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Transforaminal lumbar interbody fusion For Management of Degenerative Spondylolisthesis

Mohamed Fathy Abdallah Abdeldaim [1], Omar Abdel-Wahab Kelany [2], Mohamed Hussein Elsayed [3], Elsayed Mohamed Selim Ali [4]

1 Resident of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Egypt, drtoha172@gmail.com

2 Professor of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Egypt, O_kelany@yahoo.com

3 Assistant Professor of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Egypt, mohamed.hussein160041@gmail.com

4 Lecturer of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Egypt, Drsayed122@gmail.com.

Corresponding author: Mohamed Fathy Abdallah Abdeldaim

Email: drtoha172@gmail.com

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Abstract: Background: Spondylolisthesis is one of the most encountered spine conditions and few topics in spine surgery have received more intense debate and been the subject of more research investigations. The term was first utilized in the 1960s by Newman and Stone. It is derived from the root Greek terms “spondylos” meaning vertebra and “olisthesis” meaning to slip forward. Spondylolisthesis can be caused by several mechanisms, and a classification system developed by Marchetti and Bartlozzi has been described. Degenerative Spondylolisthesis with Intact Neural Arch is The most common form of spondylolithesis, secondary to degeneration of facet joints and disc, the most common site of structural deformity to be at the L4-5 level. Women are more commonly affected than men, and the prevalence of the condition increases with age. In contrast, isthmic spondylolisthesis usually occurs at L5-S1 and is more common in men. Different methods of spinal fusion have been developed since Albee first reported on posterior fusion in 1911. Initially, a direct posterior approach and then a posterolateral intertransverse process fusion was developed followed by anterior interbody lumbar fusion. Posterior lumbar interbody fusions (PLIFs) and circumferential 360o fusions were developed later. Over the years, there have been differing opinions among physicians as to appropriate procedures to use for various spinal etiologies. Posterior lumbar interbody fusion after lumbar disc removal was first reported by Jaslow in 1946. Wiltbergerof the United States reported using dowels for intervertebral fusion. More recently, Steffe, Brantigan, and Ray have reported on the use of posterior segmental instrumentation or the use of cage implants for PLIF. Using special curets and shavers, discectomy is performed across to the opposite side. Disk height is reestablished using special distractors or pedicle screws. One or two interbody grafts are placed. When using a single interbody device, emphasis is placed on crossing the midline. The addition of bilateral pedicle screw instrumentation is recommended to restore spinal stability.

Keywords: *Transforaminal lumbar interbody fusion, Degenerative Spondylolisthesis*

Introduction

Spondylolisthesis is one of the most encountered spine conditions and few topics in spine surgery have received more intense debate and been the subject of more research investigations. The term was first utilized in the 1960s by Newman and Stone [1]. It is derived from the root Greek terms "spondylos" meaning vertebra and "olisthesis" meaning to slip forward. Spondylolisthesis can be caused by several mechanisms, and a classification system developed by Marchetti and Bartlozzi has been described [2].

Classification

Spondylolisthesis is defined as an anterior or posterior slipping of one vertebra relative to the caudal one (Spondylos=vertebrae, Listhesis= slippage). Spondylolysis is known as a unilateral or bilateral defect of the pars interarticularis without slippage. [2].

