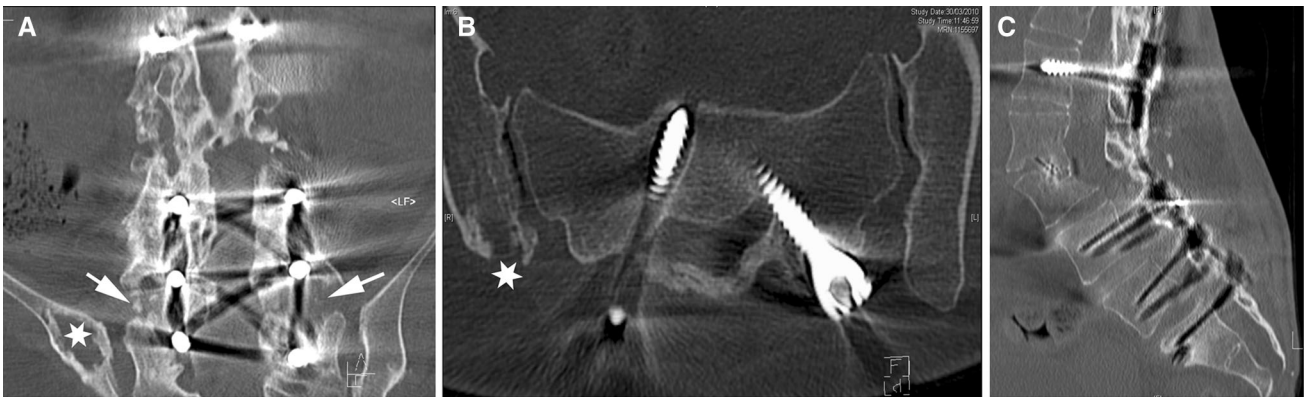

Fig. 3 Lumbosacral CT showing pseudarthrosis at L5–S1 (*arrows*) on coronal reconstructions (**a**) and right S1 screw loosening with a halo on axial reconstruction (**b**). Fusion seems achieved at L2–L3 on sagittal reconstruction (**c**). *Stars* indicate bone graft harvesting from right iliac crest

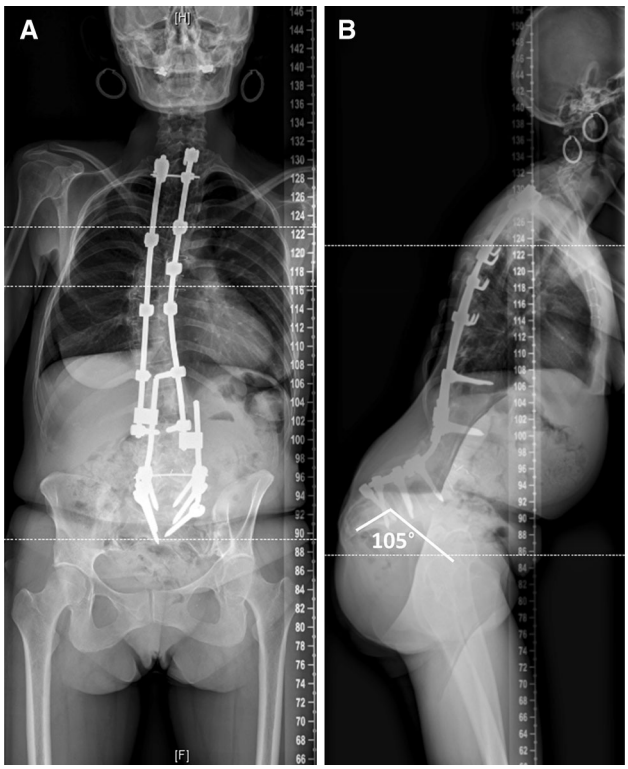

Fig. 4 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs demonstrating recurrence of anterior imbalance and 10° increase of pelvic incidence

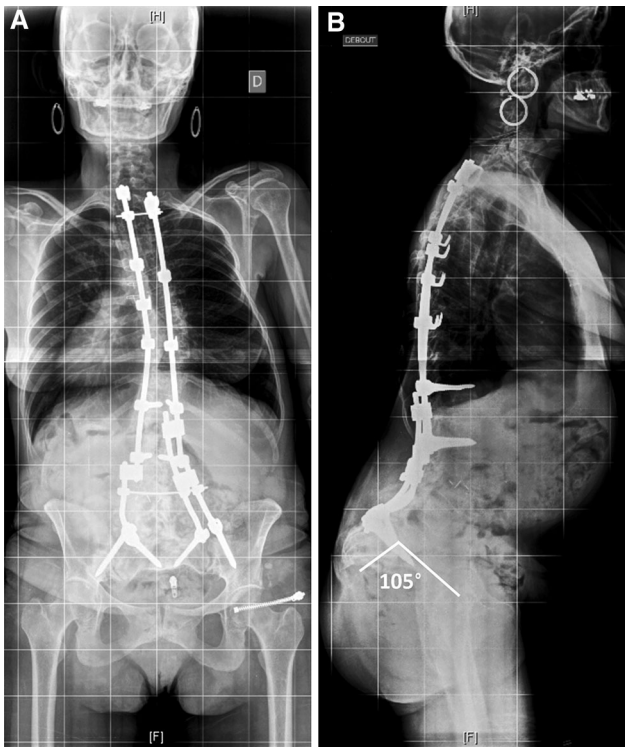

Fig. 5 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after revision of instrumentation from L2 to the pelvis and ALIF L5–S1

(Fig. 6). In 2012, revision of pelvic instrumentation became difficult because of major iliac and S1 osteolysis, and it was decided intraoperatively to remove the instrumentation as circumferential lumbosacral fusion was achieved. Postoperatively, the patient remained stable in the sagittal plane: LL 65°, PI 108°, SS 55°, PT 54°, SVA 12 cm (Fig. 7). Five months later, the patient felt a painful crack at her pelvis without trauma. Severe anterior imbalance relapsed with sharp increase of pelvic incidence and sacral slope, while the lumbar lordosis remained stable: LL 63°, PI 130°, SS 78°, PT 53°, SVA 55 cm (Fig. 8). Combined single-photon emission computed tomography

