

# Operative Treatment of Spondylolisthesis

**Mahmoud Mostafa Mohamed Taha, Essam Mohamed Elsayed Yousef,  
Mahmoud Mohamed Ali Mohamed Mansour, Mustafa Abd-Elsalam Mustafa El-  
Zohiery**

Neurosurgery Department, Faculty of Medicine- Zagazig University, Egypt

**Corresponding Author:** Mahmoud Mohamed Ali Mohamed Mansour

**E-Mail:** Mahmoudmmansour1@gmail.com

## **Abstract:**

Spondylolisthesis refers to anterior displacement of the vertebral body in reference to the bordering vertebral bodies, causing segmental instability, that mostly occurs in the middle lumbar spine and the lumbosacral junction. If surgery is indicated, open technique with lumbar pedicle screw instrumentation is the standard therapy. Recently, minimally-invasive technique can be applied in spondylolisthesis surgery using percutaneous long-arm pedicle screws with a promising short- and long-term outcome.

**Keywords:** Operative Treatment, Spondylolisthesis, screws.

## **Introduction:**

Spinal fusion is the most commonly performed surgical treatment for lumbar spondylolisthesis. Spinal fusion was initially only used to treat spinal infections and high-grade spondylolisthesis. Later this method was applied to treat fractures and deformity. Today approximately 75% of the interventions are done for painful degenerative disorders [1]. Despite its frequent use, spinal fusion for lumbar spondylosis is still not solidly based on scientific evidence in terms of its clinical effectiveness. For a long time it was hoped that outcome of spinal fusions could be significantly improved when the fusion rates come close to 100%. However, it is now apparently clear that outcome is not closely linked to the fusion status [1].

## **Surgical Techniques**

For a long time, spinal fusion has been the treatment of choice when addressing symptomatic lumbar spondylosis [2].

## **Bone Grafts**

Autologous bone is generally considered the “gold standard” as a graft material for spinal fusion and exhibits osteogenetic, osteoconductive and osteoinductive properties. Autologous bone for spinal fusion is harvested from the anterior or posterior iliac crest as cancellous bone, corticocancellous bone chips or tricortical bone blocks. The drawback of autologous bone is related to the limited quantity and potential donor site pain [3].

These drawbacks have led to the use of allograft bone early in the evolution of spinal fusion. Allografts are used in different forms for spinal fusion. They are predominately used as structural allografts (e.g. femoral ring allografts) but are available in other forms (e.g. corticocancellous bone chips). Bone allografts exhibit strong osteoconductive, weak osteoinductive but no osteogenetic properties. Fresh allografts elicit both local and systemic immune responses diminishing or destroying the osteoinductive and conductive properties. Bone graft incorporation within the host, whether autogenous or allogeneic, depends on various factors

- Type of graft.
- Site of transplant.
- Quality of transplanted bone and host bone.

- Host bed preparation.
- Preservation techniques.
- Systemic and local disease.
- Mechanical properties of the graft [4].

#### **Bone Graft Substitutes:**

Bone graft substitutes are increasingly being used for spinal fusion because of the minimal but inherent risk of a transmission of infectious disease with allografts. Among the characteristics of an optimal bone graft substitute are:

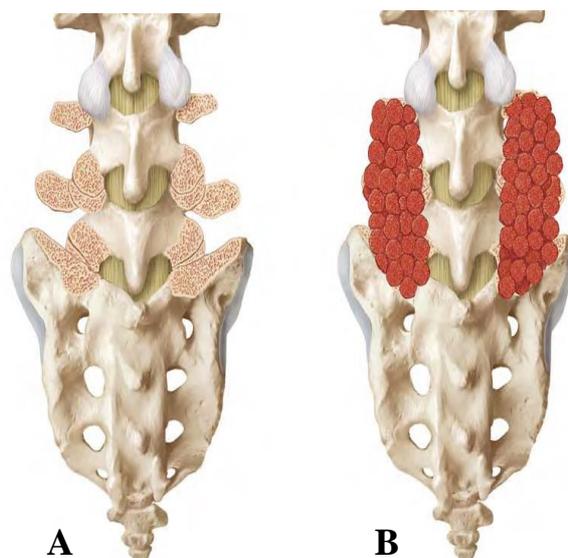
- High degree of biocompatibility.
- Lack of immunogenicity and toxicity.
- Ability for biodegradation.
- Ability to withstand sterilization.
- Availability in different sizes, shapes and amounts.
- Reasonable cost.