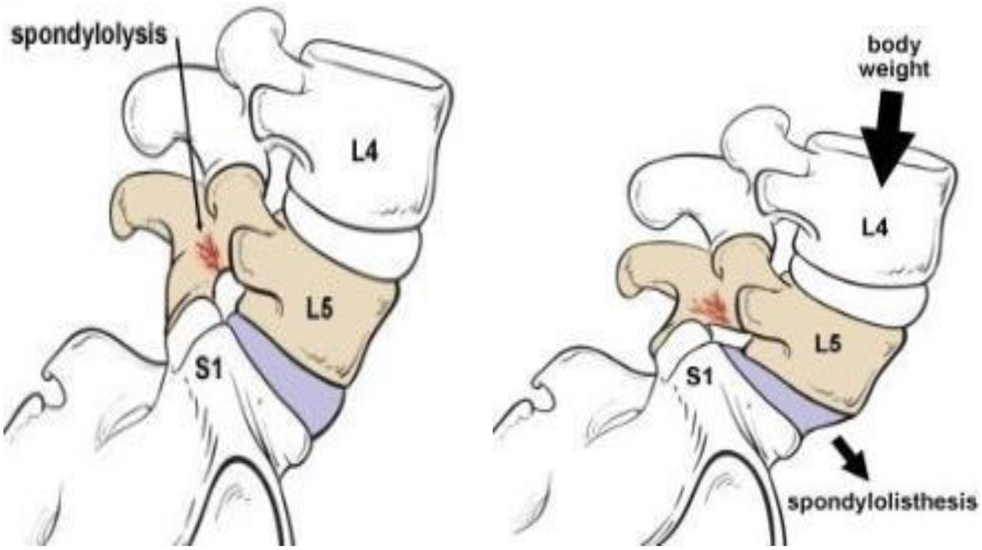

Figure (1): Diagram shows Spondylolisis & Spondylolithesis

Herbiniaux [38], a Belgian obstetrician was the first one to describe spondylolisthesis, who described an osseous prominence anterior to the sacrum that caused narrowing of the birth canal resulting from anterior subluxation of 5th lumbar vertebra **[3].**

Kilian et al. [4] suggested that various forces caused subluxation of the lumbosacral facets. Soon thereafter, Robert and Lambl realized that a neural arch defect preceded the subluxation. This defect, at the pars interarticularis, was termed spondylolysis **[4]**

In (1882) Neugebauer demonstrated that both lysis &elongation of the pars interarticularis could lead to spondylolisthesis [5].

Wiltse first described spondylolisthesis in 1962 and 10 years later published a classification system based on etiology and anatomical changes seen at lumbosacral area, the classification divide spondylolithesis into five categories [6].

- **Wiltse Classification:**

Wiltse first described spondylolisthesis in 1962 and 10 years later published the classification system depending on etiological and anatomical changes seen at lumbo-sacral area, this classification divide spondylolisthesis into five categories:

- **Dysplastic:** Congenital abnormalities of the upper sacral facets or inferior facets of the 5th lumbar vertebra led to slippage of L5 on S1. There is no pars defect in this type. The sacrum is not strong enough to withstand the weight and stresses. Thus, the pars and inferior facets of L5 are deformed leading to significant instability and major slippage [7].
- **Isthmic:** Due to a defect in pars interarticularis, 3 subtypes of isthmic spondylolisthesis are recognized [7]:

1. **Subtype (A):** classic lytic lesion indicating a stress fracture.
2. **Subtype (B):** elongated but intact isthmus, which may represent a healed fracture.
3. **Subtype (C):** refers to an acute fracture of the pars interarticularis and is the rarest one of isthmic type

- **Degenerative (Spondylolisthesis with Intact Neural Arch):** The most common form of spondylolithesis, secondary to degeneration of facet joints and disc, the most common site of structural deformity to be at the L4-5 level. Women are more commonly affected than men, and the prevalence of the condition increases with age. In contrast, isthmic spondylolisthesis usually occurs at L5-S1 and is more common in men [7].
- **Traumatic:** Traumatic spondylolisthesis related to fracture involving posterior elements other than pars and usually results from major trauma [8]
- **Pathological:** Destabilization of the facet mechanism due to internal alteration (e.g. tumors, infection, Paget's disease, osteoporosis, and hyperthyroidism) producing a pathologic spondylolisthesis [8].

The recognition of wide range of spondylolithesis deformities arising from dysplastic changes led to new classification by Marchetti and Bartolozzi which include two broad etiological groups, namely developmental and acquired [9]. This classification has relevance to the etiology, natural history, risk of progression and implications of treatment of spondylolisthesis.