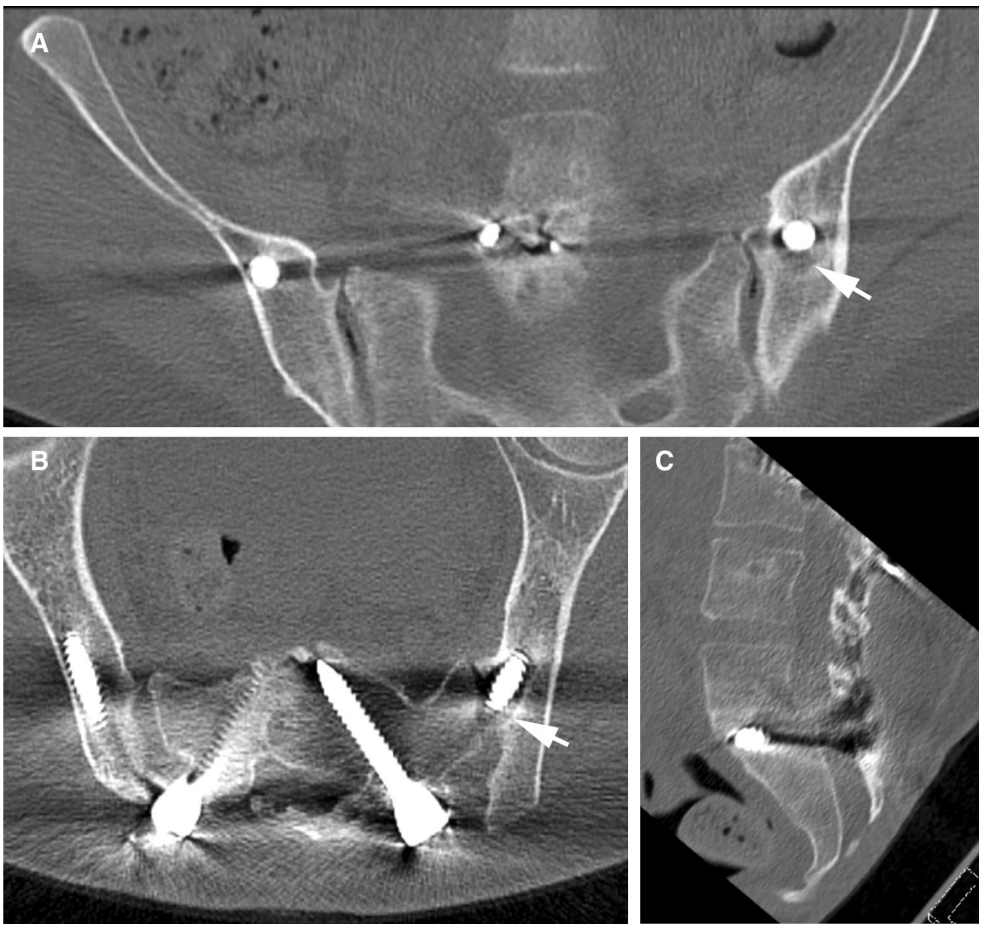

Fig. 6 CT showing left iliac screw loosening (*arrows*) on coronal (**a**) and axial (b) reconstructions. The iliac screw harms the left sacroiliac joint. Fusion seems achieved at L5–S1 on sagittal reconstruction (**c**)

(SPECT) and CT indicated a diastasis and bilateral anterior rotation at the level of the sacroiliac joints, stress at the pubic symphysis and a recurrence of L5–S1 pseudarthrosis. A sacral fracture was not evidenced (Fig. 9). A revision of posterior fixation between rod connectors and pelvis associated with bilateral trans-sacroiliac screws was performed under CT guidance. These screws traversed the former ALIF L5–S1, aiming for spontaneous fusion. Follow-up CT at 18 months shows that this construct remained in place. Sacroiliac fusion is not evidenced, whereas L5–S1 seems fused (Fig. 10). The patient remained stable in the sagittal plane: LL 62°, PI 94°, SS 53°, PT 47°, SVA 12 cm (Fig. 11). She is clinically still painful but ambulates without crutches. Bone mineral density has been investigated retrospectively: her T-score was 0.3 in the lumbar fusion area and −1.8 at the femoral neck.

Case 2

A 63-year-old female underwent posterior instrumentation and fusion L3–L5 for degenerative spondylolisthesis at L4–L5 and spinal stenosis in 2000. She presented a systemic lupus erythematosus and a chronic obstructive pulmonary disease. The patient presented at our centre in 2007 with chronic low back pain and anterior sagittal imbalance: LL 17°, PI 78°, SS 32°, PT 46°, SVA 16 cm (Fig. 12). Her preoperative T-score was −1.6 in the lumbar spine and −1.4 at the femoral neck, indicating osteopenia. She was treated by PSO at L4 and Ponte osteotomies at L1–L2 and L2–L3, which were closed using in situ bending, combined with compression on rod connectors allowing posterior column shortening by rod translation. Posterior hybrid instrumentation extended from T6 to S1 with an additional

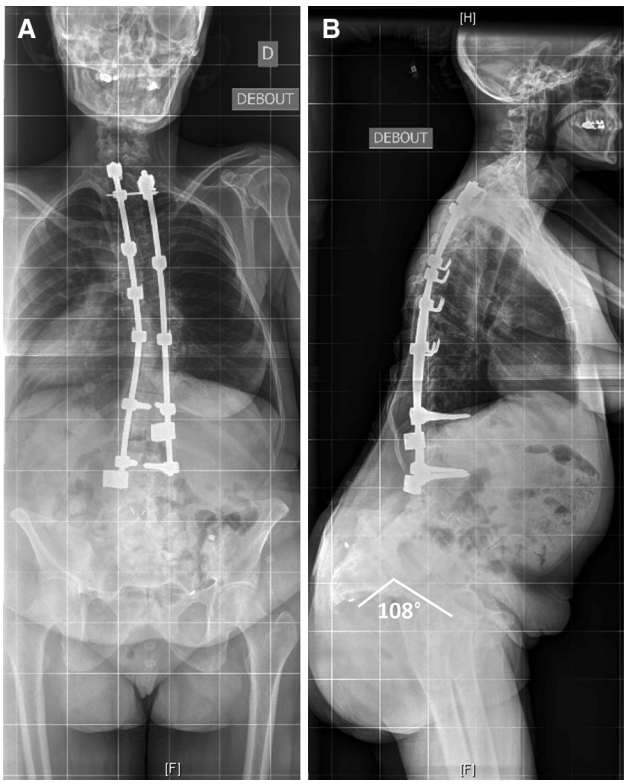

Fig. 7 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after removal of instrumentation between L2 and the pelvis

