Technique, challenges and indications for percutaneous pedicle screw fixation

Ralph J. Mobbs, Praveenan Sivabalan, Jane L

1. Introduction

Pedicle screw instrumentation enables a rigid construct to promote stability and fusion for numerous spinal pathologies including: trauma, tumours, deformity and degenerative disease. The safety of traditional open techniques for pedicle screw placement has been well documented; however, due to the advantages of minimally invasive surgery (MIS), demand for percutaneous pedicle screw insertion will increase. Improvements in minimally invasive instrumentation have also broadened the scope of spinal disorders that surgeons can operate on.

Percutaneous pedicle screw insertion can be an intimidating prospect for surgeons who have been trained in open techniques only. The initial change has a steep learning curve; however, there are several basic principles that can assist the surgeon in safe placement of the Jamshidi needle into a thoracic or lumbar pedicle.

2. Open versus minimally invasive surgery

Conventional open spine surgery has several reported limitations including extensive blood loss, post-operative muscle pain and infection risk. The paraspinous muscle dissection involved in open spine surgery (Fig. 1) can cause muscular denervation, increased intramuscular pressure, ischaemia, necrosis and revascularisation injury resulting in muscle atrophy and scarring, often associated with prolonged post-operative pain and disability. Spinal fixation utilising muscle-dilating approaches (Figs. 1 and 2) to minimise surgical incision length, surgical cavity size and the amount of iatrogenic soft-tissue injury associated with surgical spinal exposure, without compromising outcomes, is thus a desirable advancement.

No published articles of high-quality show that MIS is superior to open spinal surgery; however, there is a trend towards MIS of the spine due to lower complication rates and approach-related morbidity, with minimal soft tissue trauma, reduced intra-operative blood loss/risk of transfusion, improved cosmesis, decreased post-operative pain and narcotic usage, shorter hospital stays with faster return to work and thus reduced overall health care costs. Despite this, some reports believe that minimally invasive fusion techniques for complex spinal surgery and support these with descriptions of illustrative patients.

Abstract

Minimally invasive techniques in spinal surgery are increasing in popularity due to numerous potential advantages, including reduced length of stay, blood loss and requirements for post-operative analgesia as well as earlier return to work. This review discusses guidelines for safe implantation of percutaneous pedicle screws using an image intensifier technique. As indications for percutaneous pedicle screw techniques expand, the nuances of the minimally invasive surgery technique will also expand. It is paramount that experienced surgeons share their collective knowledge to assist surgeons at their early attempts of these complex, and potentially dangerous, procedures. Technical challenges of percutaneous pedicle screw fixation techniques are also discussed including: small pedicle cannulation, percutaneous rod insertion for multilevel constructs, incision selection for multilevel constructs, changing direction with percutaneous pedicle screw placement, L5/S1 screw head proximity and sclerotic pedicles with difficult Jamshidi placement. We discuss potential indications for minimally invasive fusion techniques for complex spinal surgery and support these with descriptions of illustrative patients.
3. Percutaneous placement of pedicle screws

The technique described here uses intra-operative radiography (image intensifier [II]). The senior author also uses intra-operative CT-based stereotactic guidance for pedicle screw placement; however, there is a greater degree of accuracy with the use of II for pedicle cannulation (RJ Mobbs, unpublished data). For small thoracic pedicles, the senior author only uses II due to the enhanced accuracy with this technique.

The sequence of percutaneous placement of pedicle screw insertion is described as follows (Figs. 2 and 3).

(i) Place the II in the anterior/posterior (AP) position. The spinous process should be midline between the pedicles to ensure a direct AP projection (Fig. 2a).

![Fig. 1.](https://example.com/fig1.png)

**Fig. 1.** Open versus (vs.) minimally invasive surgery (MIS) technique for pedicle screw insertion showing: (a) normal anatomy; (b) muscle retraction with traditional “open” surgery vs. (c) “tubular retractors” with percutaneous pedicle screws.

