14 Thoracolumbar Instrumentation and Fusion for Degenerative Disc Disease

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14.1 Introduction

With the increase of an aging population worldwide, patient's expectations and demands for an improved independent lifestyle have led to innovative strategies in the treatment of degenerative disc disease. Aside from all conservative modalities, new surgical techniques attempt to enable a rapid recovery by reducing iatrogenic injury and complications with shorter operative times. Over the past two decades, the debate over which approach may achieve the highest fusion rates has been opened to a more global view on its efficacy of restoring the overall coronal and sagittal balance of the spine. Thus, the analyses of respective spinopelvic interrelations using modern full body radiographic imaging in an upright standing position have received closer attention and have since been fully included in our therapeutic management and strategical planning. Furthermore, the increasing number of failed primary surgeries and/or adjacent segment degeneration with secondary kyphotic deformity constitute a distinct entity of challenges with rather individual and case-dependent solutions. Today's advances in spinal instrumentation allow almost any operation to be performed in a minimally-invasive fashion. Regardless of selecting either the retroperitoneal corridor (ALIF, OLIF, LLIF) or traversing the spinal canal with or without osteotomy of the facet joints for segmental mobilsation (PLIF, TLIF, minimally-invasive-surgery (MIS)-TLIF), none of today's standard techniques have proven to be superior to another. Although each approach has its own risks and benefits, fusion rates or clinical outcomes appear to be similar [1]. However, there is fundamental consensus, that interbody fusion itself is preferable to posterolateral "on-lay" fusion techniques with less postoperative complications and lower rates of pseudarthrosis [2–4]. In conclusion, the surgeon must always consider all technical options to tailor the treatment to the patient's individual, but none the less realistic expectations.

This chapter aims to outline the individual strategical considerations when treating degenerative conditions of the thoracolumbar spine and highlight the importance of the overall clinical evaluation and imaging analyses. The following two cases shall demonstrate these objectives with regard to their individual surgical management, including different techniques targeted at treating the ostensible and causally determined clinical finding.

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14.2 Case Description

14.2.1 Case 1

49 yo female complaining of progressive low back pain and left-sided radiculopathy. Previous periradicular and facet joint injections failed to permanently improve her overall mobility. Low back pain and left-sided leg pain were distributed equally with the patient-reported VAS being 7/10 regardless of posture and exposure to every day activities. With a past history of idiopathic thoracolumbar scoliosis, her main complaints were rather focussed on the lumbar spine region. After months of unsuccessful conservative treatment, including a multimodal pain management (MPM), she was finally admitted to our department and scheduled for minimally-invasive decompression and fusion surgery.

14.2.2 Case 2

76 yo male with a history of previous decompression and fusion surgery at the L4/5 level in 2003 (Fig. 14.1a). After a decade of asymptomatic recovery, he returned to seek orthopaedic treatment for progressive back pain. The posterior screw-and-rod system was removed and the decompression and fusion extended to the adjacent L3/4 level in PLIF-technique in 2014 (Fig. 14.1b). With the development of progressive lumbar scoliotic deformity and sagittal imbalance, fusion was extended to the lower adjacent level 1 year later, thus resulting in a spondylodesis from L3 to S1, respectively (Figs. 14.1c and 14.2a). However, sagittal imbalance advanced to further immobilizing low back pain. In addition, the patient then developed a pathological fracture of the sacrum with further detrioration of his sagittal imbalance (Fig. 14.2b). After an initial uneventful conservative recovery, the patient fell a few months later and suffered an instable fracture of the L1 vertebra and was referred to our department for further treatment (Fig. 14.3). Consequently, the instrumentation was extended cranially to Th10, including a conventional open TLIF at the adjacent level L2/3 with multiple Ponte osteotomies to combine fracture stabilization and deformity correction. Ten months postoperatively, the patient developed newly increasing back pain in the mid and lower thoracic region. Follow-up EOS imaging demonstrated a gradual loss of correction with increasing sagittal imbalance (Fig. 14.4). Ultimately, the patient's pain level reached an immobilizing intensity, consequently leading to a CT of the thoracolumbar spine with subsequent confirmation of screw loosening from Th10 to Th12 (Fig. 14.5). Finally, the patient was scheduled for his fourth revision surgery.

14.3 Discussion of the Cases

14.3.1 Indication

14.3.1.1 Case 1

The indication for decompression and fusion surgery was based on the progression of immobilizing symptoms in line with a monthlong history of unsuccessfull interventional and conservative treatments. Although the majority of cases with mild radiculopathy in the absence of neurological impairment may very well be treated conservatively [5, 6], the patient's history including MPM was characteristic to revise the treatment strategy and not resume a conservative path. With the spine balanced in both the coronal and sagittal plane, the predominant symptoms were related soley to the lower lumbar spine spine region and associated with unilateral leg pain corresponding to an L4 and L5 radiculopathy, respectively. Moreover, the positive response to previous periradicular and facet joint injections at the L4/5 level confirmed the diagnostic findings (Figs. 14.6, 14.7, and 14.8) with regard to reducing symptoms temporarily, but not permanently. Thus, surgical treatment may involve decompression alone or in combination with a fusion procedure. To date, the necessity to add a fusion procedure in symptomatic cases with radiating leg pain and low back pain with or without spondylolisthesis, remains a matter of debate [7]. Although the definition of

