

Review Paper

Protective Factors of Preventing Proximal Junctional Kyphosis as the Most Common Complication of Adult Spinal Deformity Surgery



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ABSTRACT

Background and Aim: This study aims to provide information about the common complications of adult spinal deformity (ASD) surgery that requires revision surgery and proximal junctional kyphosis (PJK) as the most common complication. We emphasized crucial protective factors that reduce the risk of post-operative PJK, especially the careful selection of the upper instrumented vertebra (UIV) and gradual transitional zone on the proximal end of the construct.

Methods and Materials/Patients: This study is a retrospective review of the adult population with spinal deformity who underwent posterior instrumentation surgery and requires revision surgery due to post-operative complications, such as disc herniation, screw loosening, rod breakage, distal junctional failure, and symptomatic PJK. Fifteen ASD patients requiring revision surgery were included. We evaluated the ratio of age, gender, the prevalence of postoperative complications, and the most common complication of PJK based on Cobb angle and patient symptoms.

Results: This study included 15 patients with ASD who underwent posterior spinal instrumentation surgery and experienced post-operative complications requiring revision surgery. As a result, 6 patients out of 15 (40%) had PJK, four patients (26.6%) had disc herniation and canal stenosis, two patients (13.3%) had screw loosening, one patient (6.6%) had rod breakage and two patients (13.3%) had distal junctional failure requiring revision surgery.

Conclusion: In our study, PJK is at the top of the complications and two risk factors have a great impact on predisposing ASD surgery to the post-operative PJK, that is, the UIV level, and gradual transitional zone at the proximal end of the construct. Therefore the risk of this unfortunate outcome can be significantly minimized by carefully selecting UIV and hooks using a smooth gradual transitional zone along with other protective factors.

Keywords:

Kyphosis, Instrument failure, Spinal deformity, Vertebral column

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Highlights

- Proximal junctional kyphosis (PJK) is the most common complication of adult spinal deformity (ASD).
- Complications from ASD surgery include PJK (the most common), distal junctional failure, screw loosening, disc herniation, rod breakage, and pseudoarthrosis.
- Trying to identify effective factors in this regard has always been one of the topics discussed in the field of spine surgery.

Plain Language Summary

One of the most common complications among adult spinal deformity (ASD) surgery is proximal junctional kyphosis (PJK). This study was designed to detect the risk factors associated with this problem, by detecting these risk factors; these side effects can be reduced.

1. Introduction

Due to the aging of the population, adult spinal deformity (ASD) is increasing over time, affecting the quality of life in adults [1]. Many spinal deformities in adults become symptomatic with intractable pain, gait disturbances, and even neurological deficits that require surgical intervention [2].

ASD is associated with several factors, these factors include radiological deformity, spinal canal stenosis, radiculopathy, and patient comorbidities related to age, obesity, and osteoporosis [3, 4]. ASD has an economic impact and patients with pain and ambulatory difficulties become socially isolated and reduce their quality of life [1, 5]. Complications from ASD surgery include proximal junctional kyphosis (PJK) (the most common), distal junctional failure, screw loosening, disc herniation, rod breakage, and pseudoarthrosis [3, 6-8].

One of the most common complications in ASD surgery is PJK [5, 9-17]. The prevalence of PJK varies from 6% to 60% in different studies, but it is between 30% and 40% in most studies [18-21]. As the patient's condition worsens, severe pain and structural failure occur, which is mentioned as proximal junctional failure (PJF); therefore, PJF is on the end of the same spectrum [22].

2. Methods and Materials/Patients

This study was a retrospective review. The keywords for ASD, PJK, PJF, upper instrumented vertebra (UIV), range of motion (ROM), revision surgery, and transitional zone were used as search terms and most related arti-

cles were reviewed. The setting of this study was Hazrat Rasoul Hospital. Data was collected from March 2019 to September 2022 for about three and a half years.

3. Results

Fifteen consecutive patients who had previous ASD surgery and needed revision surgery were included in this research. The average age ranged from 41 to 65 and the mean age was 53 years. Six men (40%) and nine women (60%) were included in the study. We used spinal x-rays and computerized tomography (CT) scans and magnetic resonance imaging (MRI) to examine the degenerative spine, and canal stenosis, and measure Cobb angle (Tables 1 and Table 2).