![Fig. 2.](https://example.com/fig2.png)

**Fig. 2.** Image intensifier radiographs of the percutaneous technique for pedicle screw insertion showing: (a) anterior/posterior (AP) view of the Jamshidi needle docked onto the lateral aspect of the pedicle – the “3 o’clock position”; (b) AP view of advancement of the needle 20 mm to 25 mm into the vertebral body; (c) lateral view, checking the position of the Jamshidi needle in lateral view; (d) lateral view, the K-wire and tapping of the pedicle; and (e) lateral view, insertion of the pedicle screw.

![Fig. 3.](https://example.com/fig3.png)

**Fig. 3.** Diagrams illustrating the anatomical principles of percutaneous pedicle screw insertion: views from top to bottom: (a) superior, (b) posterior, (c) lateral, (d) superior. First the initial skin incision is made with the patients’ body habitus in mind. Second, the Jamshidi needle is first “docked” onto the lateral aspect of the pedicle – “position 1” – on the anterior/posterior image intensifier (II) radiograph projection. Third, the Jamshidi needle is advanced 20 mm to 25 mm so that the needle is beyond the medial border of the pedicle and into the vertebral body – to “position 3”. Finally, the position is confirmed by lateral II radiograph projection before insertion of the K-wire.
(ii) Mark the position of the lateral aspect of the pedicle on the skin. Depending upon the depth of the tissue between skin and pedicle, the skin incision should be made laterally (Fig. 3) so that the Jamshidi needle can be angled appropriately when inserting it into the pedicle.

(iii) Place the Jamshidi needle through the skin incision and “dock” onto the lateral aspect of the pedicle (Fig. 2a). This is called the “3 o’clock” position.

(iv) Advance the Jamshidi needle 20 mm to 25 mm into the pedicle, making sure the needle remains lateral to the medial pedicle wall (Figs. 2b and 3).

(v) Position the II in the lateral plane. The Jamshidi needle should now be in the vertebral body, and therefore “safe” with no risk of medial pedicle breach (Fig. 2c).

(vi) Place a K-wire down the Jamshidi needle and place a pedicle tap down the trajectory of the K-wire (Fig. 2d).

(vii) Place the final pedicle screw with the screw placed down the K-wire in the new trajectory.

Following initial placement of the Jamshidi needle into the vertebral body, the lateral projection may demonstrate a poor trajectory that the surgeon may wish to correct. Using the pedicle tap and K-wire into a more appropriate direction, taking care to avoid bending the K-wire too much. (c) With the tap in place, the K-wire can be removed and replaced with a new, straight K-wire down the tap in the new direction.

Fig. 4. Image Intensifier lateral radiographs showing changing direction of screw placement following initial pedicle cannulation. (a) The Jamshidi needle has cannulated the pedicle and vertebral body. On review of the lateral X-ray image, the surgeon decides to re-direct the screw into a position that is more parallel with the endplate. (b) After K-wire insertion, an undersized tap can be used to force the K-wire into a more appropriate direction, taking care to avoid bending the K-wire too much. (c) With the tap in place, the K-wire can be removed and replaced with a new, straight K-wire down the tap in the new direction.

Fig. 5. Intra-operative photographs showing the use of retraction sleeves to avoid screw head proximity at L5/S1. Flexible retraction sleeves simplify the problem of screw head proximity as the retractors can easily be deflected and not “get in your way” with percutaneous pedicle screw placement. It is common at L5/S1 for the surgeon to require a single incision only as the retraction sleeves are in the same position at the skin edge. (Insert) Aerial view.

4. Challenges unique to MIS/percutaneous pedicle screw insertion

There are many technical challenges unique to the percutaneous pedicle screw insertion technique. After the surgeon is comfortable with MIS techniques for single-level degenerative pathologies, the temptation is to attempt more difficult multi-level constructs such as those required in patients with tumour and trauma pathologies.

The senior author has identified common challenges described in the following sections.

4.1. Changing direction of screw placement following initial pedicle cannulation

Following initial placement of the Jamshidi needle into the vertebral body, the lateral projection may demonstrate a poor trajectory that the surgeon may wish to correct. Using the pedicle tap will result in an acute bend in the K-wire distal to the tap. Care should be taken not to bend the K-wire too much (Fig. 4b). With the tap advanced into the vertebral body, the K-wire can be removed and then a fresh “straight” K-wire reintroduced down the tap into the new position (Fig. 4c). The pedicle screw can then be placed down the K-wire in the new trajectory.