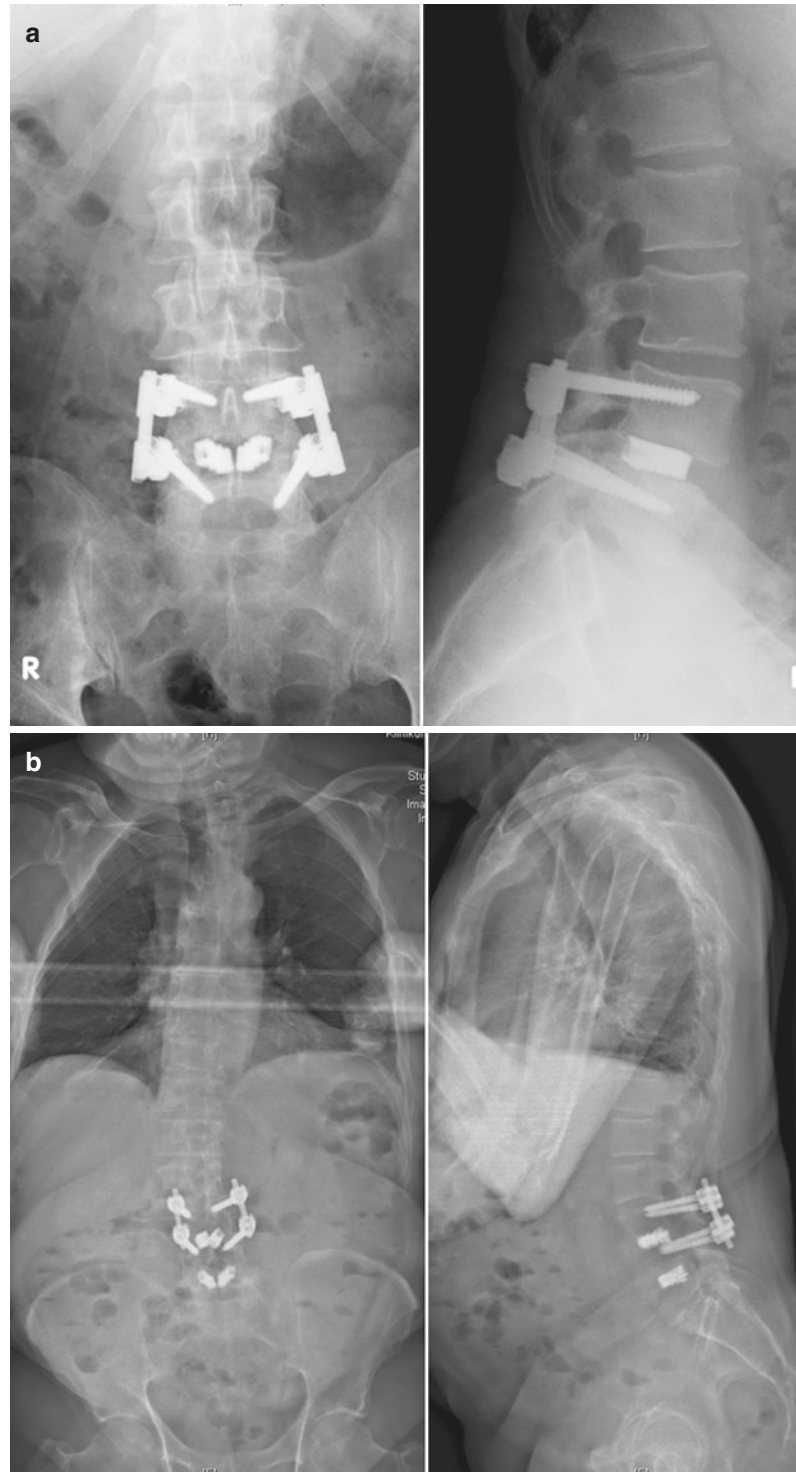

Fig. 14.1 Past history documentation of a 76yo male throughout a 13-year follow-up: (**a**) a.p. and lateral standing X-ray in 2003, (**b**) 2014 and (**c**) 2016

Fig. 14.1 (continued)