sacral ala screw on the right side (5.5-mm diameter, 45-mm length) and an iliac screw on the left side (7.5-mm diameter, 70-mm length). A thoracolumbar brace was worn postoperatively and the patient appeared balanced: LL 48°, PI 78°, SS 32°, PT 47°, SVA 3 cm (Fig. 13). After 2 weeks, the patient was taken to the operating theatre for irrigation and debridement of a deep wound infection followed by 6 weeks intravenous antibiotic treatment. The posterior instrumentation was extended to T3 at the same time, due to hook loosening at T6. In 2010, the patient presented with recurrent low back pain. CT evidenced screw loosening and pullout of right ala screw and iliac screw violation of the left sacroiliac joint with the presence of gas (Fig. 14). Pseudarthrosis was additionally diagnosed at L5–S1 (Fig. 15). An ALIF was performed at this level and the ala screw was removed percutaneously from posterior. In the postoperative course, rod fractures occurred at T11–T12 and pelvic incidence tended to increase: LL 48°, PI 91°, SS 41°, PT 50°, SVA 15 cm (Fig. 16). Due to a recurrence of back pain and pseudarthrosis at the thoracolumbar junction, the patient underwent posterior revision from T3 to the sacrum, using larger S1 screws (8.5-mm diameter, 50-mm length) and ala screws (5.5-mm diameter, 45-mm length) using a modified trajectory. Intraoperatively, multiple pseudarthrosis were evidenced from T7 to L2, which were further consolidated a week later by an

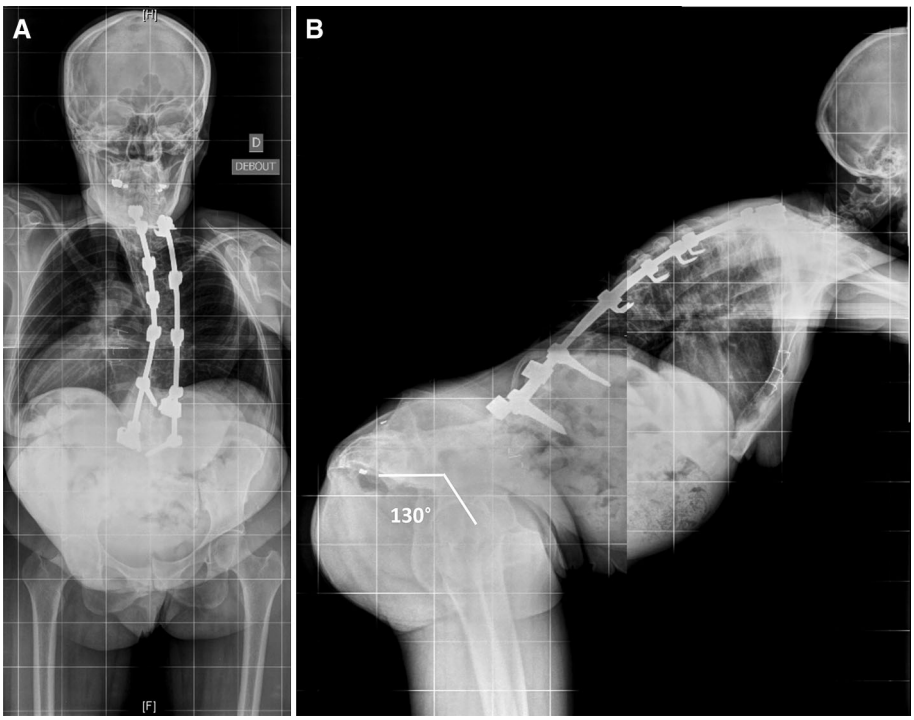

Fig. 8 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs demonstrating sudden major anterior imbalance and 22° increase of pelvic incidence due to sacroiliac joint luxation

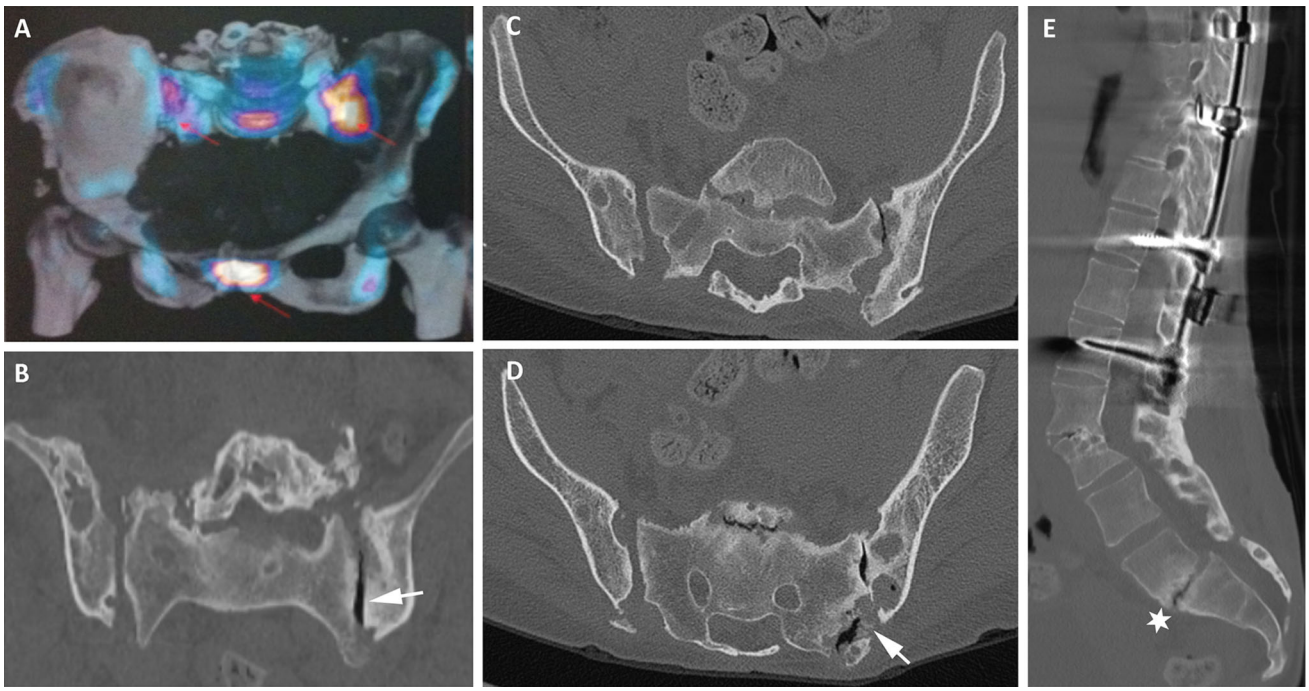

Fig. 9 SPECT-CT indicating stress at sacroiliac joints, lumbosacral junction and pubic symphysis (**a**). Coronal (**b**) and axial reconstructions at levels S1 (**c**) and S2 (**d**) demonstrate major sacroiliac osteolysis with gas formation on the left side (*arrows*). L5–S1 pseudarthrosis is evidenced on sagittal CT reconstruction (**e**)