4.2. L5/S1 screw head proximity

The percutaneous technique can be difficult at the L5/S1 level due to the L5 and S1 pedicle angulations. The percutaneous retraction sleeves can impinge on one another at skin level. The options for dealing with this common problem include either placing the S1 pedicle screw in a more inferior starting position, or to use “flexible” retraction sleeves (Fig. 5) so that the sleeves can be deflected at skin level and not impinge on each other.

4.3. Cannulation of small pedicles

The senior author has placed percutaneous pedicle screws as high as T4 in patients with tumour and trauma; however, percutaneous pedicle placement high in the thoracic spine can be technically difficult due to the small pedicle sizes in the mid-upper thoracic spine and the change in pedicle angulation at the T1 to T4 levels. The greatest challenge, however, for percutaneous placement in the thoracic spine is from small pedicles. Cannulation of small pedicles involves careful evaluation of the pre-operative CT scans and AP radiographs to ensure that the pedicle can be cannulated. The pedicle must have a width of at least 3 mm to 4 mm so that the Jamshidi needle can be navigated down the pedicle. The surgeon must have an excellent view of the pedicle prior to attempting cannulation of a small diameter pedicle. This involves small movements of the gantry of the II machine so that the II is directed in a “bull’s eye” view down the pedicle (Fig. 6). Due to the greater degree of accuracy of the II technique (Fig. 6) over stereotaxis, the senior author recommends II for small pedicle cannulation.

4.4. Skin Incision selection for multi-segmental fixation

Multi-segmental fixation procedures have numerous nuances that can make the surgeon’s life much easier. The first thought is
incision selection, as incisions that “line-up” in a straight line (Fig. 7) represent a far easier prospect for rod insertion. The qualification here is for patients who have a scoliosis, or trauma, where the pedicles may not line up in a straight line. For a single-level fixation, the rod insertion is not difficult and is usually not a problem. For multi-level fixation, a staggered line of incision points can result in a difficult rod insertion.

4.5. Insertion of a rod for multi-segmental fixation

Rod insertion for multi-segmental fixation involves the surgeon having a brief mental checklist prior to insertion. Removing the rod after an initial placement can be difficult and time consuming if the surgeon has to change the length or curvature of the rod prior to a re-insertion. The checklist includes:

(i) How long should the rod be? The length between the retraction sleeves should provide a guide to rod length.

(ii) Does the rod require bending before insertion? As a general rule, the surgeon should try to leave the pedicle screw heads at an equivalent height throughout the construct to aid with ease of rod insertion. The exception here is with trauma where a reduction manoeuvre may be required.

(iii) Initially from which end should the rod be inserted? The rod should be inserted from the end of the construct where the pedicle screw head is closest to the skin, enabling ease of insertion and navigation along the pedicle screw heads (Fig. 8).

(iv) Do I need an additional incision to insert the rod? This is usually not necessary as the rod can be inserted over many levels via the cranial incision which is usually the most superficial of the pedicle screw insertions.


Pedicles that are sclerotic or osteopetrotic (“ivory bone”) can be difficult in terms of Jamshidi placement. Advancing a Jamshidi into these pedicles can be frustrating – rarely the percutaneous...
technique needs to be abandoned and an open technique with direct cannulation of the pedicle with a high-speed drill is required (Fig. 9).

5. Indications for percutaneous pedicle screw insertion

5.1. Degenerative spine disorders

Paraspinal muscle retraction allowing adequate exposure in open procedures is a primary cause of post-laminectomy syndrome and ‘fusion disease’.11,12 Since the first endoscopic lumbar discectomy in 1991, MIS has been used to routinely treat degenerative spinal pathologies including; herniated disc removal, spinal stenosis decompression and/or fusion aiming to avoid these problems. Preliminary clinical outcomes suggest MIS is as efficacious as open spinal surgery for degenerative spinal disorders, with added advantages of reduced recovery times, pain and days to return to work. However, as the use of MIS in complex spinal surgery is only in its infancy, these favourable results are largely anecdotal and yet to be validated by long-term outcome studies.4,11