Cobb angle of more than 10° was considered proximal junctional kyphosis in these symptomatic patients. Table 1 presents complications of ASD surgery that need revision surgery. Table 2 presents the age and gender ratio in patients. PJK was the most common complication (6 patients=40%), other complications included disc herniation and canal stenosis (4 patients=26.6%), screw loosening (2 patients=13.3%), rod breakage (one patient=6.6%), and distal junctional failure (2 patients=13.3%). Figure 1 shows different complications of ASD surgery that require revision (Figure 1).

Based on the Cobb angle index, we evaluated the patients with PJK. We investigated the types of failure in patients with PJK as well as the level of UIV and the presence of gradual transitional zone-using hooks.



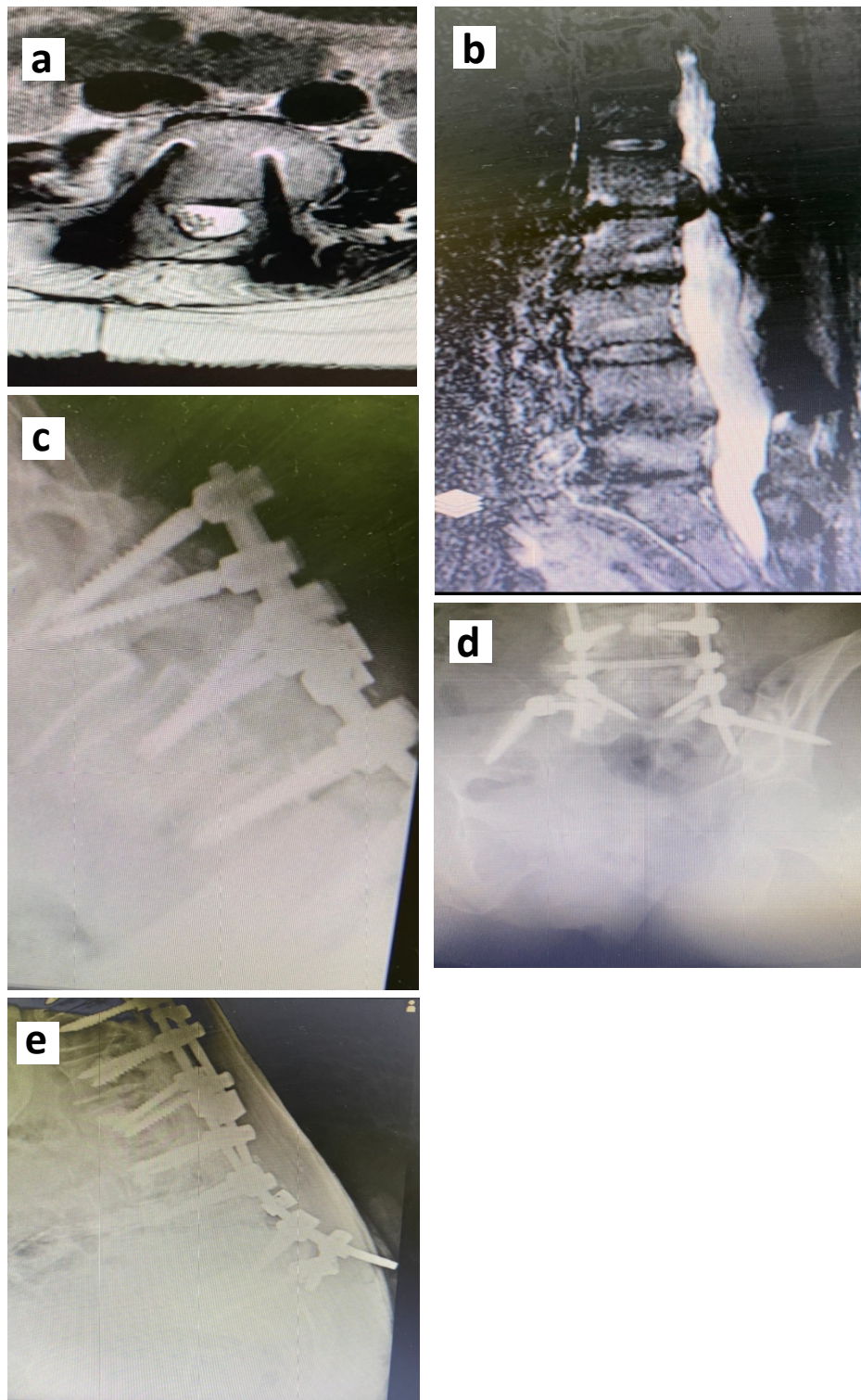


Figure 1. The relationship of patients with adult spinal deformity (ASD) surgery complications

a) T2 axial magnetic resonance imaging (MRI) including left disc herniation after adult spinal deformity (ASD) surgery, b) Sagittal T2 magnetic resonance imaging (MRI) of severe canal stenosis with disc herniation, c) Lateral radiography of patient with screw loosening and pull out failure, d) Anterior-posterior (AP) radiograph demonstrating left distal screw loosening and pseudoarthrosis, e) Lateral radiography with distal junctional failure