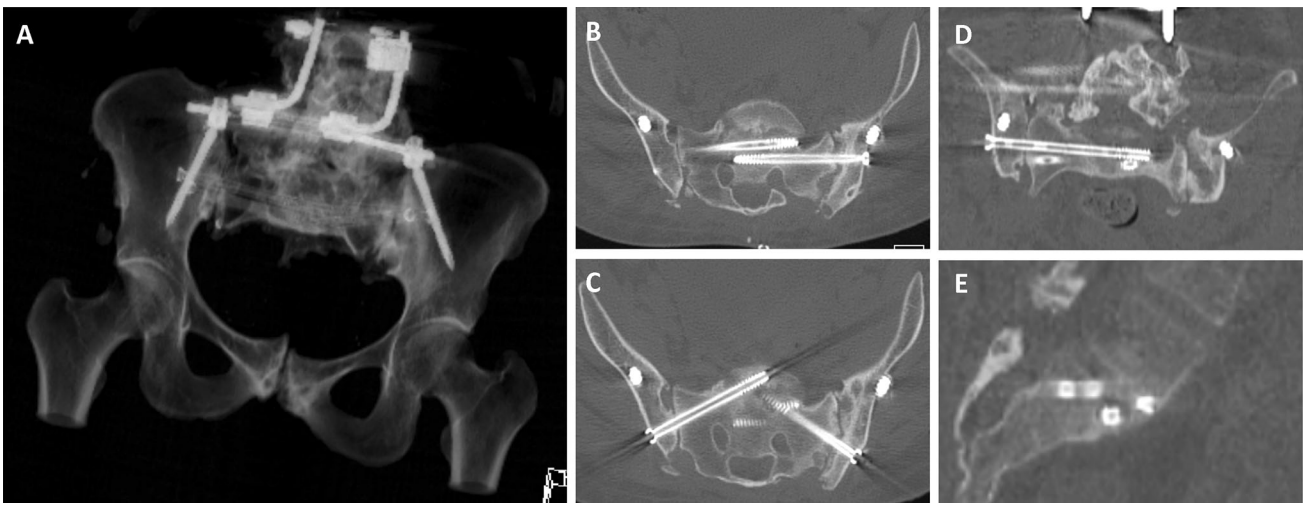

Fig. 10 Three-dimensional reconstruction of 18-month follow-up CT demonstrates the final osteosynthesis between lumbosacral spine and pelvis (**a**). Axial (**b**, **c**) and coronal (**d**) reconstructions demonstrate *trans*-sacroiliac screws and the absence of sacroiliac fusion. L5–S1 pseudarthrosis seems fused on sagittal reconstruction (**e**)

additional anterior fusion using rib and bone morphogenic protein (rhBMP-7): LL 48°, PI 90°, SS 41°, PT 48°, SVA 10 cm (Fig. 17). Three months later, the patient complained of major left hip pain without trauma and a sudden relapse of anterior imbalance. Pelvic incidence increased by 22°: LL 46°, PI 112°, SS 68°, PT 44°, SVA

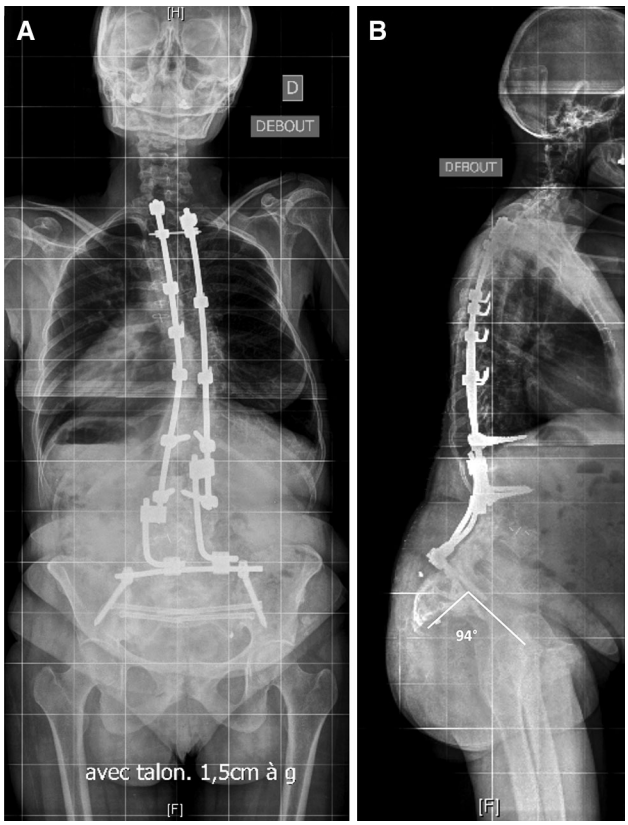

Fig. 11 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs demonstrating stability of pelvic incidence at its initial value after *trans*-sacroiliac screwing and revision of posterior instrumentation between L2 and pelvis

34 cm (Fig. 18). Radiography and CT evidenced a bilateral dislocation and anterior rotation of sacroiliac joints with fractures at the level of left superior and inferior pubic ramus (Fig. 19). A sacroiliac screw fixation was discussed but the patient refused this surgical treatment. The patient was placed on non-weight-bearing crutch ambulation with gradual rehabilitation for 1 year, then progressively to partial weight bearing. At 30-month follow-up, she continued to report moderate buttock pain and used one crutch. Anterior imbalance remained stable: LL 48°, PI 110°, SS 56°, PT 54°, SVA 23 cm (Fig. 20). CT demonstrates fusion of the thoracic and lumbosacral spine. Dislocation of sacroiliac joints remains, while partial posterior fusion seems present on the left. A pseudarthrosis is evidenced at the pubic rami (Fig. 21).