MIS fusion is indicated for mechanical lower back pain and grade I and II spondylolisthesis-associated radicular pain (Fig. 10). Higher grade spondylolistheses prove more challenging and open approaches are recommended for optimal management.14 Harris et al.’s3 comparison of 29 patients receiving single/double level posterolateral percutaneous instrumented fusion for symptomatic spondylolisthesis with published open fusion results revealed comparable improvements in pain and disability, whereas mean blood loss and operating time were significantly lower with the use of MIS (222 mL vs. 1517 mL; 141 minutes vs. 298 minutes).3

MIS is also indicated for recurrent disc herniation, pseudoarthrosis and severe discogenic lower back pain15 resulting from post-laminectomy instability or spinal trauma.14

5.1.1. Illustrative patient 1

A 73-year-old male presented with neurogenic claudication and mechanical lower back pain of 3 years’ duration. Imaging revealed severe canal stenosis at L4/5 due to spondylolisthesis, and facet joint/ligamentous hypertrophy. A midline incision and posterior lumbar interbody fusion was performed. The midline incision was closed and percutaneous screws inserted using the II technique. Blood loss was 180 mL with discharge from hospital on day 4.

5.2. Trauma

Traumatic spinal injuries are often associated with high velocity, high energy impacts, (e.g. falls, motor vehicle crashes). Early surgical intervention may prevent or potentially reverse neurological deterioration.4 Surgical management involves decompression, reduction, anterior column support if necessary, restoration of posterior tension band and fusion to prevent spinal deformity developing while providing immediate spinal stability.4,16 Current surgical spine trauma treatment is predominantly open surgery with instrumentation and fusion.16 Trauma patients, however, are at greater risk of intra-operative blood loss with infection rates of 0.7% to 10%. These vulnerabilities, along with other comorbidities and the strong likelihood of systemic injuries in spinal trauma patients, make MIS approaches highly valuable for minimising access-related morbidity.4,16

Percutaneous instrumentation with/without fusion is performed following thoracolumbar injuries for spinal stabilisation.4 Thoracic pedicle screw utilisation for degenerative and traumatic injuries is one of the newest developments in MIS; however, morbidity associated with screw misplacement in the thoracic spine is greater than for the lumbar spine as there is greater risk of spinal cord lesions, paraplegia, and fatal great vessel injury.13

Posterior MIS spinal fusion approaches such as posterior pedicle screw/rod fixation are being applied to thoracic spine fracture management (Fig. 11), providing stand-alone fixation of stable burst or flexion distraction injuries. Temporary percutaneous posterior fixation can enable mobilisation and prevent secondary injury when there is an unstable injury and complete fixation is contraindicated. Despite these developments, there are no established MIS techniques in thoracic spine trauma surgery.16

5.2.1. Illustrative patient 2

A 17-year-old male presented with a T12 American Spinal Injury Association (ASIA) – A spinal cord injury following a high velocity motorcycle accident. (a) Sagittal T2-weighted MRI showing T12 spinal injury with ASIA – A neurological deficit; (b) intra-operative photograph showing percutaneous pedicle screw fixation; (c) anterior/posterior image intensifier (II) radiograph and (d) lateral II radiograph showing stabilisation; and (e) post-operative photograph showing early mobility within 24 hours.

Fig. 11. Illustrative patient 2, a 17-year-old male who presented with a T12 American Spinal Injury Association (ASIA) – A spinal cord injury following a high velocity motorcycle accident. (a) Sagittal T2-weighted MRI showing T12 spinal injury with ASIA – A neurological deficit; (b) intra-operative photograph showing percutaneous pedicle screw fixation; (c) anterior/posterior image intensifier (II) radiograph and (d) lateral II radiograph showing stabilisation; and (e) post-operative photograph showing early mobility within 24 hours.