Table 1. Types of post-ASD-surgery complications

Complication	No. (%)
PJK	6(40)
Disc herniation and canal stenosis	4(26.6)
Screw loosening	2(13.3)
Rod breakage	1(6.6)
Distal junctional failure	2(13.3)

PJK: Proximal junctional kyphosis.



In this article, we examined patients with ASD who underwent revision surgery. As a result, of these fifteen patients, six people (40%) were men and nine people (60%) were women. Also in terms of age ratio, the mean age was 53 years. We measured Cobb angle in radiographic and CT-scan parameters to separate patients with Cobb angle equal or greater than 10° for PJK complication in our research. Complications after ASD surgery that needed revision surgery in our study involved PJK, disc herniation and canal stenosis, screw loosening, rod breakage, and distal junctional failure.

Six patients out of fifteen patients who required revision surgery had PJK (40%). We determined:

1. UIV level in three categories:

1-1 Upper thoracic

1-2 Lower thoracic and thoracolumbar junction

1-3 Lumbar region

Also,

2. Existence of gradual transitional zone-using hooks

Analysis showed that an upper instrumented vertebra in the lower thoracic region, especially in the thoraco-

lumbar junction and lumbar area were mostly associated with developing PJK.

Regarding the level of UIV, no patient had UIV in the upper thoracic and 4 patients (66.6%) in the lower thoracic and thoracolumbar junction, and 2 patients (33.3%) in the lumbar area (Table 3).

Regarding the transitional zone, all these patients with PJK had a rigid pedicular screw on the top of the construct. We also noticed that pedicular screws on the proximal end of the construct in most of these patients were the largest size, which can produce a good fusion, but unfortunately can lead to adjacent segment disease and PJK.

Also, according to Table 4, bone failure is at the top of PJK-related failures (three patients=50%), two patients (33.3%) had implant/bone interface failure and one patient (16.6%) had a disc-ligamentous failure (Figure 2) (Table 4).

4. Discussion

There is no consensus on the definition, classification, and indication of PJK/PJF for revision surgery but there is consensus on treatment and prevention strategies [19, 23]. Hart et al. defined PJF as increased kyphosis of more than 10° at UIV or UIV+2 related to disruption

Table 2. Prevalence of age and gender in ASD-revision surgery

Parameters		Values
Age (y)		Average=53 41 to 65
Gender	Female	9 patients=60%
	Male	4 patients=40%



of osseo-ligamentous or pull-out of instrumentation at UIV [9]. Hostin et al. described PJF as 15° or more PJK related to fracture of UIV or UIV+1 or the need for an extension instrument [23]. However, Bridwell et al. investigated the proximal junctional angle of more than 20° as a threshold for PJK outcome [11]. Therefore the definition of PJK/PJF and clinical information can significantly vary in different studies [25]. Three symptoms are involved with severe PJK or PJF, that is, severe pain, neurological deficit, and progressive trunk deformity [19]. Effective factors in deciding on revision surgery in PJK include traumatic etiology, the severity of angulation, high sagittal vertical axis, and female gender [26]. Yagi et al. classified PJK/PJF into three categories, disc-ligamentous failure, bone failure, and implant-bone interface failure [27]. Failure in the thoracolumbar and lumbar is mostly due to bony fracture; however, in the upper-thoracic, it is more common with soft tissue failure and failure in the thoracolumbar region [24]. Risk factors for PJK include age, low bone mineral density, shorter instrumentation below L2, and inadequate restoration of sagittal balance [18]. In clinical outcomes measured by the Scoliosis Research Society (SRS), the pain has a strong predictive value for PJK [20], also, old age, obesity, and osteopenia can increase the risk of fracture at the top of the long segmental pedicle screw construct [7, 8]. Muscle atrophy and relative reduction of muscle mass in obese patients affect the developing PJK. Pennington et al. demonstrated para-spinal muscle size as a risk factor for PJK [28].