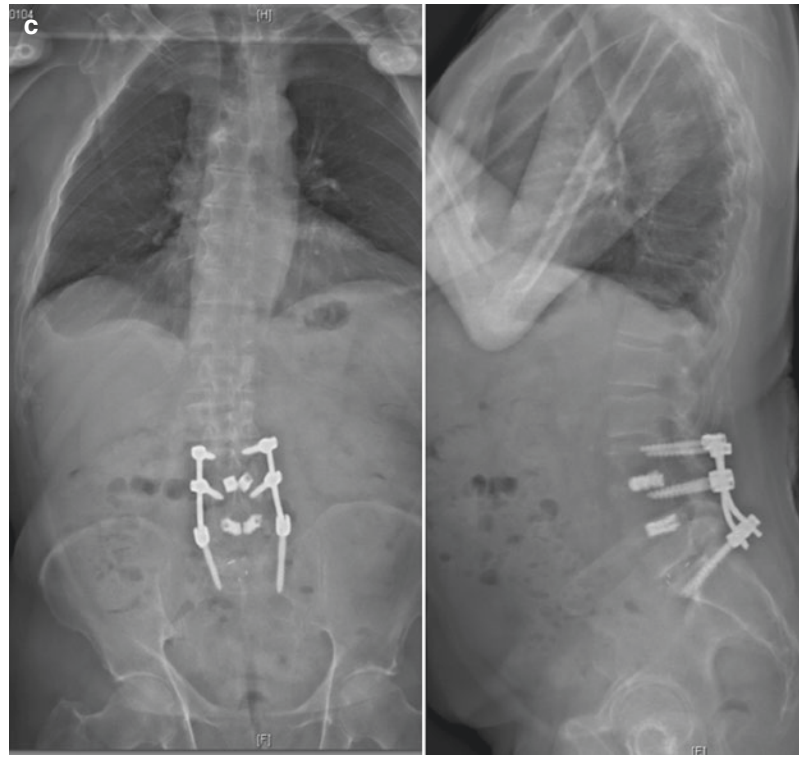

Fig. 14.2 Upright standing lateral total spine X-ray in (**a**) 2016 and (**b**) at 6 months follow-up after conservative treatment of a sacral fracture

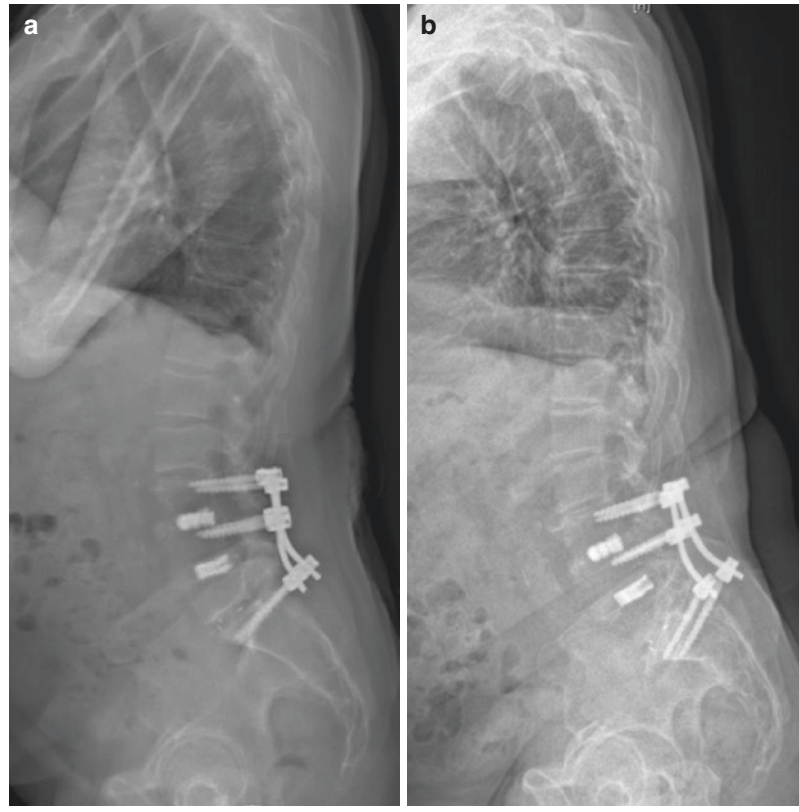

Fig. 14.3 (**a**) MRI showing the fracture at L1 in the T2-weighted (left) and T1-weighted (right) sequence with disc degeneration at the L2/3 level, (**b**) CT showing the instable L1 fracture involving both pedicles

instability is inconsistent [8], there are certain imaging characteristics that have been reported to predict a negative outcome when applying decompression alone in corresponding cases. These include a reduced disc space height of <6 mm, hypermobility at the spondylolisthetic level (<1.25 mm) and a high pelvic incidence with anterior sagittal imbalance [9–11]. In our Case 1 described here, these diagnostic parameters were complemented by the temporary pos-