Discussion

Mechanical complications and recurrence of sagittal imbalance after PSO might be linked not only to intrinsic patient-related factors, but also to the surgical technique

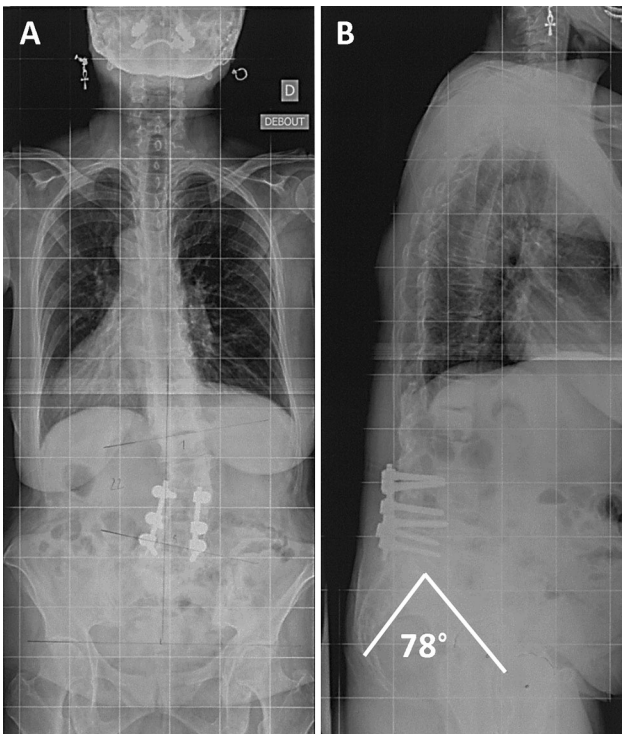

Fig. 12 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs 7 years after posterior fusion and decompression L3–L5 showing a lumbar scoliosis and anterior sagittal imbalance

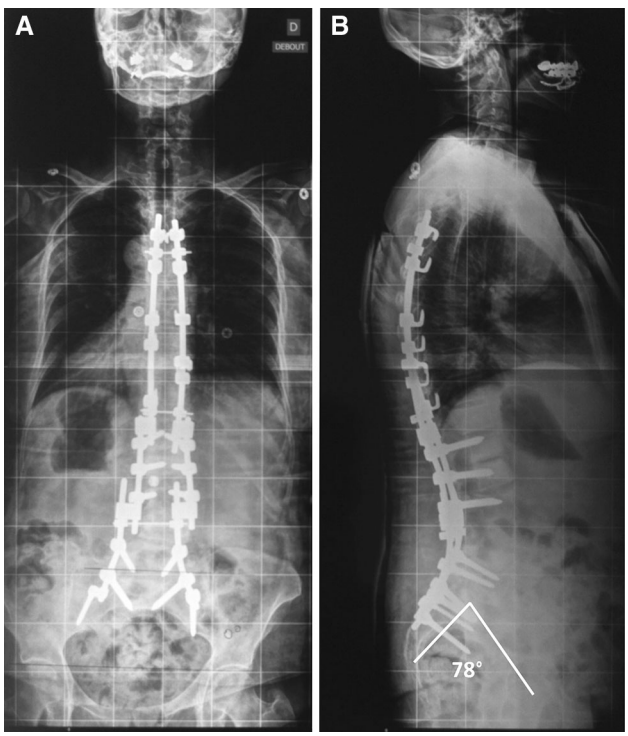

Fig. 13 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after PSO at L4 and posterior instrumentation from T6 to the sacrum on the *right* and pelvis on the *left*

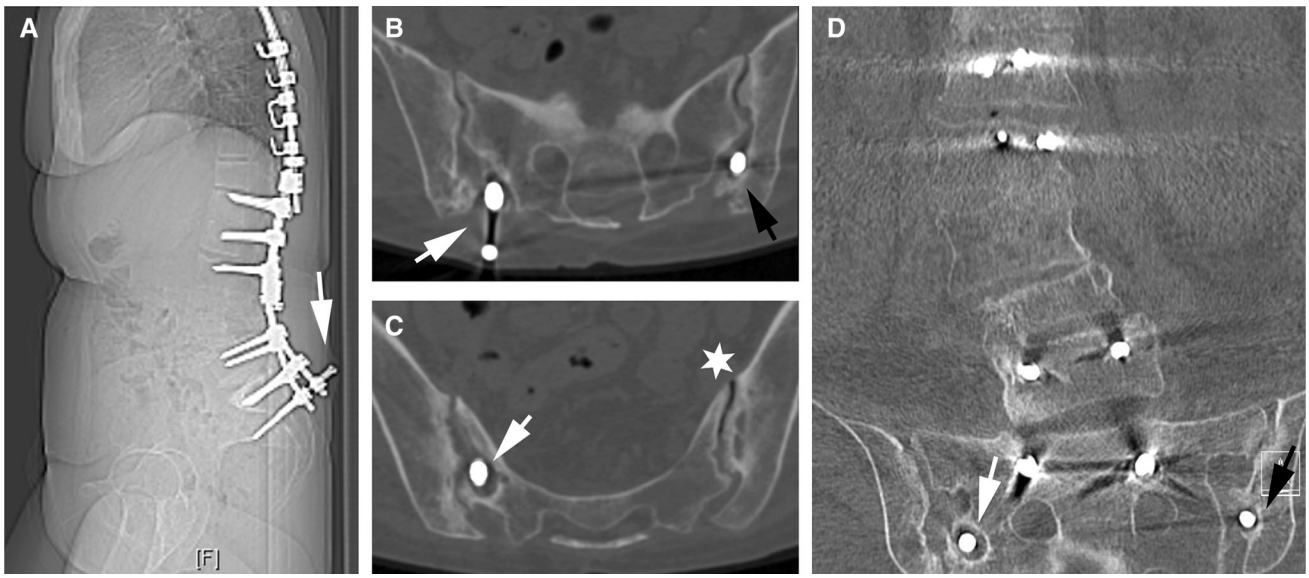

Fig. 14 CT scout view (**a**) and axial (**b**, **c**) and coronal (**d**) reconstructions demonstrate ala screw loosening and pullout (*white arrows*) and iliac screw violation of the sacroiliac joint (*black arrows*) with gas formation (*star*)