Risk factors for PJK are classified as patient-specific, surgical, and radiographic parameters [1, 8, 10, 17, 29].

Some PJK with minimal deformity are asymptomatic with only benign radiologic findings and deserve follow-up without any surgical intervention, but severe cases are extremely debilitating and require aggressive and extensive revision surgery. They are a common reason for returning to the operating room as well as a common source of poor postoperative outcomes. Reducing junctional complications has a potential impact on the patient's quality of life as well as the cost-effectiveness of surgery, which should not be ignored.

Protective factors to prevent PJK are discussed a lot, including soft tissue protection, cement augmentation, ligamentous augmentation, hybrid instrumentation, such as hook, and adequate selection of UIV [2, 3, 30]. In most studies, a significant reduction of PJK by gradual transitional zone at the top of the construct is observed and overall data showed that the use of hooks, tension bands, and tethers can make a softer loading zone, cre-

ate less rigidity, and in comparison, hooks are the best technique to distribute forces at the proximal end of the instrument and reduce the risk of PJK eventually [30-37]. It can improve ROM and flexibility within the UIV and make a smooth transitional zone.

On the other hand, careful selection of UIV can reduce the risk of PJK after ASD surgery [24, 31, 33].

In this study, we focus on choosing the UIV level pre-operatively and figuring out where to stop the construct and the goal is always to try to avoid stopping in the kyphotic segment. We also emphasize that stopping the UIV at the lumbar region and thoracolumbar junction level between T11 and L1 is considered a high-risk factor for developing PJK [24]. This study aims to provide attention to protective factors against developing PJK, especially two crucial aspects by careful selection of UIV, and gradual transitional zone using hooks in terms of the ROM.

Elderly people are prone to degenerative spinal disease with a wide spectrum and related complications. ASD is one crucial part of this range. In some cases, no severe situation is observed and the patient can be treated conservatively with the following methods:

1. Restriction of high physical activity
2. Getting more rest
3. Using an appropriate brace
4. Losing weight
5. Physiotherapy with the functional exercise of spinal muscles
6. Taking analgesic and osteoporotic medication such as teriparatide
7. Having a diet with more calcium and protein
8. Injections (corticosteroids) to help reduce pain and swelling [35, 37].

However, despite all these conditions, some of these patients end up with surgery, and even though many successful results for ASD surgery exist, a significant percentage of patients experience post-operative complications, the most common of which is PJK [1, 2, 5, 9]. Minimizing the risk of PJK after ASD surgery is still very challenging because different risk factors related to the