#### **The most commonly used bone graft substitutes in spinal fusion are:**

- Calcium phosphates.
- Demineralized bone matrix (DBM) [5].

#### **Posterolateral Fusion:**

Posterolateral fusion was first described by Watkins in 1953 and remains the gold standard for spinal fusion. The technique consisted of a decortication of the transverse spinous processes, pars interarticularis and facet joints with application of a large corticocancellous iliac bone block. This method has been modified by Truchly and Thompson, who used multiple thin iliac bone strips as graft material instead of a single corticocancellous bone block because of frequent graft dislocation. In (1972), **Stauffer and Coventry** presented the technique still used today by most surgeons, which consisted of a single midline approach (**Figure 1**) [6].



**Figure (1):** Surgical technique of posterolateral fusion. [6].

### Instrumented Spinal Fusion:

With the advent of pedicle screw fixation devices in the 1980s and the introduction of fusion cages in the 1990s, spinal instrumentation was widely used with the rationale that the improved segmental stability may enhance the fusion rate and simultaneously improve clinical outcome [6].

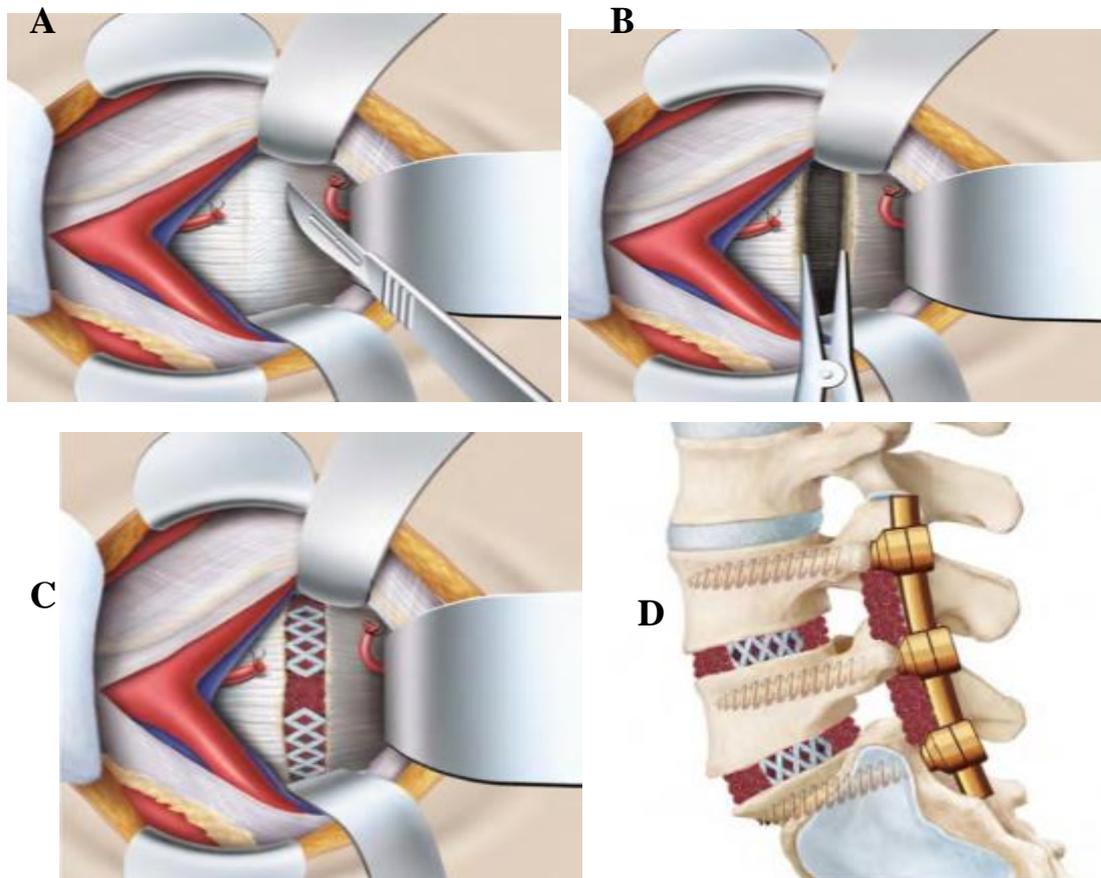
### Pedicle Screw Fixation:

