

Proximal Junctional Failure

A patient guide

In brief: Proximal junctional failure, usually shortened to PJF, is the severe, structural form of a problem that can develop at the top of a long spinal fusion. After a stretch of the spine has been instrumented and fused with screws and rods, the join between the rigid fused segment and the mobile spine above it becomes a stress point. When that junction merely tips forward into a little extra forward curve on the X-ray, without breaking, the term used is proximal junctional kyphosis, or PJK, and it is often silent and harmless. Proximal junctional failure is the opposite end of that spectrum: an actual mechanical breakdown at the junction, in which the topmost fixed vertebra or the one just above it fractures, the bone-and-ligament hinge at the back tears, the screws pull out, or one vertebra slips on another, sometimes with pressure on the nerves. It is a structural failure rather than a radiographic angle, it tends to cause symptoms, and it commonly needs further surgery to put right.

What proximal junctional failure is (and why the top of a fusion is vulnerable)

To understand proximal junctional failure it helps to picture what a long spinal fusion does. In the treatment of adult spinal deformity, such as scoliosis or a forward-stooping posture, a surgeon may join together many vertebrae with pedicle screws and rods, often reaching down to the sacrum or pelvis. The fused length becomes a single rigid beam. Above the highest screwed vertebra, known as the upper instrumented vertebra or UIV, the spine remains mobile and flexible as normal. The point where the stiff construct meets the supple spine above is the proximal junction, and it is here that the trouble arises.

The reason is mechanical. Whenever a rigid structure is bolted to a flexible one, the boundary between them concentrates stress. Every time the body bends forward, the load that the long lever of the fused spine generates is delivered abruptly to the first free segment above the metalwork. The vertebra at the top of the construct, and the disc, ligaments and joints just above it, must absorb a sudden change in stiffness. Over time, or sometimes quite suddenly, that concentrated load can exceed what the bone and soft tissues can bear, and the junction gives way. This is the essential idea behind proximal junctional failure: it is a failure of the transition zone at the top of a fusion, driven by the way load is handed from rigid metal to living, moving spine.

This vulnerability is not a sign that anything was done wrongly. It is an inherent consequence of fusing a long segment of spine, and it is one of the most studied complications in deformity surgery precisely because the junction is, by its nature, a weak link. Much of modern deformity practice is concerned with softening that transition so that the handover of load is gradual rather than abrupt.

Proximal junctional kyphosis versus proximal junctional failure — why the distinction matters

The single most important idea in this whole subject is the difference between proximal junctional kyphosis, PJK, and proximal junctional failure, PJF. They are often spoken of together, and they sit on the same spectrum, but they are not the same thing, and confusing them leads to a great deal of unnecessary alarm.

Proximal junctional kyphosis is a ****radiographic measurement****. It is defined, by criteria set out by Glattes and colleagues in 2005, as a forward angle at the junction of at least ten degrees, measured between the top fixed vertebra and the vertebra two levels above it, and at least ten degrees greater than it was before surgery. That is all PJK is: an angle on an X-ray that has increased beyond a threshold. Crucially, PJK is ****frequently without symptoms****, is ****often non-progressive****, and in many studies the patients who have it report quality-of-life scores no different from those who do not. Reported rates of PJK vary widely, from roughly one in ten to nearly

two in five, partly because different studies use different angle thresholds. In a large proportion of cases it is simply observed.

Proximal junctional failure is a **mechanical, structural event**. It is not merely a bigger angle. PJF means that something at the junction has actually broken or come apart: a fracture of the upper instrumented vertebra or the vertebra just above it, a tearing of the posterior bone-and-ligament complex at the back of the spine, a pulling-out of the screws from the bone, a slip of one vertebra on another, and in some cases pressure on the spinal cord or nerve roots. Because something has physically failed, PJF tends to cause pain and deformity, it can progress, and it **commonly requires revision surgery** to extend and rebuild the construct. Hart and colleagues, working with the International Spine Study Group, formalised this in 2013 by defining PJF as proximal junctional kyphosis together with at least one of fracture, posterior ligamentous disruption, or implant pull-out, and they devised a severity scale taking account of pain, neurology, instrumentation and the level involved.

The practical message is that PJK is an angle that is usually watched, whereas PJF is a failure that usually must be acted upon. The same junction can show a harmless increase in curve in one person and a structural collapse in another, and telling the two apart is central to deciding what, if anything, needs to be done.

How PJF differs from adjacent segment disease

A second distinction is worth drawing, because proximal junctional failure is sometimes confused with adjacent segment disease, which is a different problem with a different time-course. Adjacent segment disease refers to the gradual wearing out of the mobile segment next to a fusion, the disc thinning, the joints becoming arthritic and the canal narrowing, over a period of years, as the segment shoulders extra work that the fused part no longer shares. It is a degenerative process, slow and cumulative, and it tends to declare itself long after the original operation.