Fig. 10. Middle panel. Post-operative photograph of illustrative patient 1, a 73-year-old male who presented with L4/5 degenerative spondylolisthesis with neurogenic claudication. (a) Lateral image intensifier (II) radiograph showing Grade I spondylolisthesis; (b) sagittal T2-weighted MRI showing severe canal stenosis; (c) photograph at 8 weeks showing post-operative incision; (d) lateral II image showing initial midline incision and posterior lumbar interbody fusion; (e) lateral II percutaneous pedicle screw fixation pre-reduction; and (f) lateral II final radiograph showing reduction of spondylolisthesis.
motorcycle accident. Stabilisation surgery was performed the day of presentation with mobilisation and wheelchair rehabilitation within 24 hours (Fig. 11). Surgical time was 2 hours, 5 minutes with 80 mL of blood loss. The patient requested pedicle screw removal 12 months following surgery due to discomfort of the pedicle screw tulips against his wheelchair.

5.3. Spinal neoplasia

Up to 70% of cancer patients show evidence of metastatic disease at death, with 40% having spinal involvement. Improvements in systemic cancer management and imaging is expected to increase the incidence of spinal metastases detection. Metastatic spine disease arises most commonly in the thoracic spine (thoracic 70%; lumbar 20%; cervical 10%) with 10% to 20% suffering symptomatic cord compression causing neurological dysfunction and debilitating pain requiring treatment.

Studies on metastatic spinal disease show better functional outcomes following surgical decompression/stabilisation prior to radiation than radiation alone (84% vs. 57%). Surgery prolongs survival, maintains continence and reduces corticosteroids and analgesic use. Oncology patients often suffer multiple comorbidities, so efforts to reduce surgical morbidity are essential. Although treatment is often palliative, it is crucial in improving quality of life (QOL) by improving pain and ambulatory function. Thus, the advantages of MIS, including smaller incisions limiting wound complications, are crucial for maintaining/improving the QOL of cancer patients with a mean survival of only 8 to 12 months.

Another recently introduced stabilisation technique for spinal neoplasia utilises percutaneous instrumentation with cement reconstruction and/or placement of intervertebral structural grafts. The combination of increasingly available MIS management options (Fig. 12), and chemo/radiotherapy will likely improve spinal cancer treatment.

5.3.1. Illustrative patient 3

A 69-year-old male presented with progressive paraparesis and cord compression at T9. He had metastatic lung cancer with an expected longevity of less than 12 months. MIS decompression was proposed; however, stabilisation was recommended due to the anterior compression and pediculectomy/partial vertebrectomy necessary for adequate tumour resection. Surgical time was 2 hours and 35 minutes with 210 mL of blood loss and a length of stay (LOS) of 5 days. The patient remained independently mobile until his death 7 months following surgery.

5.4. Infection

Vertebral osteomyelitis is relatively uncommon, accounting for 3% of total osteomyelitis; however, its incidence worldwide is growing and it causes substantial morbidity. Osteomyelitis of the thoracic spine causes vertebral body collapse and thus spinal cord compromise or kyphosis. Surgical indications exist, although most treatment is conservative, utilising antibiotics. These indications include the need for bacterial diagnosis when other methods fail, abscess drainage, decompression of neural elements causing worsening neurological deficit, debridement of persisting infection and restoration and/or maintenance of spinal alignment and stability.

Current surgical management of osteomyelitis includes thoracotomy, corpectomy and reconstruction. Open anterior thoracic spine exposure for vertebral osteomyelitis is associated with high mortality, partly due to the frequent occurrence of vertebral osteomyelitis in the elderly, the debilitated and patients with multiple comorbidities. Thus MIS can potentially improve outcomes.

A small study of patients with pyogenic vertebral osteomyelitis, who were treated with thoracoscopic debridement, decompression and anterior fusion with no disease recurrence after two years, suggested the feasibility of MIS for vertebral osteomyelitis. Larger studies are required to further deduce whether MIS is beneficial as only small MIS studies for vertebral osteomyelitis with short-term follow-up exist.