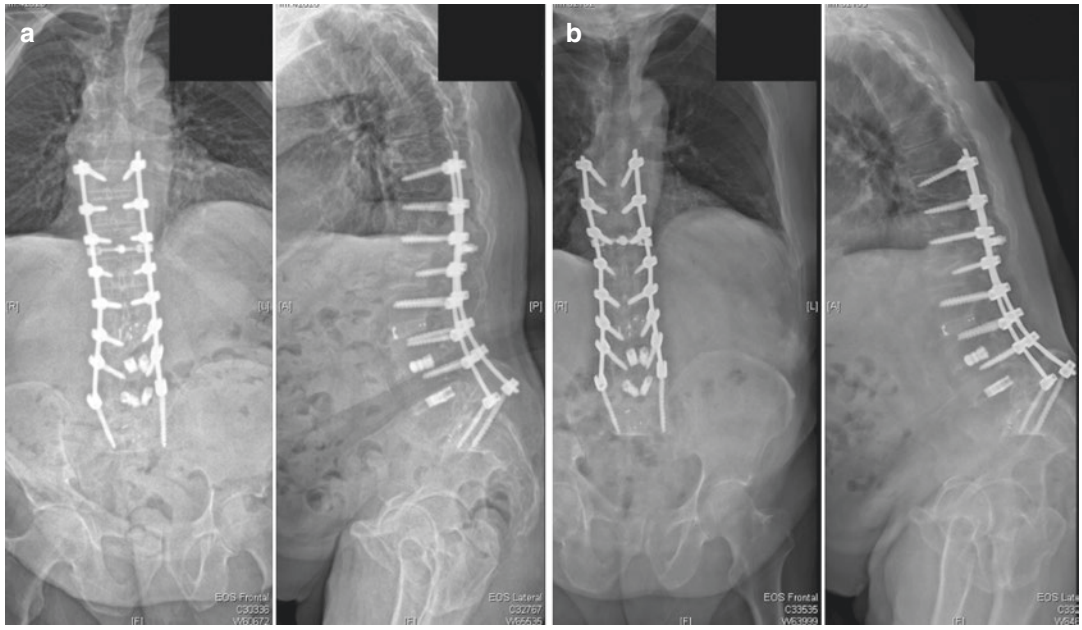

Fig. 14.4 (**a**) Postoperative result after extending the posterior screw-and-rod instrumentation to Th10 with fracture-level screws at L1 and an additional TLIF at L2/3, (**b**) 6 month postoperative follow-up demonstrating a progressive sagittal imbalance

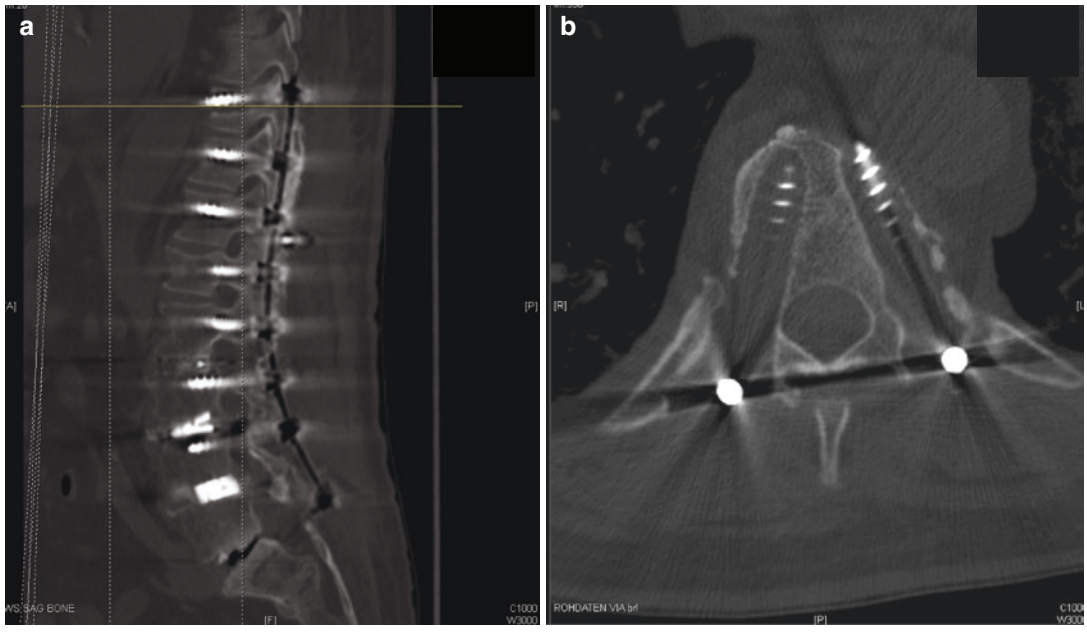

Fig. 14.5 Conventional CT at 1 year post-OP follow-up: (**a**) sagittal plane demonstrating screw loosening at Th10, 11 and 12 with a consolidated L1 vertebra, (**b**) axial plane at the Th10 level showing the large bony defect and screw migration

Fig. 14.6 Functional lateral X-rays showing a discrete instability with antelisthesis in anteflexion at the L4/5 level

itive response to both a periradicular injection and injections of the facet joints at the L4/5 level.

14.3.1.2 Case 2

Despite the previous surgery attempting to not only stabilize the L1 fracture, but also implement the correction of deformity, sagittal imbalance progressed to an immobilizing level of pain. Moreover, the patient complained of feeling restraint to actively convert any compensatory retroflexion of the pelvis or his thoracolumbar spine for the purpose of rebalancing a tolerable standing or walking posture. In addition to the significant screw loosening evident at the Th10, Th11 and Th12 level, the indication for revision surgery was given to reestablish a functional sagittal profile.