Proximal junctional failure is, by contrast, an acute or subacute **structural collapse**. It is not the slow grinding of degeneration but a mechanical breakdown of bone, ligament or fixation under concentrated load, and much of it happens within months of surgery rather than years. The two can both occur at the top of a construct, but the mechanism, the timing and the management are different: adjacent segment disease is degeneration, while proximal junctional failure is failure. Keeping them separate avoids treating a structural emergency as if it were ordinary wear, or vice versa.

When it tends to happen — early-onset failure

The timing of proximal junctional failure is one of its most striking features and one of the clearest ways it differs from both PJK progression and adjacent segment disease. PJF tends to occur **early**. Several published series report that the failure declares itself at a median of around three months after the original surgery, with much of it occurring within the first three to six months, although later presentations also occur, with some cohorts reporting a median nearer a year. The acute fracture type in particular tends to appear in those first few months, while the bone is still adapting to its new mechanical role.

This early window is the reason that careful follow-up in the months after long deformity surgery is emphasised so heavily in the literature, and why repeat imaging is often arranged during that period. A junction that is failing structurally will usually show itself within that early phase, and recognising it promptly is part of why the distinction between a benign angle and a true failure is taken so seriously. None of this describes any individual's course, which is a matter for the treating team, but the general pattern of early onset is well established.

The mechanisms of failure — fracture, ligament and implant

Proximal junctional failure does not happen in a single way. The literature recognises three principal modes of failure, and which one occurs depends partly on where the top of the construct sits and partly on the quality of the bone.

The first mode is **acute bony failure**, a fracture of the upper instrumented vertebra or the vertebra immediately above it. The vertebra collapses, usually in a flexion or compression pattern, and the spine above tips forward. This is the commonest mode when the top of the construct lies in the lower thoracic or thoracolumbar region, and it is strongly associated with weakened, osteoporotic bone. A fracture of this kind can, in severe cases, drive fragments of bone backwards towards the spinal canal.

The second mode is **ligamentous or soft-tissue failure**, a tearing of the posterior osseoligamentous complex, the bone-and-ligament hinge at the back of the spine made up of the ligaments between and over the spinous processes, the ligamentum flavum and the joint capsules. When this hinge gives way, the junction loses its restraint and falls into kyphosis. This mode is more often seen when the top of the construct lies in the upper thoracic spine.

The third mode is **implant or interface failure**, in which the fixation itself fails: the pedicle screws pull out of the bone, a hook cuts out, or the bone around the metalwork crumbles. This is again more likely in poor-quality bone. In practice the three modes overlap, and a single failure may combine a fracture with ligament disruption and a slip of one vertebra on another. Yagi and colleagues captured this in a classification that sorts failures by mode, by the degree of kyphosis, and by whether one vertebra has slipped forward on another.

Risk factors

The risk factors for proximal junctional failure are well described, and they fall into three groups: the patient, the shape of the spine and the surgery itself.

Among **patient factors**, the most consistent is **bone quality**. Osteoporosis and osteopenia stand out across the literature as the strongest structural risk for PJF, with one body of work reporting failure in around one in five osteoporotic patients against fewer than one in fifteen of those with stronger bone. Older age, frailty, loss of muscle bulk and a higher body weight are also recognised contributors, because each places more demand on the junction or leaves it less able to cope.

Among factors relating to the **shape of the spine and the correction performed**, two themes recur. One is the size of the deformity being corrected: a spine that started badly out of balance, with a large forward lean, carries more risk. The other, perhaps counter-intuitively, is the **magnitude of the correction itself**. A large correction, and in particular an **over-correction** that swings the spine further than is ideal for the patient's age, concentrates stress at the top of the construct and raises the risk of failure. Tellingly, the literature shows that failure can occur even when an apparently ideal, age-adjusted alignment has been achieved, which underlines that alignment is not the whole story and that bone quality and the abruptness of the transition matter just as much.

Among **surgical and construct factors**, ending the fusion at the sacrum or pelvis, using rigid pedicle screws at the very top of the construct rather than a softer fixation, performing major osteotomies, and the choice of where to end the construct, the selection of the upper instrumented vertebra, all influence the risk. Ending the construct at a level that is already tipping into kyphosis is recognised as particularly hazardous.

The neurological dimension

One of the features that most sharply separates proximal junctional failure from ordinary proximal junctional kyphosis is that PJF can, in some cases, threaten the nerves. Because PJF involves real structural movement, a fracture, a slip, or a sharp kyphotic collapse, it can narrow the canal and press on the spinal cord or the nerve roots. The recognised consequences described in the literature range from nerve-root pain and altered sensation, through signs of spinal cord involvement such as weakness, balance disturbance and changes in hand or leg function, to, in the most severe acute failures, significant cord or cauda equina compromise from displaced bone.

This neurological potential is one of the reasons proximal junctional failure is regarded as a genuine structural problem rather than a cosmetic one, and it is one of the features that, when present, tends to move the situation firmly towards surgery. Plain proximal junctional kyphosis, by contrast, only rarely involves the nerves. The presence or absence of any neurological feature in a given person is a matter for direct assessment rather than something that can be assumed from the category.

