# Proximal Junctional Kyphosis and Proximal Junctional Failure

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**KEYWORDS**

• Proximal junctional failure • Proximal junctional kyphosis • Complications • Spine deformity

**KEY POINTS**

- Proximal junctional failure should be distinguished from proximal junctional kyphosis, which is a recurrent deformity with limited clinical impact.
- Proximal junctional failure is a significant complication following adult spinal deformity surgery with potential for neurologic injury and increased need for surgical revision.
- Risk factors for proximal junctional failure include age, severity of sagittal plane deformity, and extent of operative sagittal plane realignment.
- Techniques for avoiding proximal junctional failure will likely require multiple refinements in perioperative and surgical strategies.

## BACKGROUND AND DEFINITIONS

Proximal junctional kyphosis (PJK) is a recognized complication for patients undergoing posterior segmental instrumented fusion for spinal deformity.[1–5] However, descriptions of criteria for defining PJK, its incidence and clinical impact, and the basis for its development vary in the literature. Measured radiographically with a sagittal view, PJK has traditionally been defined by a 10° or greater increase in kyphosis at the proximal junction as measured by the Cobb angle from the caudal endplate of the uppermost instrumented vertebrae (UIV) to the cephalad endplate of the vertebrae 2 segments cranial to the UIV. This was the measurement used by Glattes and colleagues[1] and proved reliable in a study by Sacramento-Dominguez and colleagues[6] testing the reproducibility of different methods of measuring PJK.

Several investigators have reported that PJK according to the definition mentioned earlier does not generate significant clinical or quality-of-life issues.[1,4] In general, PJK is often well tolerated and does not lead to revision surgery in most cases.[7] Yagi and colleagues[8] reported that 4 of 32 PJK patients underwent additional surgery because of local pain but found no significant differences in Scoliosis Research Society (SRS) or Oswestry Disability Index (ODI) scores at final follow-up. Kim and colleagues[7] found no significant differences in clinical outcomes with SRS scores except in the self-image domain when PJK was greater than 20°. Similarly, no differences in clinical outcomes were found among PJK patients in the studies of Glattes and colleagues[1] and Hyun and Rhim.[9] Collectively, these reports support the idea that PJK defined radiographically amounts really to recurrent deformity, which is both infrequently associated with revision surgery and has a limited impact on clinical outcomes (**Fig. 1**).

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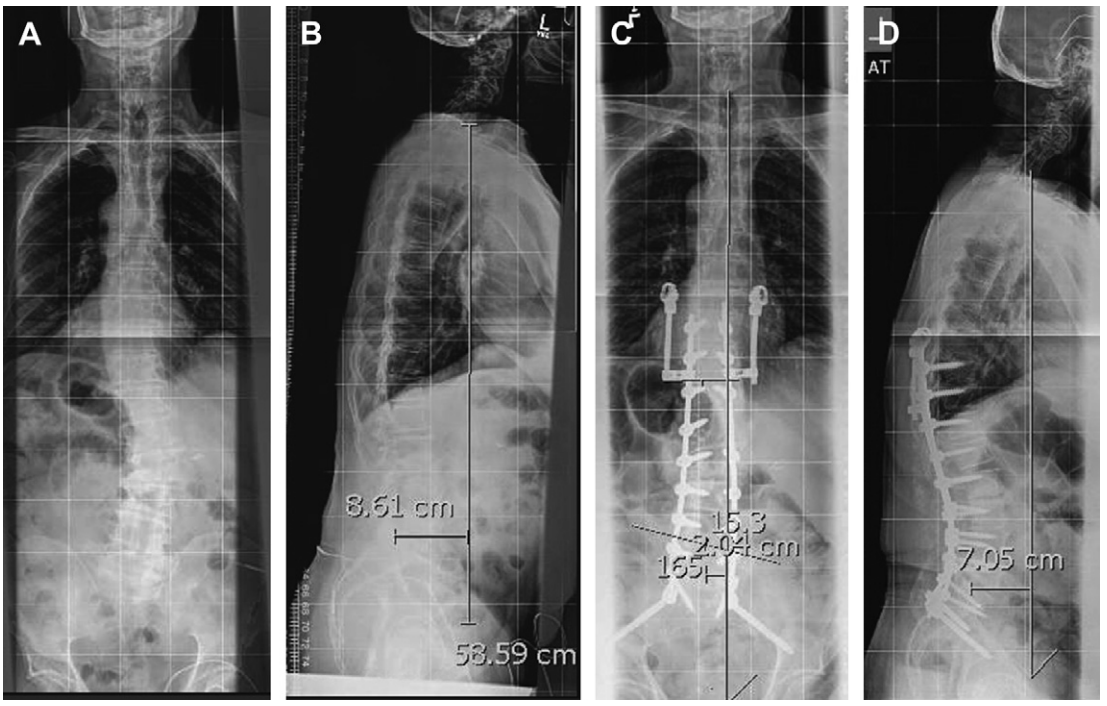