- **Marchetti and Bartolozzi Classification:**
- **The developmental type:** The developmental category defines spondylolisthesis resulting from an inherited dysplasia of the pars, lumbar facets, discs, and vertebral endplates, combining the dysplastic and isthmic categories of Wiltse- Newman classification and is subdivided into [7]:

1. **High-dysplastic:** significant lumbosacral kyphosis, trapezoidal 5th lumbar vertebra, dysplasia of L5 & S1 posterior elements and S1upper end plate anomaly.
2. **Low-dysplastic:** there is relatively normal lumbosacral profile, rectangular 5th lumbar vertebra, preservation of S1 normal upper endplate, and no sacral verticalization or hyperlordosis.

- **Acquired spondylolisthesis:** Following trauma, surgery, pathologic disease or a degenerative process. The traumatic form can be due to either acute or stress fracture and can be distinguished from the isthmic dysplastic type of developmental spondylolisthesis by the absence of significant dysplastic changes [10].

Marchetti classification avoids the term sthmic in Wiltse classification which does not differentiate between developmental and acquired forms of slippage. Both types may have defects of the pars, however, they present different pathologic processes [10].

Epidemiology and Natural History

Degenerative spondylolisthesis (DS) is a disease of aging. Although more commonly found in women (2–3:1, female: male), its incidence increases in both sexes with age. Its predilection for women is thought to be due to an increase in ligamentous laxity and hormonal effects. There is also evidence to support that baseline lumbar and pelvic parameters may lead to the development of DS [11].

The development of DS is likely a multifactorial process taken together with the above causes as well as degenerative processes of aging affecting both the intervertebral disk and facet joints. There is little known about the natural history of DS. Matsunaga and colleagues reported 145 non-surgically managed patients with a minimum of 10 years' follow-up evaluation. The authors reported slip progression in 49 patients (34%) [12]. Intervertebral disk heights of the diseased segment decreased significantly throughout the length of the study with a concomitant decrease in low back pain. They also concluded that this narrowing of the intervertebral disk as well as spur formation, subcartilaginous sclerosis, and/or ossification of ligaments may prevent the progression of the disease in a process they call spinal restabilization. More than three quarters of their patient population failed to develop any neurological sequelae after >10 years of follow-up [13].

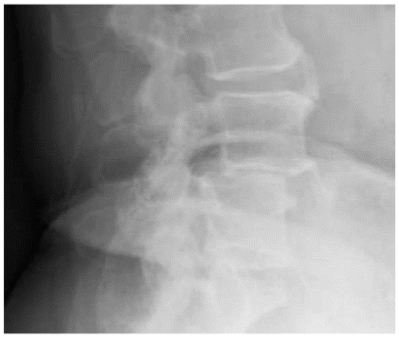

Figure (2): standing lateral radiograph showed L4/L5 degenerative spondylolisthesis [14].

Pathophysiology

Degenerative spondylolisthesis is common in individuals older than 50 years. Previous studies have indicated that the condition occurs most seen at L4–L5 with the etiology of degenerative spondylolisthesis being multifactorial. Pregnancy, generalized joint laxity, and oophorectomy are thought to be predisposing factors of the condition and its predominance in women. Sagittal orientation of the facet joints and increased pedicle-facet angle have been described as predisposing factors [15].

A correlation has been observed between L4–L5 degenerative spondylolisthesis, and coronal orientation of the L5–S1 facets and sacralization of this segment. This association could be interpreted as leading to greater stresses at L4–L5. However, in a comparative study of facet orientation in younger and older patients, the sagittal orientation of the facet angle is a result of arthritic remodeling in the older age group, and not a primary cause of degenerative spondylolisthesis [16].

Figure (3): Lateral radiographs in a 65-year-old man showing retrolisthesis at L1–L2, L2–L3, and L3–L4 segment, and anterolisthesis at L4 –L5 segment secondary to degenerative disorder [17].

In the single-level DS, anterolisthesis was found in 70% cases, which is predominant at L4–L5 and in women, whereas retrolisthesis was found in 30% cases, which were predominant in L2–L3 and equal in both sexes. Even in the multiple-level group, anterolisthesis is more common in women and involved L3–L4 or L4–L5, whereas retrolisthesis was more common in men and at L2–L3 [17].