14.3.2 Choice of Approach

14.3.2.1 Case 1

Since the initial description of the PLIF technique by Briggs and Milligan in 1944, different methods of spinal segmental fusions have evolved, incorporating a variety of innovative implants with the option of autologous and synthetic bone grafting, and the use of pedicle screw fixation for posterior instrumentation [3]. In a

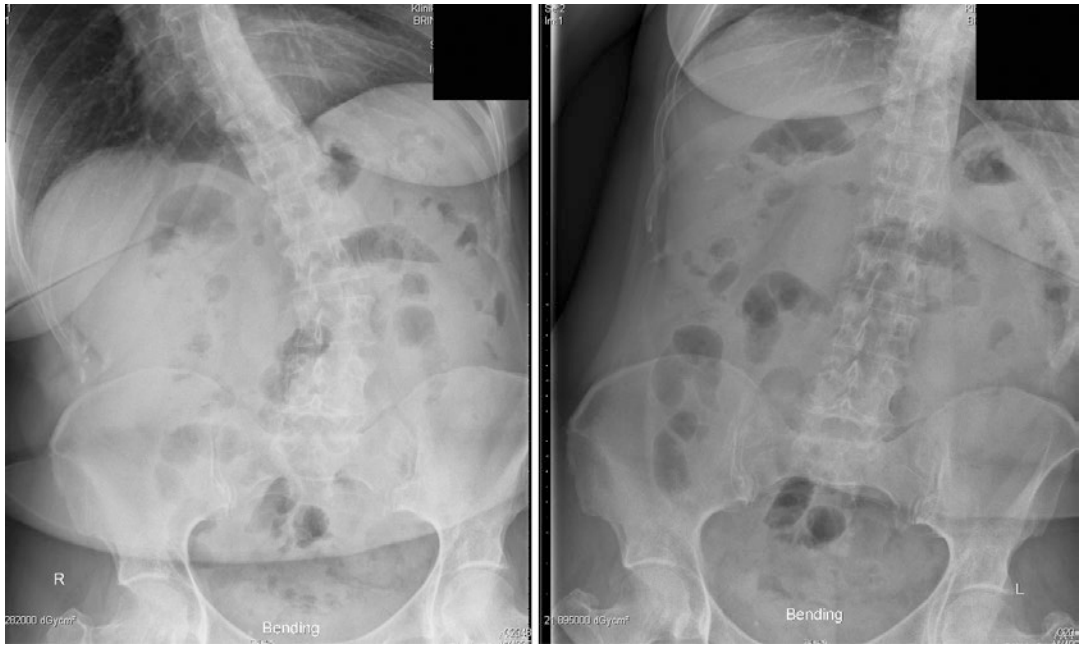

Fig. 14.7 Bending X-rays demonstrating translational instability at the L4/5 level

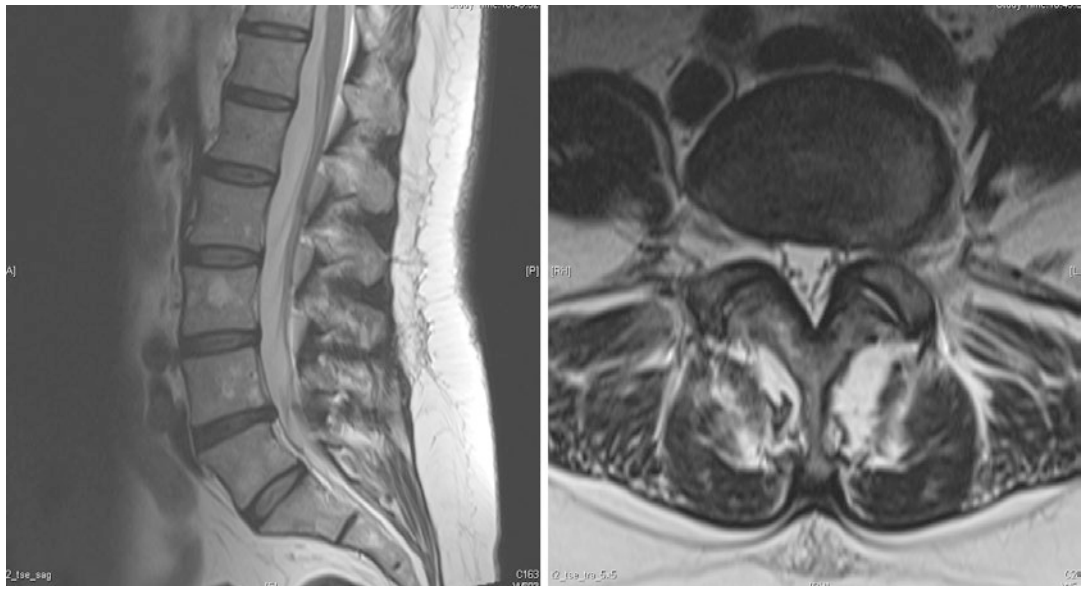

Fig. 14.8 MRI (T2-weighted images) of the lumbar spine demonstrating the degenerative disc in L4/5 with leftsided neuroforaminal stenosis

recent meta-analysis by Teng and colleagues, however, none of today's standard techniques (ALIF, OLIF/LLIF, TLIF and PLIF) stand out with significantly superior outcomes in either a direct of indirect comparison to another [1]. In a systematical search of the literature and subsequent inclusion of 30 studies, all approaches had similar fusion rates with complications such