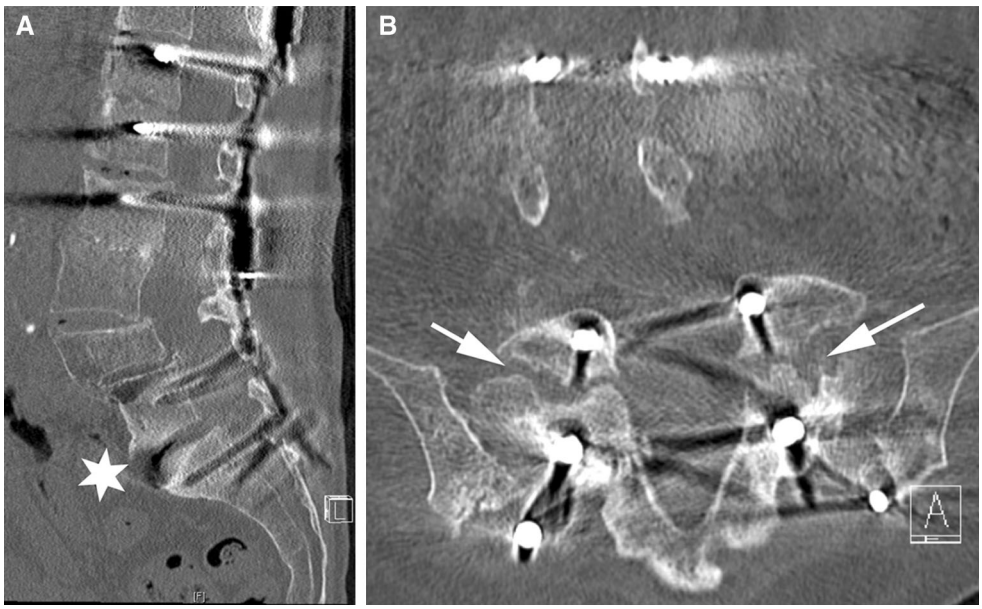

Fig. 15 Sagittal (**a**) and axial (**b**) CT reconstructions demonstrate gas in the disc L5–S1 (*star*) and pseudarthrosis of postero-lateral bone graft (*arrows*)

leading to failure of lumbosacral fixation. The failure mechanism of sacroiliac joint luxation seems different from previously reported sacral and pelvic fractures after long posterior fusion [10–15].

Pelvic incidence is regarded as key parameter when planning a sagittal deformity correction in order to set an appropriate lordosis. Patients with high PI are prone to under correction by PSO and PI-LL mismatch. A large PI was found to be a risk factor for sagittal decompensation after long fusion in adult deformities [16]. PI is thought to remain unchanged because of the rigidity of the pelvis. Legaye [17] has recently demonstrated that PI might

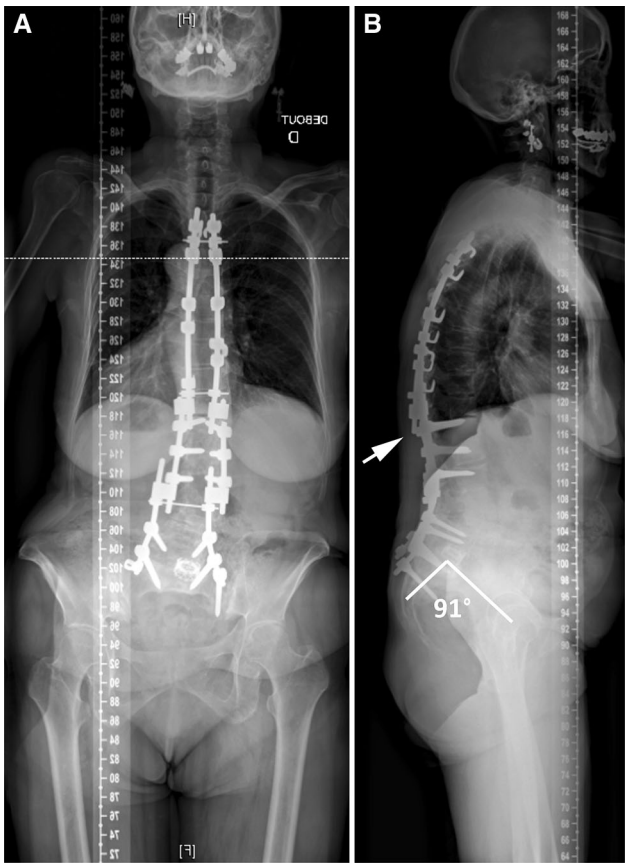

Fig. 16 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs showing 13° increase of pelvic incidence and a rod fracture due to at T12–L1 (*arrow*)

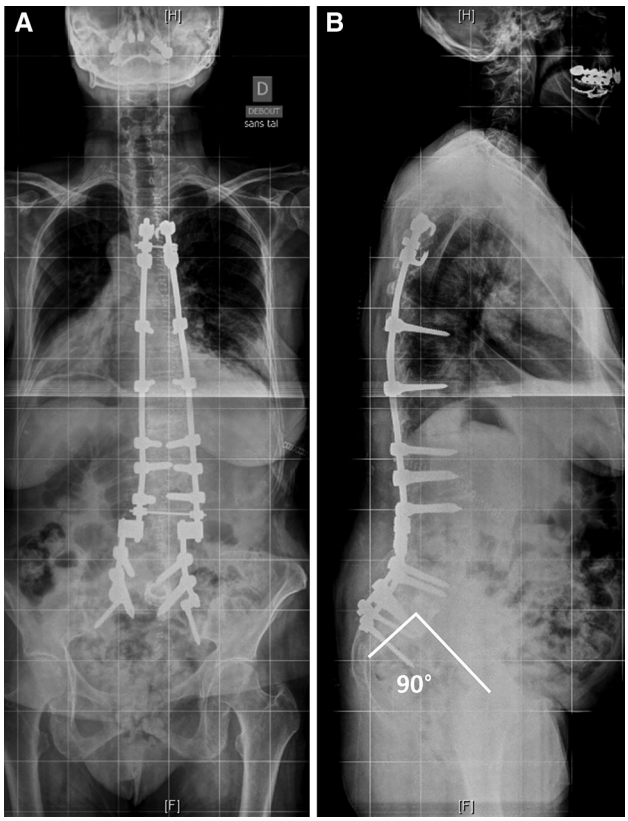

Fig. 17 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs after posterior revision from T6 to sacrum and anterior fusion T11–L2

increase with age as LL decreases with degenerative lumbar changes. Prolonged forward projection of the gravity line increases the lever arm resulting from the centre of rotation at the SIJ. Retroversion of the pelvis further increases this lever arm and stress across SIJ, which could lead to progressive twisting mobilization within the SIJ and weakening of sacroiliac ligaments. This phenomenon might have occurred in our patients as PI has slowly increased in the postoperative course. Insufficient lordosis correction by PSO seems likely in patients with high PI, which are at risk remaining anterior gravity line and subsequent pelvic retroversion and SIJ mobilization. Mao et al. [18] demonstrated on a finite element model that lack of lordosis (i.e. 5° and 10° kyphosis in a fused lumbar spine) increases angular displacements of the sacrum and stress across the SIJ significantly.