**Fig. 1.** (*A*, *B*) Posteroanterior (PA) and lateral full length views of a 77-year-old man with a history of 3 lumbar laminectomies, with persistent complaints of sciatica, low back pain, and sagittal imbalance. Preoperative lumbar lordosis is 43°, thoracic kyphosis is 27°, and junctional kyphosis (T8–T10) is 2°. Pelvic incidence measures 44°. (*C*, *D*) PA and lateral full length views following posterior instrumented fusion from T10-pelvis. Prophyllactic stabilization of T9 rib without fusion has been performed. Anterior diskectomy and fusion from L2-S1 was performed as a separate stage 6 weeks postoperatively. Postoperative lumbar lordosis is 53° (PI-LL = −9°), thoracic kyphosis has increased to 44°, and junctional kyphosis (T8–T10) has increased to 17°, meeting the definition of PJK. Patient was asymptomatic at the junction of his construct and was delighted with his clinical outcome.

Despite these relatively benign reports, other investigators have recognized that there is a subset of patients with a more severe version of PJK, which does seem to increase need for revision surgery and even carries a risk of neurologic deficit in addition to increased deformity and pain. This phenomenon has been variously termed "topping-off syndrome," proximal junctional acute collapse, or fractures of the vertebrae at the top of long pedicle screw constructs.[2,10–14] More recently, the term proximal junctional failure (PJF) has been proposed to distinguish between junctional kyphosis because of structural failure and more common, but less severe, PJK.[15–17]

The definition and classification of PJF is ongoing. *Hart* and colleagues[12] (2008) offered a definition of proximal junctional acute collapse as a failure of greater severity based on the clinical impact of the fracture. Similarly, Watanabe and colleagues[2] described a group of patients with fractures above pedicle screw constructs, which resulted in greater clinical effect but did not offer a clear definition of the phenomenon, and did not describe cases that resulted more from soft tissue failure than from fracture. Finally, although Yagi and colleagues[8] provided a classification of PJK, their description included less severe cases with deformity as opposed to mechanical failure, and ultimately concluded that PJK has limited clinical impact.

Increasingly, the phenomenon of PJF has been distinguished from PJK in that it includes not only an increase in kyphosis but also structural failure of either the UIV or the vertebra immediately proximal to the fusion construct (UIV +1).[15–17] Structural failure is considered a vertebral body fracture, disruption of the posterior osseo-ligamentous complex, or both. Unlike traditionally defined PJK, PJF has been clearly shown to be associated with higher morbidity including increased pain, spinal instability, risk of neurologic injury, and need for revision surgery.[15–17] PJF is thus defined as a change of more than 10° of kyphosis between the UIV and the vertebra 2 levels above the UIV (UIV +2), along with one or more of the following: fracture of the vertebral body of UIV or UIV +1, posterior osseo-ligamentous disruption, or pull-out of instrumentation at the UIV (**Fig. 2**).