as incidental dural tears, motor or sensory deficits and visceral or vascular injuries being approach-related, but at a comparable rate throughout the included studies. Therefore, one must be careful in advancing a "one-fits-all" solution, since every approach has its own risks and benefits. Moreover, the socio-economical aspects of perioperative and postoperative care should also be taken into account, where a specific approach may be less effective in terms of implant costs, readmission rates, socio-professional reintegration and overall long-term patient-reported outcomes (PRO) [12]. The decision on which approach may be most appropriate to address all symptomatic and potentially modifiable factors is thus tailored to the individual case. In our Case 1, we therefore chose a minimally-invasive posterior procedure. To address the symptomatic left-sided radiculopathy and foraminal stenosis, the traversing L4 nerve root and spinal canal were accessed via a mini-open exposure in a modified Wiltse technique from the left. The two contralateral pedicle screws were placed percutaneously and the ipsilateral screws via the mini-open exposure in similar fashion. After performing a left-sided laminotomy and facetectomie for direct neural decompression, the disc space was thoroughly debrided and a titanium-coated PEEK cage including bone graft inserted in an oblique bridging fashion. After insertion of both rods, readjustment of lordosis was achieved via bilateral compression to complete the MIS-TLIF procedure. By utilizing the resected facet joint and bone from the laminotomy by punching only (no burr), this technique provided sufficient autologous bone graft without the additional need to harvest autologous bone from the iliac crest or resort any further bone substitution (Fig. 14.9).

In this particular case, a variety of alternative approaches would have been acceptable to achieve fusion at the L4/5 level. However, anterior approaches including the ALIF, LLIF and OLIF technique all require an additional form of autologous bone harvesting. In the majority of cases, harvesting of autologous bone is limited to the iliac crest, yet bearing an additional risk of postoperative immobilizing pain. Although there is an ongoing debate on whether the incidence of pain is strictly related to the harvesting site [13], its efficacy regarding fusion rates appears to be comparable to local bone harvested through the common posterior approaches to the lumbar spine, regardless of the choice of incision [14].

Yet, there are some advantages of anterior approaches that should be considered. While ALIF has proven to achieve a superior radiological outcome with improved restoration of postoperative disc height and segmental lordosis, OLIF and LLIF procedures have rendered the preservation of the anterior and posterior annular/ligamentous structures, equally permitting the insertion of wide cages resting bilaterally on the dense apophyseal ring and augmentation of disc height with indirect decompression of neural elements [1, 15].

However, ALIF, OLIF or LLIF at the L4/5 level with instability is not reasonable as a standalone procedure. Thus, complementing the respective treatment of the disc space with a posterior instrumentation (e.g. pedicle screw-and-rod system) is mandatory and requires a repositioning of the patient as an additional step in the operation.

Considering similar fusion rates amongst all four common approaches to the lumbar spine, each specific aspect and approach-related risk and benefit must be carefully weighed out with regard to the individual therapeutic goal.

14.3.2.2 Case 2

A characteristic challenge to any revision case is that there is no gold standard or generally accepted treatment guideline. In the particular setting of Case 2, the patient presented with all lumbar levels fused in addition to an angular kyphosis of the sacrum. Thus, all common approaches for lumbar fusion were exhausted. Furthermore, the cranial pedicle screws at Th10, 11 and 12 were severely loosened bilaterally due to the patient's repetitive attempt to actively convert to a rebalanced upright standing posture. As a result, our strategical considerations regarding the posterior instrumentation included two options: (1) Remove all loosened screws and extend the instrumentation cranially or (2) reduce