Cho et al. [4] found that the postoperative loss of lordosis occurred at the discs of fused segments in elderly patients with degenerative sagittal imbalance treated by PSO. They pointed out that additional anterior column support would help maintaining correction and reducing recurrence of anterior imbalance. The risk for pseudarthrosis, predominantly at the lumbosacral junction, is reported over 30 % in adult spinal deformity [19, 20]. Lumbosacral pseudarthrosis occurred in both of our patients, which might have increased stress at sacral screws and led to toggle migration. Circumferential fusion using a postero-lateral bone graft combined with an L5–S1 ALIF might have been preferable to prevent screw loosening and revision of lumbosacral fixation. Finger et al. [21] demonstrated that iliac screw fixation led to significantly less pseudarthrosis and screw loosening in long constructs, compared to S1 screw fixation only and sacral plate fixation with ala screws. The use of a pelvic fixation using long iliac screws is aimed to distribute load from the lumbar spine to the pelvis and thus lower stress at L5–S1, sacral implants and SIJ [22]. This construct type might have been preferable in our patients thus preventing lumbosacral pseudarthrosis and excessive stress across the SIJ. It further appears essential to prevent SIJ violation using either sacral

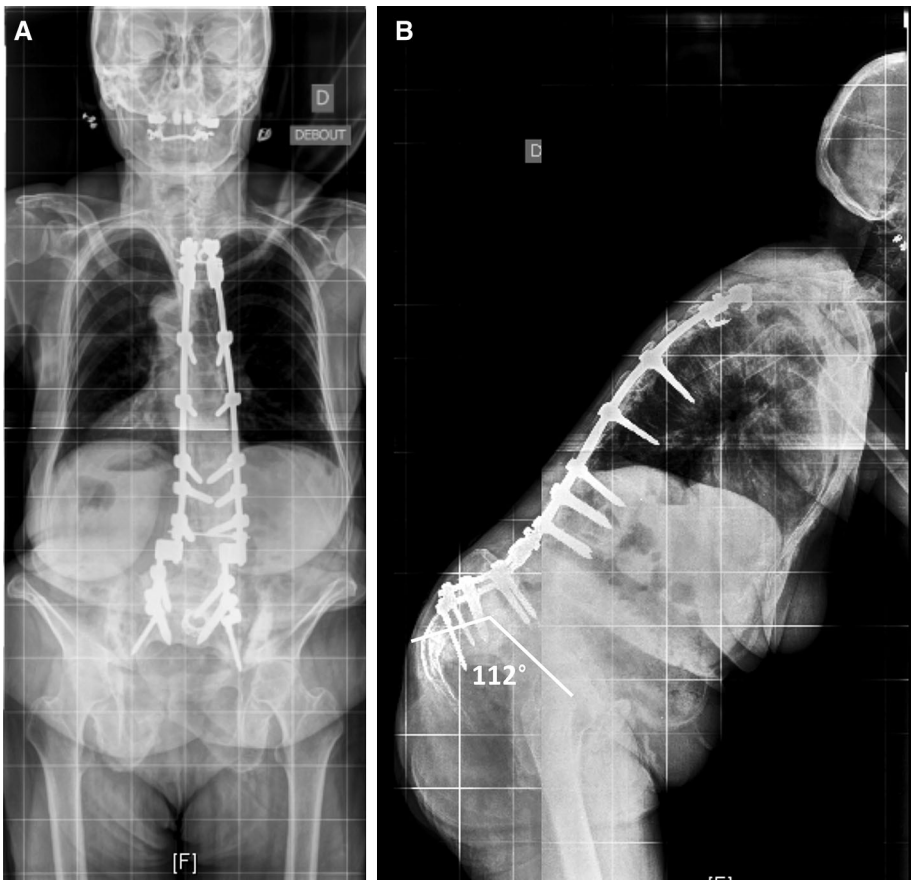

Fig. 18 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs showing acute 22° increase of pelvic incidence and major anterior imbalance due to sacroiliac joint luxation

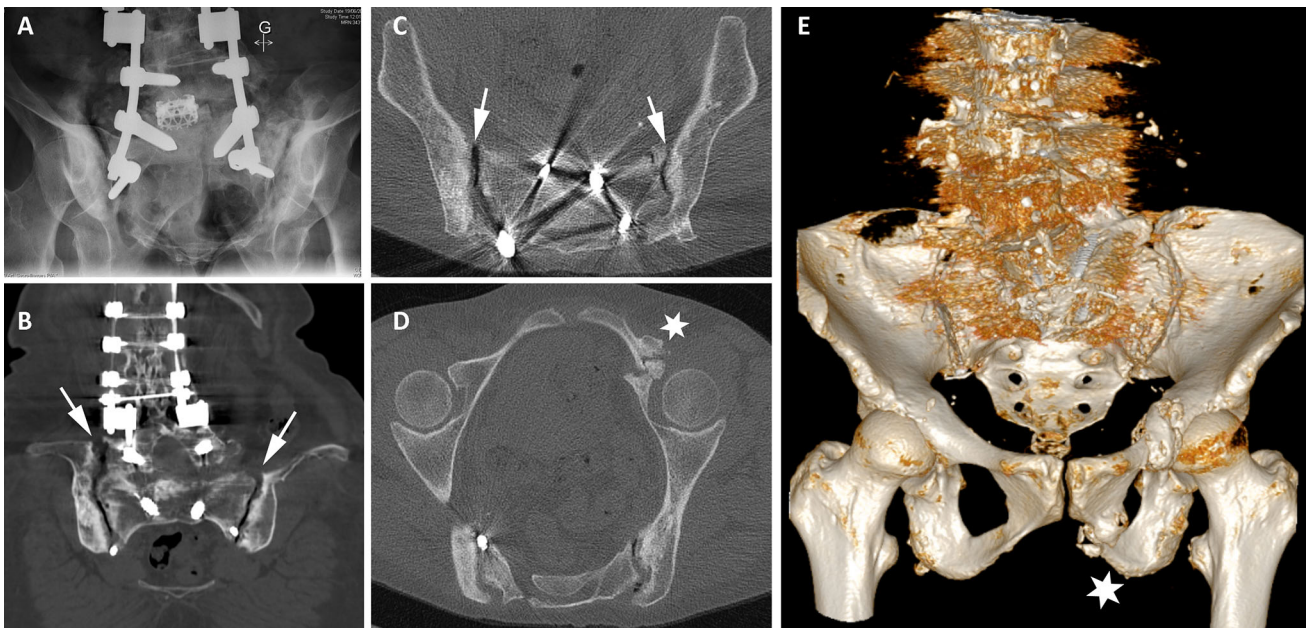

Fig. 19 Sacroiliac radiograph (**a**), coronal (**b**), axial (**c**, **d**) and 3D CT reconstructions (**e**) demonstrate sacroiliac luxation with gas formation (*arrows*) and fractures of left pubic rami (*star*). The sacrum has rotated anteriorly, while the pelvis is in maximal retroversion