The pedicle is the strongest part of the vertebra, which predestines it as an anchorage for screw fixation of the vertebral segments. Pedicle screw fixation had its origins in France. From 1963, Raymond Roy-Camille first used pedicle screws with plates to stabilize the lumbar spine for various disorders [7]. Some years later, Louis and Maresca modified Roy-Camille's plate and technique to better adapt to the lumbosacral junction [8].

Around the same time, [9] developed the variable screw system (VSP), a plate pedicle screw construct. A further milestone in the development was the introduction of a new screw-rod system by Cotrel and Dubousset in 1984. The versatile Cotrel-Dubousset instrumentation system became widely used for the treatment of degenerative disorders. The current system offers the advantage of polyaxial screw heads which facilitate the rod screw connection. The most frequently used fusion technique today is to combine pedicle screw fixation with posterolateral fusion [10].

### Cage Augmented Interbody Fusion:

The application of interbody fusion cages for fusion enhancement is based on the rationale that a strong structural support is needed for the anterior column which does not migrate or collapse. Interbody cages were designed and first used by Bagby and Kuslich (BAK cage) in the 1990s and consisted of threaded hollow cylinders filled with bone graft. After that, different designs and materials are available for anterior and posterior use [11].

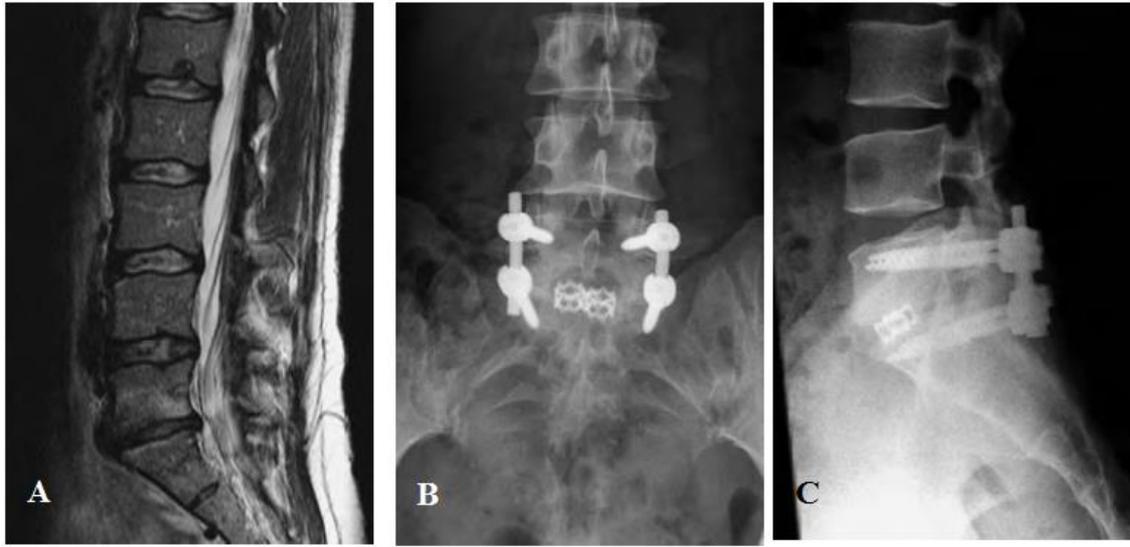


**Figure (2):** Surgical technique of anterior lumbar interbody fusion.. **a** The intervertebral disc is excised; **b** the endplates can be distracted with a spreader and the endplate cartilage is removed with curettes; **c** the disc space

is filled with cancellous bone and supported with two cages.. **d** Pedicle screw fixation is added in conjunction with posterolateral fusion [12].