How it is assessed

The assessment of a suspected proximal junctional failure rests on imaging interpreted against the picture before and immediately after the original surgery. Standing X-rays of the whole spine are the starting point, because they show the alignment of the junction, the proximal junctional angle, and any change from the post-operative films, and they allow the overall sagittal balance to be measured. A junction that has tipped sharply forward, or a vertebra that has visibly fractured or slipped, is apparent on these films.

Computed tomography, the CT scan, defines the bony injury in detail. It shows a fracture of the upper instrumented vertebra or the vertebra above, the integrity of the screws and their grip on the bone, and any bone displaced towards the canal, and it distinguishes a true bony failure from a soft-tissue one. Magnetic resonance imaging, the MRI scan, is the test that shows the soft tissues and, most importantly, the nerves: it reveals disruption of the posterior ligament complex, swelling within a freshly fractured vertebra, and any compression of the spinal cord or nerve roots. Where the question is whether the nerves are involved, MRI is central. Taken together, the standing films, the CT and the MRI define both the structural nature of the failure and its effect, if any, on the nerves, which is what determines how it is managed.

What the evidence shows about prevention — impersonal

A great deal of the modern literature on proximal junctional failure is concerned with prevention, because a junction that never fails is far better than one that has to be revised. It should be said plainly that the evidence here rests largely on cohort studies, biomechanical experiments and consensus rather than on large randomised trials, so the measures described are reported associations and engineering rationale rather than guarantees, and decisions are individualised. What follows describes what the literature reports, not guidance for any person.

The central theme of prevention is **softening the transition** so that load is handed from the rigid construct to the mobile spine gradually rather than abruptly. Several approaches towards this are described. **Cement augmentation**, in which bone cement is placed into the top one or two vertebrae of the construct, is reported in a number of cohorts and a meta-analysis to reduce failure and revision, particularly in weakened bone, although some studies are more cautious about how reliably two-level augmentation prevents complications. **Ligament or tether augmentation**, in which a flexible band of tape or suture is threaded across the top vertebrae and tensioned to the rod, aims to create a graded zone of movement; a large case series reported less proximal junctional failure with this technique, and biomechanical work shows it produces a smoother gradient of stiffness and lower disc pressure than rigid screws alone. Using **softer fixation at the top of the construct**, such as hooks or tapes rather than rigid screws at the uppermost level, follows the same logic.

Beyond the hardware, the literature emphasises **gentler, matched correction**, aiming for alignment appropriate to the patient's age rather than over-correcting to the alignment of a young adult, and avoiding excessive backward

tilt at the thoracolumbar junction. It emphasises **bone-health optimisation**, the assessment and treatment of osteoporosis around the time of surgery, given how central bone quality is. And it emphasises careful **selection** of the upper instrumented vertebra, choosing a level that is stable rather than one already tipping into kyphosis. None of these is presented as a single solution; rather, the evidence describes a multimodal approach in which several measures together reduce, though they do not abolish, the risk.

What the evidence shows about management — impersonal

When proximal junctional failure has occurred and is unstable, progressive, or pressing on the nerves, the literature describes revision surgery as the usual treatment, and the principle is straightforward: the failed junction is bypassed by **extending the construct upwards** to a new, higher and more stable level, re-establishing a sound load path above the point of failure. In effect, a new top is built above the one that gave way.

The detail depends on the failure. Where the junction has collapsed into a fixed forward bend, the extension is commonly combined with **focal correction** of that kyphosis, achieved through osteotomies that release and realign the spine at the junction, ranging from posterior column osteotomies to, where the deformity is rigid, a larger three-column osteotomy. Where bone is displaced towards the canal and the nerves are compressed, **decompression** to relieve that pressure is undertaken alongside the fixation. Attention to bone quality and to achieving sound alignment is emphasised at revision just as it is at the first operation.

An important and sobering theme in the literature is **recurrent failure**. Extending a construct creates a new junction, which is itself a potential point of failure, and series following patients after fusion-extension surgery for proximal junctional failure report that a substantial proportion, in some cohorts approaching half, go on to develop a further failure requiring another revision. Osteoporosis and inadequate restoration of alignment are among the factors that predict recurrence. For selected failures that are stable, neurologically intact and only minimally displaced, non-operative measures may have a place, but by its nature proximal junctional failure often crosses the threshold into surgery. As with prevention, these are descriptions of what the evidence reports, within a framework of individualised, shared decision-making rather than fixed rules.

Outlook

The outlook after proximal junctional failure depends on its mode, on whether the nerves are involved, on the quality of the bone and on how well a revision re-establishes a sound and balanced construct. A failure that is recognised early, that has not damaged the nerves and that is revised into good alignment with secure fixation can do well, and many patients regain a stable spine. The principal shadows over the outlook are weakened bone and over-correction, both of which raise the risk of a further failure at the new junction, and neurological involvement, where recovery can be incomplete.

The consistent themes across the literature are that proximal junctional failure is a structural problem distinct from the often-harmless angle of proximal junctional kyphosis, that it tends to declare itself early, that bone quality and the abruptness of the transition lie at its heart, and that prevention and prompt recognition offer the best prospects. Any individual outlook is a matter for assessment by the treating team rather than something that can be read from a category alone.