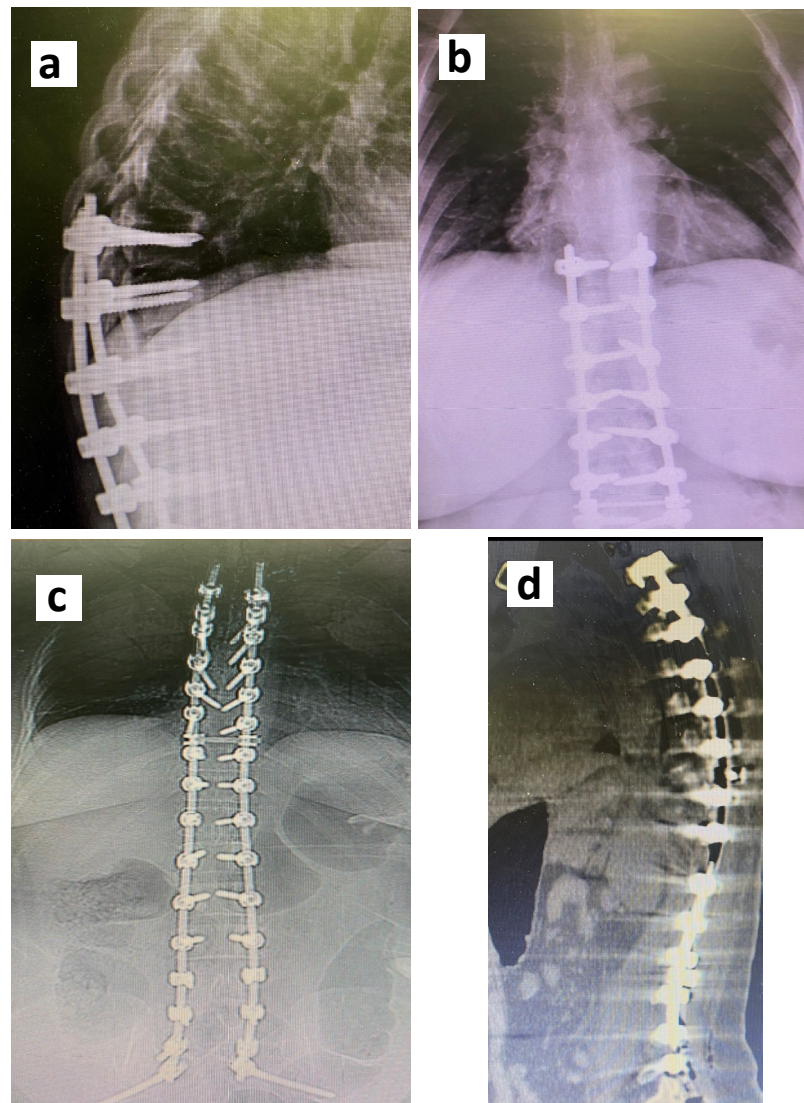


Figure 2. A 47 year-old woman, a case of PJK associated with post adult spinal deformity (ASD)-surgery

a) Lateral radiography illustration of postoperative PJK with pedicle screws in proximal end of construct, b) Antero-posterior x-ray view of same patient with PJK before revision surgery, c) Anterior-posterior (AP) full-length radiography after revision surgery with extension of instrumentation to Upper thoracic, d) Lateral computerized tomography (CT) scan of whole spine post revision surgery demonstrating good correction of deformity and Insertion of transverse process hooks at the proximal part of construct

patient-specific/surgical techniques and radiological parameters are involved [17, 29].

In this study, we reviewed protective factors to minimize the risk of PJK and focused on two crucial aspects:

- 1) Careful selection of UIV
- 2) Gradual-transitional zone on the proximal end of construct-using hooks.

1. Careful selection of UIV:

It is essential to determine the location of UIV by pre-operative planning on the x-ray, CT scan, and MRI.

Stopping the instrument in the kyphotic segment should be avoided to prevent post-operative PJK. Also, placing UIV at the thoracolumbar junction (T11 to L1) or lumbar region is more likely to develop PJK, especially in elderly patients with poor bone quality and osteoporosis [1, 24, 33].

Table 3. Level of UIV in patients with PJK

Level of UIV	No. (%)
Lower thoracic and thoracolumbar junction	4(66.6)
Lumbar region	2(33.3)

UIV: upper instrumented vertebra; PJK: Proximal junctional kyphosis.

Table 4. Types of failure in patients with postoperative PJK

Types of Failure	No. (%)
Bone failure	3(50.0)
Implant/Bone interface	2(33.3)
Disc/Ligamentous failure	1(16.6)

PJK: Proximal junctional kyphosis.



2. Gradual-transitional zone on the proximal end of instrumented construct:

Many studies have been conducted to gradually reduce the forces on the top of the instrumentation using hooks and diminish the stiffness between rigid-instrumented-spine and mobile-non-instrumented-spine on the top [36, 37].

Almost any smooth passage from the fused spine to the mobile unfused spine on the top decreases the risk of PJK post-operatively, thus even though pedicle screw fixation gives us a better fusion system, but still ends up with significant motion at the top of the construct and eventually leads to disruption of posterior ligamentous complex, instability and eventually PJK [33-35].

In these patients, most flexibility of the spine ends up just above UIV and as a result, the patient fails at the top.

By using hooks, we share loading on the top of the construct and distribute the forces by gradually transitioning toward the mobile segment above the UIV. Most studies in this field exist and this challenge still needs more research.

5. Conclusion

We studied ASD patients who needed revision surgery for the prevalence of common complications and the development of PJK as the most common complication as well as the most common cause of revision surgery. In our study, 40% of patients with ASD who needed revision surgery suffered from PJK. We also found out that

in the majority of these PJK patients, UIV was placed in the lower thoracic or thoracolumbar junction or lumbar area. Besides, in patients with PJK, no gradual transitional zone in the proximal part of the construct is observed and more studies are needed to show using hooks either transverse process hooks or sub-laminar hooks for making smooth passage on the proximal end of the construct and reducing risk for PJK.

Ethical Considerations

Compliance with ethical guidelines

This article is a review with no human or animal samples.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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