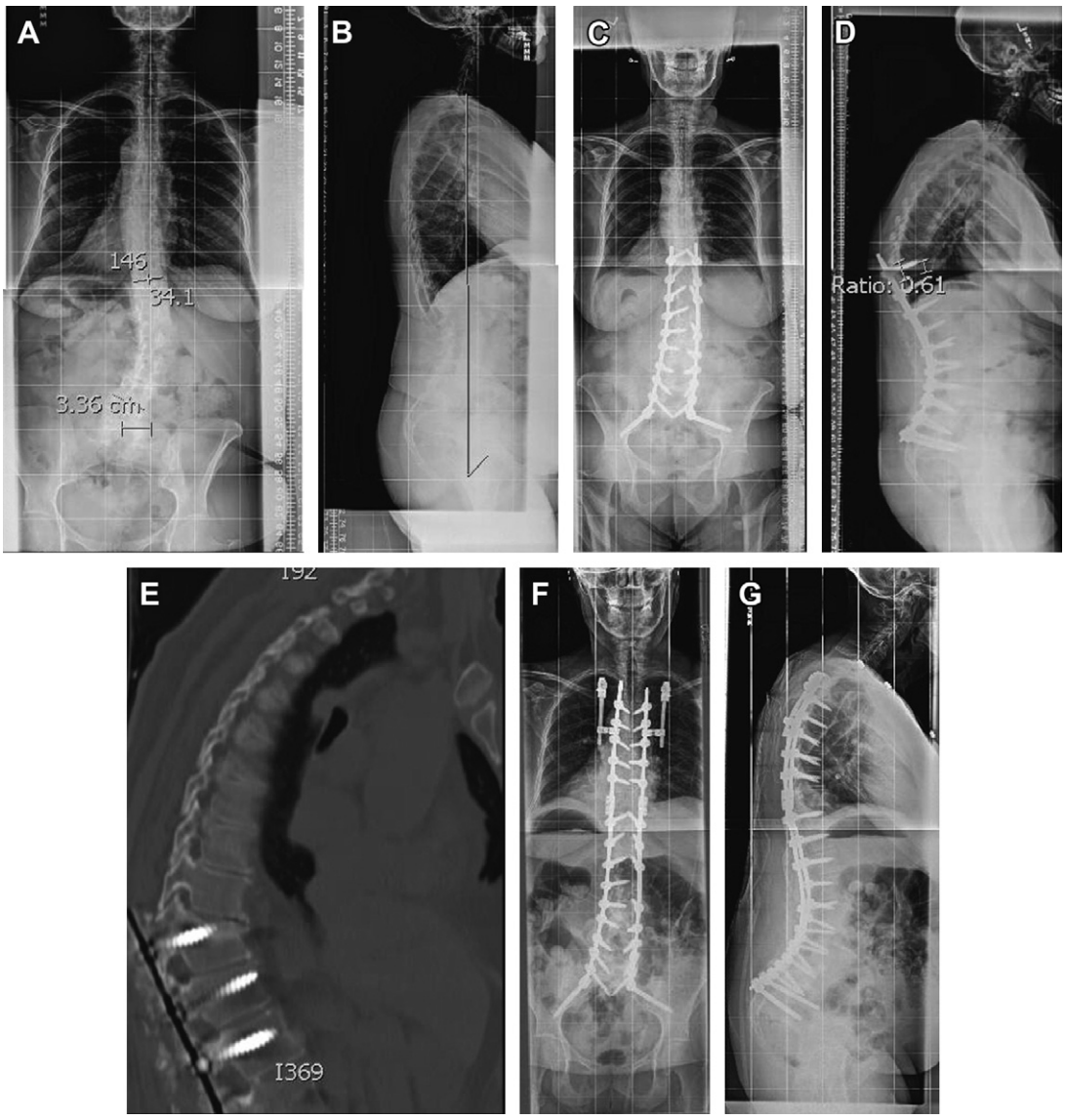


**Fig. 2.** (*A*, *B*) Posteroanterior and lateral full length radiographs of a 61-year-old woman with progressive symptoms of spinal stenosis and scoliosis. There was no history of prior surgery, and bone density was normal. Preoperative lumbar lordosis is 68°, thoracic kyphosis is 65°, and junctional kyphosis (T8–T10) is 11°. Pelvic incidence measures 75°. (*C–E*) Six week postoperatively from T10-pelvis instrumented fusion with transforaminal lumbar interbody fusion at L4/5 and L5/S1, she demonstrated a fracture of T10 vertebral body with disruption of the posterior tension band, although nondisplaced. She was symptomatic with significant axial pain and was quite bothered by the junctional kyphosis. Immediate postoperative radiographs had shown lumbar lordosis of 79° (PI-LL = −4°), thoracic kyphosis of 71°, and junctional kyphosis of 16°. Thus her immediate postoperative films did not display PJK despite early reciprocal increase in thoracic kyphosis and good matching of lumbar lordosis to pelvic incidence. (*F*, *G*) At 3 months postoperatively she underwent extension of the fusion to T4 with a Smith-Petersen osteotomy at T9–10 and prophylactic rib fixation at T3 without fusion. Early postoperative results from her revision surgery have been encouraging.