5.4.1. Illustrative patient 4

A 47-year-old woman positive for hepatitis C and human immunodeficiency virus presented with L1/L2 osteomyelitis. The patient had developed progressive pain and leg weakness over 2 months with vertebral body collapse and gross mechanical instability at L1/L2. Open surgery was not offered due to her pre-morbid status and high-risk to the surgical team. Percutaneous stabilisation of the progressive kyphosis/vertebral body collapse was offered. Surgical time was 1 hour, 55 minutes with 120 mL of blood loss. The patient was mobilised on day 1 with significantly reduced pain scores and discharged to the infectious diseases team. Follow-up at 4 months revealed bone union across the L1/L2 interspace.
5.5. Obesity

All spinal operations prove more difficult in patients with obesity,\(^9\) and they have increased complication risks including surgical site infection following fusion. However, MIS posterior lumbar fusion is especially useful for these patients.\(^9,19\) Open posterior lumbar fusions require longer incisions to access the deeper spine in obese patients.\(^9,19\) Tubular retraction systems used in MIS, however, enable the use of similarly sized incisions for all patients. Shorter incisions minimise surgical cavity size, reduce soft-tissue trauma, and produce an instrument-only surgical field, reducing complications experienced by obese patients, including wound infections.\(^9,19\) Excessive body weight also requires longer operating times for open posterior lumbar spine fusion, but no significant difference in operative times for MIS techniques, as the greater skin to spine distance does not require additional dissection time when using minimally invasive tubular retractor systems.\(^9,19\) These advantages indicate the use of MIS in obese patients (Fig. 14).

5.5.1. Illustrative patient 5

A 59-year-old male presented with mechanical back pain, unilateral L5 radiculopathy due to lateral recess stenosis and an elevated body mass index. MIS–transforaminal lumbar interbody fusion (TLIF) was recommended to avoid a lengthy incision and prolonged hospital stay. Surgical time was 4 hours and 50 minutes with 240 mL of blood loss. LOS was 3 days. Frameless stereotaxis was used to assist with percutaneous pedicle screw placement.

5.6. Revision surgery

Revision surgery is often more technically challenging because of local scarring and greater complication rates such as nerve root injury and incidental durotomy. Along with altered anatomy, absent bony landmarks and limited surgical exposure, it is no surprise that surgeons avoid MIS approaches for revision surgery.\(^8,9\)

Lumbar interbody fusions are indicated for revision surgery of recurrent disc herniation and post-laminectomy instability. Selznick et al.’s study\(^6\) of 43 patients who underwent minimally invasive posterior lumbar interbody fusion (PLIF) or TLIF, compared the outcomes following primary surgery to revision surgery at a prior operative level. The primary surgery group consisted of 26 patients undergoing operations for degenerative spondylolisthesis and spondyloysis, degenerative scoliosis. The revision surgery group consisted of 17 patients with the primary indications for the surgery being post-laminectomy instability and multiple recurrent disc herniations. They concluded that minimally invasive lumbar interbody fusion is a possible option for revision surgery, without significantly higher rates of blood loss, transfusion, infection or neurological complications compared to primary surgery. However, minimally invasive revision lumbar interbody fusions had significantly higher complication rates, with the risk of inadvertent durotomy and cerebrospinal fluid (CSF) leak approximately six times higher than in the primary surgery cohort. All CSF leaks were fixed intra-operatively without developing into a pseudomeningocele or requiring further surgery.\(^6\)

It is recommended that surgeons gain substantial experience with MIS techniques of primary patients, before attempting minimally invasive revision interbody fusion of the lumbar spine.\(^8,9\) Surgeons attempting minimally invasive revision surgery (Fig. 15) should also be ready to convert to wider exposures if necessary, for safe exposure of the relevant spinal region.\(^9\)

5.6.1. Illustrative patient 6

A 48-year-old male presented with ongoing back pain and evidence of a non-union following a L5/S1 stand-alone posterior lumbar interbody fusion (PLIF). (Fig. 15) A lateral image intensifier (II) radiograph showing pedicle screw fixation and posterolateral graft. (b, c) Intra-operative photographs showing completion of procedure prior to removal of tubular dilators. (d) Post-operative photograph at 10 weeks showing previous midline incision and bilateral revision fixation using minimally invasive surgery.

5.7. MIS grafting

Autografts involve transferring bone within the same individual.\(^20\) Throughout the 1990s, as spinal fusion rates rose, bone graft
harvests were most commonly used for spinal arthrodesis. With fusion, the gaps between host bone and graft fill via new bone formation and with more bone deposition and remodelling on the osteoconductive matrix, segmental stiffness increases. Thus, spinal bone grafting is a race between fusion healing and failure of intersegmental motion fixation to immobilise spinal elements.