The previously described predisposing radiologic factors, such as sagittal orientation of facet joints and increased pedicle-facet angle, were more commonly seen in anterolisthesis group, but not in the retrolisthesis group. The authors suggested that retrolisthesis was consequent to a spinal alignment disorder in the sagittal plane without any architectural bony changes [16].

Transforaminal lumbar interbody fusion

Different methods of spinal fusion have been developed since Albee first reported on posterior fusion in 1911. Initially, a direct posterior approach and then a posterolateral intertransverse process fusion was developed followed by anterior interbody lumbar fusion. Posterior lumbar interbody fusions (PLIFs) and circumferential 360o fusions were developed later. Over the years, there have been differing opinions among physicians as to appropriate procedures to use for various spinal etiologies [18].

Posterior lumbar interbody fusion after lumbar disc removal was first reported by Jaslow in 1946. Wiltbergerof the United States reported using dowels for intervertebral fusion. More recently, Steffe, Brantigan, and Ray have reported on the use of posterior segmental instrumentation or the use of cage implants for PLIF [19].

Since the inception of the concept of PLIF, the procedure has come into a fair amount of disfavor because of perceived and actual complications related to the procedure. These complications include problems with bleeding, dural laceration, nerve root and other neural injuries, graft migration, graft collapse, and pseudarthrosis. The concept of a unilateral approach to the anterior column was refined and popularized by Jurgen Harms. The purpose of this approach was to obtain the same goals as a PLIF without the potential risks and complications [20]. Transforaminal lumbar interbody fusion (TLIF) is a modification of the PLIF technique involving unilateral total facetectomy. The pars interarticularis is resected, and the inferior facet is removed. The superior facet is then resected until it is flush with the pedicle. The traversing nerve root is mobilized and retracted medially, but to a much lesser degree than with PLIF. Access to the disk can then be obtained transforaminally.

Using special curets and shavers, discectomy is performed across to the opposite side. Disk height is reestablished using special distractors or pedicle screws. One or two interbody grafts are placed. When using a single interbody device, emphasis is placed on crossing the midline. The addition of bilateral pedicle screw instrumentation is recommended to restore spinal stability [21].

Figure (4): Different TLIF interbody devices designed to cross the midline after application of them unilaterally [21].

Biomechanics

When the anterior column is insufficient, a posterolateral fusion alone may not be the procedure of choice. Classic studies by Rolander [22] have shown that there is motion in the spine despite a solid posterior fusion. Zdeblick has shown that the decrease of motion of the motion segment is through the disc, not the facets, transverse process, or spinous processes. Weatherly reported on five patients who had a solid posterior spinal fusion but had continued low back pain. They subsequently underwent positive discography and had pain relief with an interbody fusion.

Biomechanically, 80% of the weight bearing of the lumbar spine involves the anterior column and only 20% involves the posterior column, which leads to the concept of load sharing. The various forces on the spine are axial compression anteriorly, tensile forces posteriorly, and a combination of anterior and posterior structures that resist the forces of bending and sheer. The disc plays a critical part in anterior column stability; therefore, loss of disc integrity leads to an inadequate anterior column and indicates the need for anterior column support [23].

The posterior tension band can work only if the anterior column is intact, which explains why posterior constructs cannot stabilize the spine fully in cases of anterior column insufficiency. Load sharing cannot exist without an intact posterior column (tension band), and the tension band does not work without an intact or reconstructed anterior column. The tension band principle and load sharing are co-dependent [24].

The TLIF is load sharing approach providing for anterior column support and provides a posterior tension band. TLIF has no exposure or manipulation of the dura there is a lower risk of neurologic injury. It provides the benefits of a 360^{o} fusion by helping to improve the success rate of the fusion. It immobilizes the anterior column more effectively than a posterior or posterolateral fusion with or without instrumentation. It helps restore the normal anatomy of the motion segment and regains or at least maintains normal lumbar lordosis. The distraction of the disc space and regaining disc space height restores the height of the neural foramen, improves foraminal narrowing, and decreases foraminal stenosis. Indirectly, central stenosis may be relieved if it is caused by the ligamentum flavum infolding or annular compression [25].