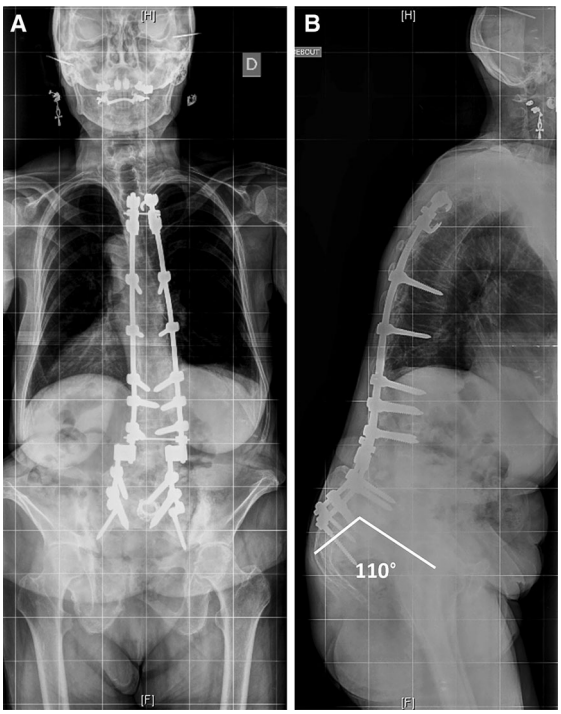

Fig. 20 Posterior-anterior (**a**) and lateral (**b**) full spine radiographs at 30-month follow-up demonstrating fixed anterior imbalance

ala or iliac screws, since damage to the syndesmosis might increase pelvic instability by premature SIJ degeneration [23].

Osteoporosis, age, female gender and obesity account for the patient-related risk factors in sacro-pelvic insufficiency fractures after long posterior fusion [12, 13]. One of our patients presented osteopenia preoperatively. The second patient has only been investigated on osteoporosis retrospectively. Osteopenia might have contributed to sacral and pelvic implant loosening in addition to aforementioned mechanical considerations of lumbosacral fixation. Bone mineral density should be assessed preoperatively in order to treat osteoporosis if present. There is some evidence that preoperative systemic treatment (teriparatide) might lower the risk for screw loosening in postmenopausal women with osteoporosis [24].

Conclusion

These two cases illustrate that we still lack of knowledge in the comprehension of surgical treatment of sagittal imbalance. Our static planning of deformity correction by PSO did not achieve the theoretical goal of matching LL

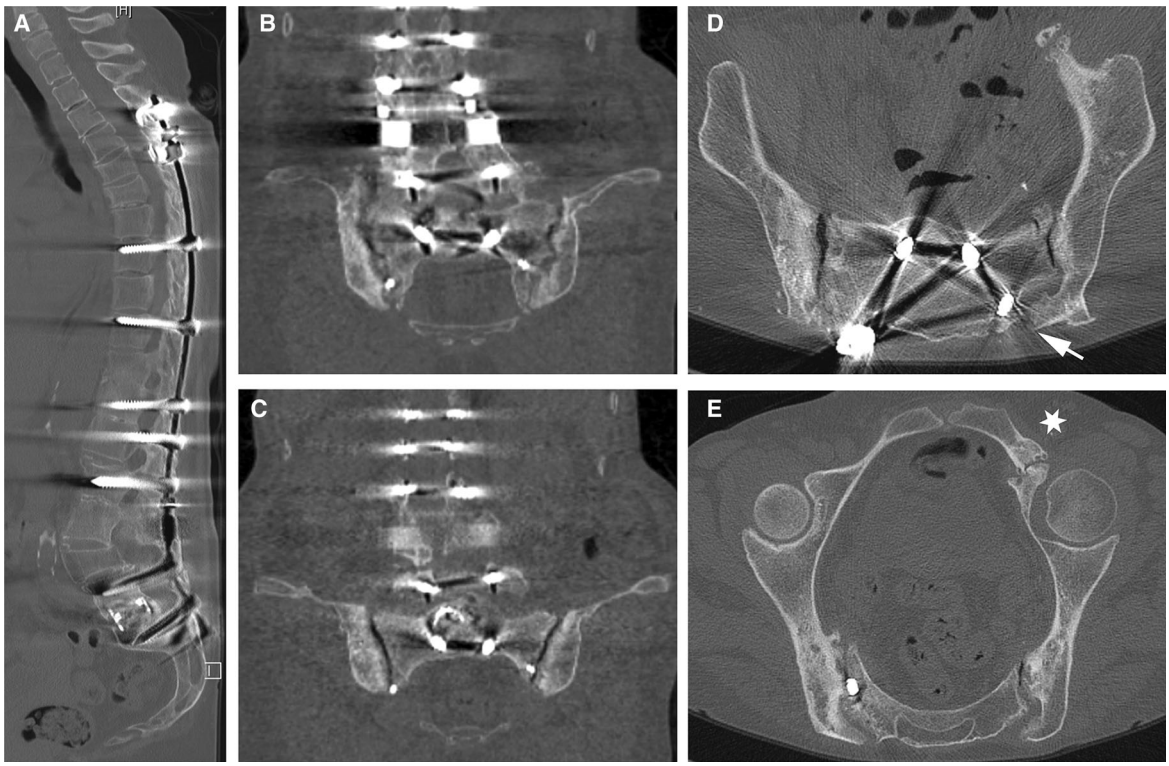

Fig. 21 Follow-up CT showing thoracic and lumbosacral fusion on sagittal (**a**) and coronal (**b**) reconstructions. Gas remains in luxated sacroiliac joints (**c**). Partial posterior sacroiliac fusion (*arrow*) seems present on axial reconstruction (**d**). Pseudarthrosis (*star*) is evidenced at left pubic rami (**e**)

and PI in patients with very large PI. These patients remained imbalanced with an anterior plumb line, which might explain residual pelvic retroversion and progressive twisting mobilization of the SIJ. Extremely, high preoperative PI might be an important risk factor for progressive PI increase and SIJ luxation after PSO. Initial circumferential lumbosacral fusion and proper iliac fixation without SIJ violation might prevent this catastrophic scenario. Bone mineral density should further be assessed and osteoporosis treated preoperatively if present.

Conflict of interest None of the authors has any potential conflict of interest.

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