An adequate blood supply is necessary to encourage healing. Excessive muscle stripping and devascularisation limits oxygen, nutrient, neovascularisation and cellular migration to the fusion mass. Significant muscle necrosis may also provide environments suitable for bacterial growth, which compete for nutrients and interfere with the inflammatory processes necessary for the developing fusion mass, thus causing graft failure. MIS, which aims to interfere with the inflammatory processes necessary for the development of fusion, can be inserted via minimally invasive paraspinal techniques, thus avoiding significant muscle and ligament damage.

Although similar to rigid pedicle screw systems, posterior dynamic stabilisation (PDS), including pedicle screw-based stabilisation, aims to relieve pain, other compressive neurological symptoms, and restore stabilisation by re-establishing the natural anatomic position and enabling restricted segmental motion. In contrast to fusion systems that aim to withstand loading until fusion occurs, pedicle screws in dynamic stabilisation systems need to withstand cyclical loading indefinitely, which makes the screws prone to loosening.

As the PDS technology has only recently emerged, the available literature is sparse with most studies having only 2 years of follow-up at most. Furthermore, it may take 5 years to 10 years before the beneficial effects of PDS, like adjacent segment degeneration, can be detected when compared with rigid forms of spinal fusion. Thus, multiple, similarly designed trials need to be undertaken before any conclusions about the benefits of PDS over current fusion techniques can be drawn.

5.8. Emerging technology

Despite the benefits of MIS fusion in well-selected patients, there are limitations which include: accelerated adjacent level degeneration, symptomatic pseudoarthrosis and graft site morbidity. Motion sparing techniques now offer improved stability and intersegmental motion compared to current fusion operations, following procedures for degenerative disc disease, spinal stenosis and spondylolisthesis. This allows surgeons to avoid the aforementioned limitations, while treating patients at earlier stages of degeneration than traditional fusion. Furthermore, motion-sparing techniques like pedicle screw-based systems can be inserted via minimally invasive paraspinal techniques, thus avoiding significant muscle and ligament damage.

6. Discussion

Since 2000, the techniques of minimally invasive spinal fusion have improved substantially. With increasing experience, indications for minimally invasive spinal fusion have expanded. Currently, indications are similar to those for open surgery and strongly rely on the surgeon’s experience with the procedure. Most MIS spinal techniques have steep learning curves, requiring different cognitive, psychomotor and technical skills. It is
recommended that surgeons have adequate experience with open procedures before attempting minimally invasive methods\textsuperscript{14} and that they begin with simple MIS procedures. Depending on the procedure, the patient and the surgeon’s experience, MIS may take more time to perform than open surgery.\textsuperscript{9}

As indications for percutaneous pedicle screw techniques expand, the nuances of the MIS technique will also expand. It is paramount that experienced surgeons share their collective knowledge to assist surgeons at their early attempts of these complex, and potentially very dangerous procedures.

MIS aims to minimise surgery-associated risk and morbidity, including irreversible muscle injury from muscle stripping and retraction, which are associated with poor clinical results, while achieving the same results as conventional approaches.\textsuperscript{5,8,10,16} Despite encouraging clinical results, MIS techniques are in their infancy with the results being preliminary at best. Prospective outcome studies with long-term follow-up comparing new minimally invasive spinal fusion to conventional open fusions are required to ultimately determine the safety, effectiveness and clinical benefit of minimally invasive spinal fixation.\textsuperscript{4,5,17}

7. Conclusion

Spinal fusion is the gold standard in maintaining the stability of unstable spinal segments for multiple potential pathologies. As the techniques and instruments in MIS spinal surgery have evolved, the indications for minimally invasive spinal fusion have expanded to include: degeneration, trauma, deformity, infection and neoplasia. With technological advancements, it is expected that MIS fusion techniques will become a prominent part of spinal surgery and that indications for minimally invasive spinal fusion will expand. This review adds to the literature to inform prospective surgeons of the nuances of the percutaneous technique for pedicle screw insertion.

References