### **Circumferential Fusion:**

Circumferential fusion (i.e. interbody and posterolateral fusion) was first used for the treatment of spinal trauma and deformity, then expanded to failed previous spinal fusion operations and is now used also as a primary procedure for chronic low-back pain. Theoretically, this technique should increase the fusion rate by maximizing the stability within the motion segment and enhance outcome because of an elimination of potential pain sources in anterior and posterior spinal structures (**Figure 3**) [13].



**Figure (3):** Circumferential fusion a Young (28 years) female patient with endplate changes (Modic Type II) undergoing pedicle screw fixation L5/S1 and posterolateral fusion in combination with a cage augmented anterior lumbar interbody fusion. Postoperative b anteroposterior view and c lateral view [14].

### **Posterior Approaches for Lumbar Interbody Fusion:**

Posterior lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) create intervertebral fusion by means of a posterior approach. Both techniques are useful in managing degenerative disc disease, severe instability, spondylolisthesis, deformity, and pseudarthrosis. Successful results have been reported with allograft, various cages (for interbody support) and autograft [15].

PLIF and TLIF allow access to both anterior and posterior spinal columns by way of an all-posterior approach. Fusion is achieved at the site of the intervertebral joint, and the anterior column is reconstructed as the load-bearing structures are reconstructed. The resulting fusion is biomechanically superior to posterolateral fusion (PLF) and creates a biomechanically superior environment for bone healing. Interbody fusion also offers increased surface area for bone graft. Because of these factors, PLIF may offer an advantage when performing surgery for pseudarthrosis. In a patient in whom standard PLF has failed, the posterior interbody approach may provide additional support for fusion. Neural foraminal distraction may occur during PLIF, which can result in nerve root decompression and correction of scoliosis or kyphosis [16].

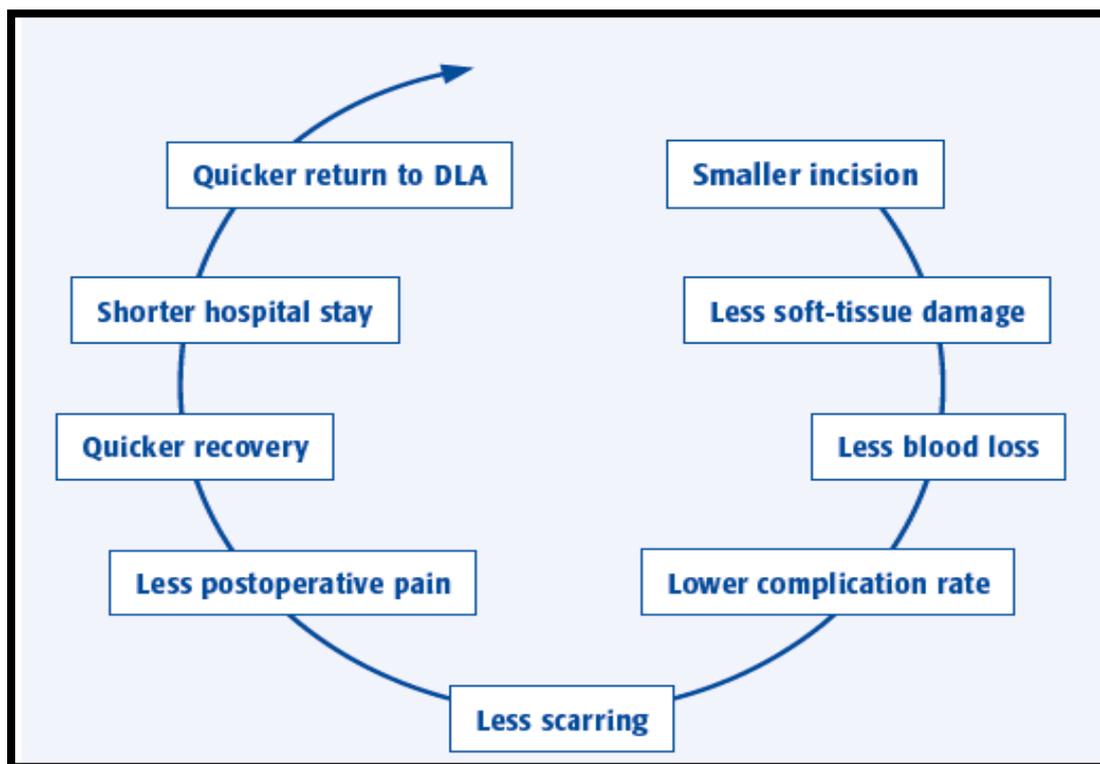
### **Minimally Invasive Spine Surgery (MISS)**