## PREVALENCE AND RISK FACTORS FOR PJK AND PJF

With respect to the prevalence of PJK and PJF, it is important to assess the timing of occurrence of these events. Kim and colleagues[7] found that the development of PJK was most frequent in the first 8 weeks after surgery, representing 59% of total kyphosis progression; however, it was also noted that after 2 years, the progression

was also substantial with 41% of total progression. In a study on adolescent idiopathic scoliosis (AIS) correction and PJK with average age of 14.3 years and an average 11.6 levels fused, Kim and colleagues[5] reported a prevalence of 50/193 (26%). PJK did not progress significantly from 2 to 7.3 years average final follow-up period. It thus appears that the most dramatic progression of PJK occurs early in the postoperative period.

Several studies have analyzed the incidence of PJK after instrumented spinal fusion operations for adolescent idiopathic scoliosis, Scheuermann kyphosis,[4,14,18–22] and adult spinal deformity[1,7,9,23–25] as well as risk factors for the complication. With respect to adult patients, Kim and colleagues[7] investigated prevalence of PJK at a minimum 5-year follow-up following segmental posterior instrumented fusion of 5 or more vertebrae in 161 adults. They found a prevalence of 62/161 (39%). The same study also found age over 55 years to be a significant risk factor for development of PJK as well as a combined anterior/posterior fusion versus an isolated posterior approach. As described earlier, patients in this study had no significant differences in their clinical outcomes as measured by SRS-22 except in the self-image domain when PJK was greater than 20°.[7]

Glattes and colleagues[1] reported a lower PJK prevalence of 21/81 (26%) in their study, which retrospectively examined 81 adults with a minimum of 6 levels fused posteriorly with an average follow-up of 5.3 years. Again there were no differences in SRS-24 outcome scores and also no identifiable risk factors for the complication. Hyun and Rhim[9] investigated the clinical outcomes of pedicle subtraction osteotomy and found 3 of 13 patients (23%) with PJK on a 3-year follow-up although again no effects of PJK on clinical outcome scores were found. Mendoza-Lattes and colleagues[24] analyzed 54 adult patients undergoing spinal deformity surgery with an average follow-up of 26.8 months in a retrospective case-control study. They found a PJK prevalence of 19/54 (35%), with risks for PJK including a smaller difference in magnitude between lumbar lordosis and thoracic kyphosis (measured as LL-TK) at baseline and early postoperatively. In a retrospective case series of 157 adult scoliosis patients undergoing long fusion (>5 vertebrae) by Yagi and colleagues,[8] the PJK prevalence was 32/157 (20%), with an average follow-up of 4.3 years. These investigators also reported no differences in SRS and ODI outcomes scores, although 4 patients did undergo additional surgery due to local pain. They reported fusion to the sacrum and posterior fusion with segmental instrumentation risk factors for PJK and felt that the incidence of PJK could be minimized with normal sagittal global realignment postoperatively.[8]

The common theme among these studies suggesting limited clinical impact of PJK is that they combine PJF with PJK patients and typically do not have a PJF cohort of sufficient size to make stronger statistical statements. Although several of the investigators have commented on the more significant impact on patients of PJF, the data of single-center studies have not allowed a more detailed analysis of PJF as a distinct entity. Despite the commonality of increased proximal kyphosis shared by both PJK and PJF, it appears that PJF represents a separate phenomenon with a substantial clinical impact in patients suffering this complication and thus deserves separation from analyses of PJK.

## PJF VERSUS PJK: MECHANICAL FAILURE AS OPPOSED TO RECURRENT DEFORMITY

The underlying pathology of PJF appears to be an acute event rather than a progressive deformity. Some cases of PJK may develop from similar structural issues. For example, Hollenbeck and colleagues[20] focused on adolescent patients and postulated that PJK was due to posterior ligament disruption and muscular support. Rhee and colleagues[22] also support this claim in a study focusing on adolescents, which found an increased incidence of PJK with posterior instrumentation compared with an anterior approach. They hypothesized that PJK is at least partially a result of damage to the posterior tension band from surgery, deformity correction forces applied during surgery, and a resulting compensation for reduced kyphosis in the thoracic region.