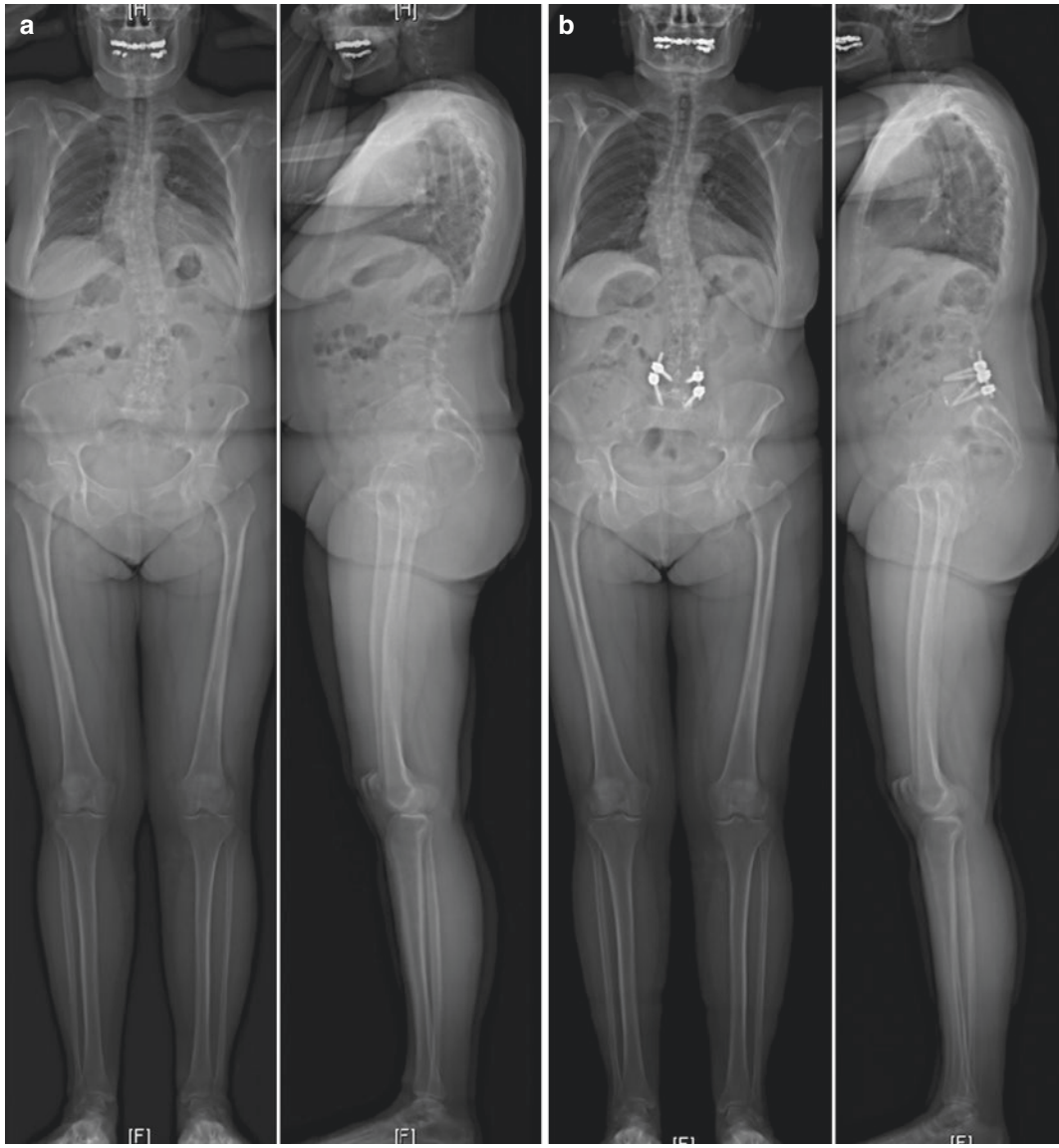

Fig. 14.9 EOS total spine imaging. (**a**) pre-operative upright standing ap and lateral, (**b**) 1 year post-operative follow-up upright standing ap and lateral

the instrumentation to the last cranially adjacent and intact motion segment.

In the event of any implant loosening or pseudarthrosis, insufficient bony fusion or hypermobility of the involved motion segment must be assumed. In cases where segmental fusion is mandatory to achieve sufficient stability and maintain the overall balance along with a functionally appropriate spinal alignment, the particular region must be addressed accordingly. However, in Case 2, the posterior instrumentation was initially extended to Th10 for stabilzation of an instable L1 fracture with regard to the existing lumbar fusion. In consideration of the meanwhile consolidated L1 fracture, intact thoracic and thoracolumbar discs and the patient's thoracolumbar discomfort, we interpreted his sense to be an indication of intact compensatory mechanisms