Minimal Invasive spine Surgeries (MISS) are a new technology-dependent surgeries and approaches that decreases both local tissue trauma and systemic surgical stresses allowing more earlier return to daily life activity with better outcomes than traditional old techniques[17].

Open techniques were accepted as standard practice to achieve the treatment goals by attacking the pathology itself with no focus on the tissue trauma that may occur with that approach. Open surgical exposures are associated with adverse effects like muscle damage and denervation, bleeding and postoperative scarring of the tissues. Further side effects include the need for prolonged pain medication, a longer hospitalization and recovery period with a longer period of physical disability and delayed return to work and inability to resume previous work activity in some cases [17].

To decrease the intraoperative iatrogenic trauma to the tissues, we need to reduce the access entry size by making smaller incisions, and using anatomical neurovascular and muscle working channel and planes to achieve the same or even better results in comparison to the open techniques not only decreasing the size of the wound. The muscle-splitting dissection allows less muscle denervation in comparison to muscle-cutting techniques, and reduces the blood loss with less postoperative scar-tissue formation, with a decrease in postoperative pain medication, with a quicker return to daily life activity and a shorter hospitalization time (figure 4) [18].

With all these benefits, an increase in the use of minimally invasive spine surgery (MISS) from the early 1990s onwards was seen. At the beginning, percutaneous pedicle screw for fusion surgery was limited to one or two segmental cases of in situ fusion. Nowadays, multi-segmental pedicle screw insertion and segmental reduction is done as it is facilitated by computer-assisted navigation, so that the range of indications for treatment by MISS is now nearly the same as for open surgery that can be applied for the entire spine [18].