Denis and colleagues[18] expands on the idea of soft tissue injury during surgery in their study of patients undergoing posterior instrumentation for Scheuermann kyphosis. In 67 patients with an average age of 37 years and a PJK prevalence of 20/67 (30%), they reported that 3/20 were attributable to ligamentum flavum damage and an additional 2 were due to a combination of ligamentum flavum trauma and failure to incorporate the proximal end vertebrae. Helgeson and colleagues[19] draw a similar conclusion in their study examining PJK after AIS corrective surgery comparing pedicle screw only (n = 37), hook-only (n = 51), hybrid (n = 177), and pedicle screws with hooks at the UIV (n = 18) in a sample of 283 adolescent patients. A significant increase in PJK was found with the screw-only patients compared with both the hybrid and hook-only groups.[19] It thus seems that some juvenile PJK may result from structural injury and that the stronger correction forces

applied with pedicle screw constructs may also increase the impact on adjacent segments. Given this, the overlap in definition and description is perhaps not surprising.

With respect to adult patients, Watanabe and colleagues[2] also studied the effects of segmental pedicle screw constructs on the incidence of proximal vertebral fracture in 10 adult spinal deformity patients. It was conjectured that the vertebral body fractures were at least in part because of the mechanical stress generated by pedicle screw instrumentation at the proximal junction, especially with inclusion of the sacrum.[2] Yagi and colleagues[8] also found that fusion to the sacrum and segmental posterior instrumentation were risk factors for PJK in their adult study. Both of these reports support the idea that correction force, and possibly surgical dissection, contribute to PJK and PJF in adults as well as adolescents.

Several preoperative risk factors have consistently emerged among adult deformity patients. These include age and preoperative sagittal malaignment.[1,2,7–10,15,16] Hart and colleagues[16] reported a multicenter comparison of adult deformity patients experiencing PFJ with a large prospective cohort of non-PJF patients. Age-matched and procedure-matched control groups were developed. Besides age, they found that several measures of preoperative sagittal imbalance correlated strongly with development of PJF, including increased sagittal vertical alignment (SVA), increased mismatch of pelvic incidence with lumbar lordosis (LL-PI), and increased thoracic kyphosis.

Concordant with the preoperative sagittal malalignment of patients at highest risk for PJF is the demonstration that patients undergoing greater sagittal realignments are also at higher risk of PJF.[2,8,15,16] In this regard, the analysis by Hart and colleagues[16] showed that adult patients experiencing PJF underwent a greater number of pedicle subtraction osteotomies, and had greater corrections of SVA, greater increases in lumbar lordosis, and greater reduction in the difference between pelvic incidence and lumbar lordosis (LL-PI). This is consistent with the findings of prior investigators.[2,8]

Most importantly from a clinical perspective is increasing evidence that patients with PJF do suffer a worsened clinical course than patients without this complication. Hostin and colleagues[15] reported a retrospective consecutive case review of 1218 adult deformity surgeries, with 68 cases of PJF identified (5.6%). Twenty-eight of the 68 patients underwent revision surgery within 6 months of the index operation. Patients undergoing revision surgery were identified with PJF on average of 9 weeks after index, in comparison to 13 weeks for patients who did not undergo revision, again demonstrating the impact of mechanical failure as opposed to recurrent deformity.[15] The results of the cohort comparison by Hart and colleagues[16] further validated the concept that PJF results in a higher rate of revision surgery in the early postoperative course after adult deformity reconstruction.

Given the frequent need for extension of instrumentation proximal to junctional failures, the occurrence of PJF has clear clinical significance. From a clinical standpoint, revisions subject the patient to additional risks of perioperative and postoperative complications and hospitals and payers to greater economic costs. Given the expected increase in frequency of surgical reconstruction for patients with adult spinal deformity, efforts at defining and ultimately preventing PJF appear warranted.

## SUMMARY

Although several studies have reported incidence and risk factors for PJK, understanding of risk factors and means of prevention of PJF remains incomplete. Most patients experiencing PJF develop the complication in the early postoperative period, resulting from a combination of reciprocal kyphosis in the unfused portions of the spine, increased loads in the mobile segments adjacent to the fusion, and surgical trauma to soft tissues at the proximal junction. PJF appears to be increasing in incidence, due perhaps both to increasing numbers of older patients undergoing extended spinal reconstruction, as well as changes in surgical techniques producing more substantial spinal realignment and greater construct stiffness. Although some patients with PJF may be successfully followed without intervention, there is a consistent relationship between development of PJF and a need for early revision surgery. Further efforts to define this complication, and more importantly to reduce its incidence, remain an important goal for adult spinal deformity surgeons.

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