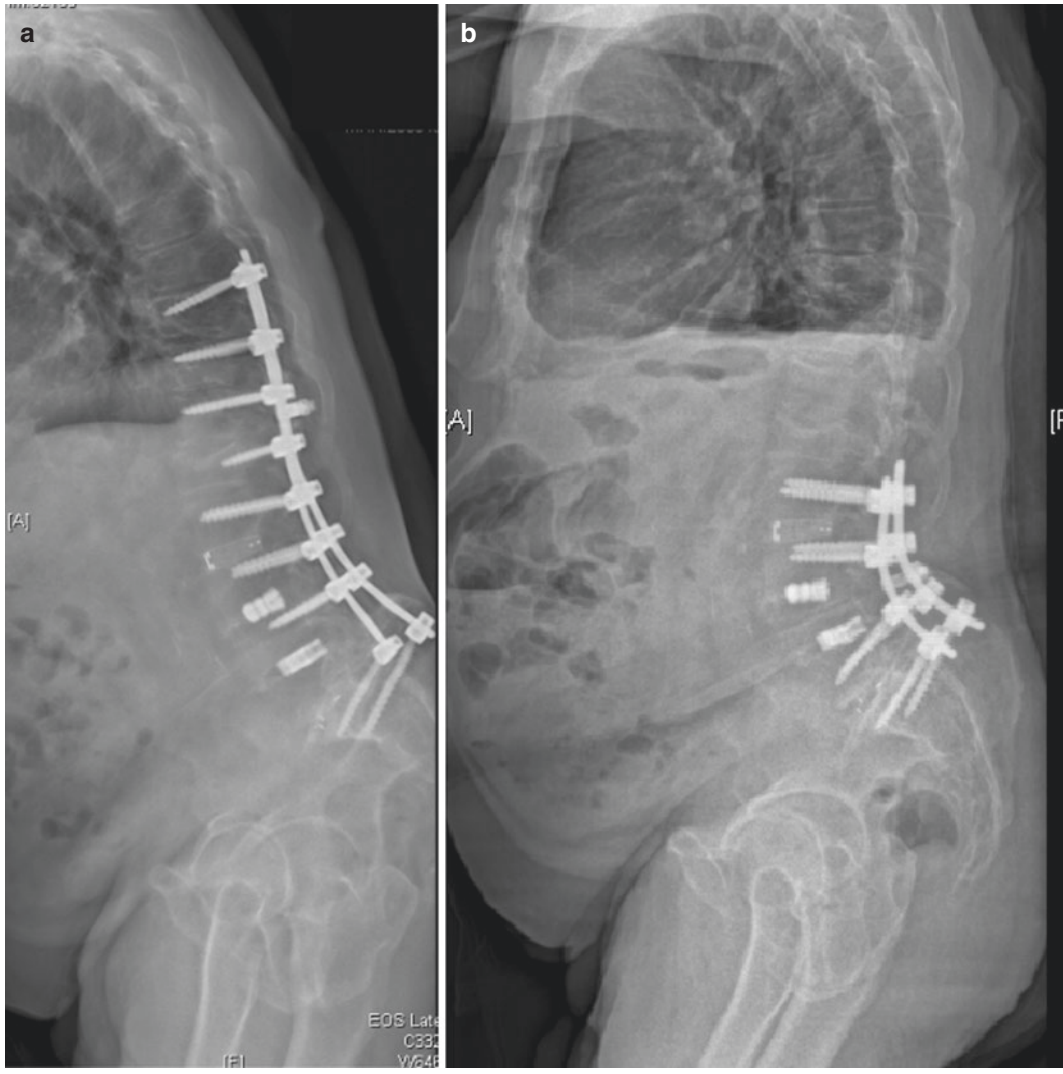

Fig. 14.10 (**a**) pre-operative lateral X-ray with sagittal imbalance, (**b**) 3-month postoperative follow-up after partial implant removal and PSO at L4

within the lower thoracic spine region. Hence, our approach was to follow the conviction, that implant removal may reestablish segmental motion in analogous manner to previous reports on thoracolumbar burst fractures [16–18].

In addition, the decreased lumbar lordosis demanded further attention to adequately rebalance the global sagittal profile. For this reason, we chose to include a pedicle subtraction osteotomy (PSO) at L4 to equally preserve the existing instrumentation and stability from L2 to S1 (Fig. 14.10).

In patients with fixed coronal or sagittal plane deformities of the lumbar and thoracolumbar spine, a single level PSO may generate a lumbar lordosis from 20 to 40 degrees with an approximate change in the sagittal vertical axis of up to 12 cm [19–21]. Although other techniques such as multiple segment Ponte osteotomies or a vertebral column resection (VCR) may similarly address hypolordotic or kyphotic deformities with subsequent sagittal imbalance, our Case 2 presented fused lumbar segments with the patient's demand to remobilize the structural

dynamics of the thoracic and thoracolumbar region. Thus, our stretegy was to limit any manipulation to the already existing length of lumbar fusion by equally avoiding further immobilization of the cranially adjacent spine.

14.3.3 Accordance with the Literature Guidelines

Despite todays technical advances and improved surgical techniques, we must always acknowledge the fact that balance is a dynamic property which involves more than the bony alignment evaluated in diagnostic imaging. This suggests a more complex evaluation of the (aging) patient's abilities and requirements by equally considering the full portfolio of techniques with respect to the related risks and limitations. To date, there are no specific guidelines in the literature. Particularly revision cases demand an individual approach, preferebly managed in an interdisciplinary setting to allow for a patient-tailored and comprehensive evaluation.

14.4 Conclusions and Take Home Message

Both cases presented here display unexceptional encounters to the majority of spine surgeons. Careful evaluation and treatment of the major and foremost causally determined pathology is key to an overall good clinical outcome. In cases where the spine is well balanced, instrumentation and fusion should be limited to the pathological finding and equally preserve all dynamically intact structures involved to maintain the respective coronal and sagittal balance. In contrast, it may be very similar to liberate these structures and reactivate individual compensatory mechanisms in an otherwise fixed imbalanced posture. Despite aiming at correcting deformity by all means to restore a functional coronal and sagittal balance, soft tissue preparation should always be performed with reasonable care in either a minimally-invasive or conventional open fashion.

Pearls

- In the balanced spine, segmental pathologies may be addressed by "short segment" procedures.
- Selective periradicular or facet joint injections can aid the decision making between lumbar fusion versus non-fusion strategies.
- The choice of surgical approach and technique must give consideration to the therapeutic aim by equally including the patient's individual risks and conditions.
- Revision cases with signs of segmental hypermobility must be critically evaluated with regard to its relation of cause and effect. In justified case constellations, the revision strategy should preserve or reintegrate intact compensatory mechanisms supporting the overall sagittal balance of the spine.

Editorial Comment

This chapter illustrates in a nutshell that despite the fact, that a huge variety of techniques and instrumentations are available today, outcomes are often disappointing, especially with poorly localized low back pain. While the first patient went well, the second had many revisions and was never really satisfied. Why that is so, remains elusiveand explanations for it pure assumptions. By the way, the screw loosening illustrated here is according to our opinion not only caused by inadequate balance, but certainly also by an underlying low grade infection.

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