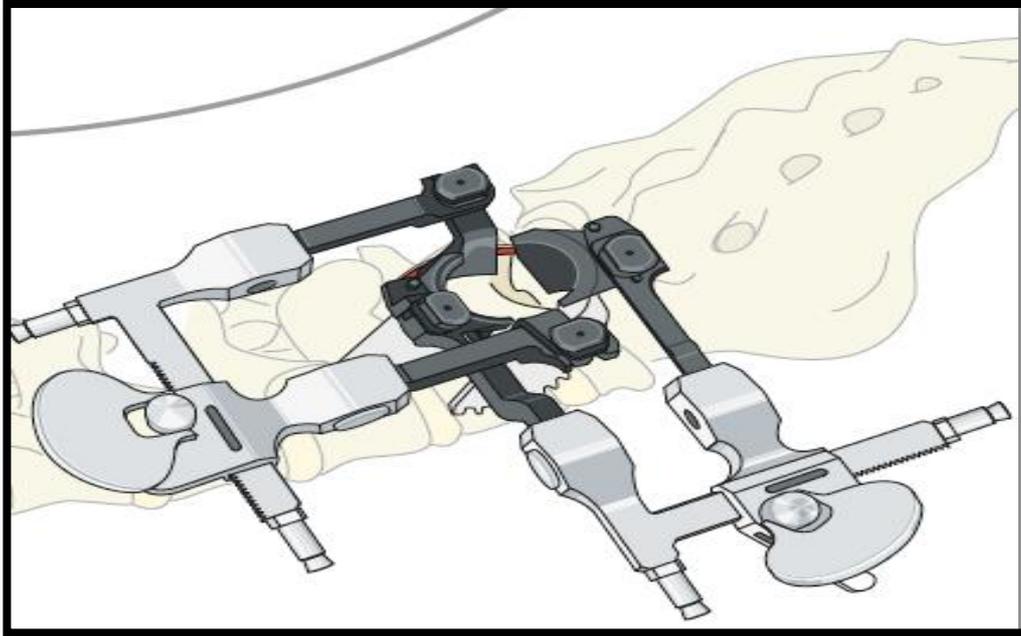


**Figure (4):** Benefits associated with a MISS strategy (DLA=daily life activities) [18]

#### **Pillars of MISS:**

The four “pillars” of MISS are; first the use of microsurgical techniques with the increasingly use of the microscope and also more recently of the endoscope for visualization and magnification of the intraoperative field, the second pillar is the access strategies for the spine using percutaneous mini-open and tubular dilator access strategies to minimize muscle injury (Figure 5). The third pillar is the imaging/navigation technology like Computer-assisted navigation and intraoperative neuromonitoring. The final pillar is the special instrumentation

and implants like Specific tube or frame-like retractor systems to provide the tiny “keyhole” access present nowadays. It is most important that these approach modifications do not affect the treatment strategy at the target site itself, which should not depend on the size of the access pathway, and be efficient and identical to the macro-surgical procedures [19].



**Figure (5):** The type of retractor, which can be used for “mini-open” surgery, typically consists of several components that allow tissue blades to expand and expose larger portions of the anatomy.[18]

**Learning curve:**

Accepting a steep learning curve and a prolonged time for surgery must be taken into account in earlier cases. Also, the learning curve will have an effect on the intraoperative tissue trauma, blood loss and radiation exposure with or without an increased complication rate at the beginning of the use of MISS that is always present even with experienced surgeons [20].

The use of a strategy like doing more straightforward cases at the beginning with careful patient selection will help to reduce any doubt about this new technique. Also, it is a good idea to do the first MISS cases together with an experienced MISS surgeon, for example; percutaneous pedicle screw placement, with each surgeon dealing with his side. Furthermore, human anatomical specimen workshops on the needed surgical technique will help in improving the learning curve. In the literature, a range between 10 to 20 cases are the known number needed for a surgeon to become familiar with a specific MISS, this number may vary with the type of surgery. [21]

**Radiation exposure:**

The smaller the access route is the more decrease in the visualization of the surgical field. The use of x-ray radiography for local orientation and visual anatomical landmarks that are familiar for most of spine surgeons under macro-surgical conditions may help in the orientation to the spinal anatomy. Imaging tools are mandatory at the preoperative stage and intra-operatively for localization and verification of the needed area. A repeated x-ray of the intraoperative surgical steps like cement distribution, reduction maneuvers, or percutaneous pedicle screw placement may be needed. As a result, the radiation dose to the patient, surgeon and support team increases. Intraoperative use of leaded glasses, thyroid shields, and lead aprons help to reduce local radiation exposure. [21]

Standard micro-discectomy usually requires two lateral images, a preoperative view for localization and an intraoperative view for verification of the target area. In comparison, MISS lumbar discectomy using

tubular retractors requires a 10- 20-fold increase in the amount of radiation dose needed for level verification, dilator positioning and tube placement. Computer-assisted navigation with preoperative or intraoperative CT-scan or image intensifier helps to reduce the amount of radiation exposure to the surgeon. [22]

#### **Cost effectiveness:**

The cost-analysis and cost-effectiveness aspects must be taken into account when calculating the benefit of this new surgical strategy in terms of direct and indirect costs. The direct cost include factors related to time (duration of stay in the emergency room and intensive care unit; time in the operating room, the duration of surgery; length of hospital stay), additional investigations (such as laboratory, radiological, or interdisciplinary investigation, eg, cardiology), other like (eg, medication, blood units), and professional fees (eg, surgeon, anesthetist), which together affect the overall cost of MISS. Indirect costs (up approximately 85% of the total costs) include post-operative factors such as patient rehabilitation, return to work, loss of productivity and the inability to work or even early retirement. Also the surgeon's learning curve may influence the cost-effectiveness of a given procedure. [23]

Little doubt exists for a mono-segmental pathology with the use of posterior surgery (TLIF) that will limit the cost compared to a combined anterior-posterior strategy (anterior-posterior interbody fusion) in terms of reduced time of surgery, shorter stay in the intensive care unit, less blood loss, and shorter period of hospitalization. [23]

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