Indications [26]

- The ideal indication for a TLIF is a grade I or grade II spondylolisthesis without neurologic deficit or with a deficit on one side only.
- Degenerative disease with positive discography without any intracanal pathologic condition.
- Segmental kyphosis related to disk narrowing.
- Grade II or III spondylolisthesis can also be reduced with this technique without the need for anterior surgery.
- The TLIF procedure can also be used to decrease pseudoarthrosis at the lumbosacral junction

Contraindications [27]:

- Tight anterior disc space with osteophyte formation in which there is no potential for disc space distraction.
- Extensive epidural scarring or history of prior infection.

Operative procedures:

- **Preoperative evaluation:**
- Studies to determine the appropriate pathology and plan for the procedure may include [28]:
    - Selective nerve root blocks.
    - Myelography.
    - Discography.
    - Compute tomography (CT).
    - Magnetic resonance imaging (MRI).
- Before surgery, one to two units of autologous blood are obtained from the patient.
- **Positioning [29]:**

- The patient is placed in the prone position, and one of two positioning frames is helpful.
- An appropriate adjustable frame may be used with the spine in flexion to make the approach to the disc easier, but it can be extended before placement of the final instrumentation and tightening to create lordosis.
- The second option is to place the patient with fully extended hips and legs on a four-poster frame to maintain lordosis throughout the procedure.
- In either case, it is important to allow the abdomen to hang free and to allow positioning for appropriate radiographs, including C-arm.

- **Preoperative preparation [30]:**

- Hypotensive anesthesia and a cell saver are routinely used.
- Broad-spectrum antibiotics are started at the time of surgery and used for 48 hours postoperatively.
- The patient is fitted with Ted stocking and sequential boots.

- **TLIF steps:**

Pedicle preparation and screw placement [30]:

- The midline is approached for exposure of the appropriate levels to be addressed. The exposure is carried out to the tips of the transverse processes bilaterally, with care being taken to avoid injury to facet capsules above and below the levels to be exposed.
- Pedicle instrumentation then is placed in standard fashion. For this procedure, it is helpful to use polyaxial screws. The polyaxial nature of the screw permits the head of the screw to move independently of the position of the screw in the pedicle, which allows the use of a straight rodand gives full resistance to traction forces and bending moments.
- It allows distraction of the disc space to do the disc space work and further allows compression at the conclusion of the procedure to create lordosis.
- The starting point for the screws is identified, and K wires are placed in small holes made in the pedicle using a pedicle probe. The C-arm is used in the lateral position to ascertain the exact direction of the screws in the sagittal plane and ascertain the depth of the screws.
- After placement of the screws, a rod is placed on the side opposite the side from which one approaches the disc. The spine is then placed under mild distraction by distracting against the screw heads.
- It is important to watch the screws within the pedicles, especially if osteopenia is present. A screw that moves too easily along the long axis of the rod may indicate a fracture of the underlying pedicle.

Disc exposure and preparation [30]:

- The inferior facet is removed on the side being approached. The superior facet is then removed completely. This procedure may be done in piecemeal fashion, or a small osteotome may be used to remove the superior facet just proximal to the distal pedicle.
- It is important to be prepared for potentially excessive bleeding upon removal of the superior facet. It is also important to be aware of the exiting nerve root as it exits the spine around the proximal pedicle but tends to come distally and may often be seen just lateral to the disc at this level.
- Hemostasis is obtained with bipolar mallis cautery and gel foam pledgets. It may be necessary to remove a small amount of lamina to expose the lateral aspect of the ligamentum flavum. The second rod is placed, and the spine is further distracted. To help with distraction, it is advantageous to remove the inferior facet on the contralateral side. The disc is identified, and disc work may commence.

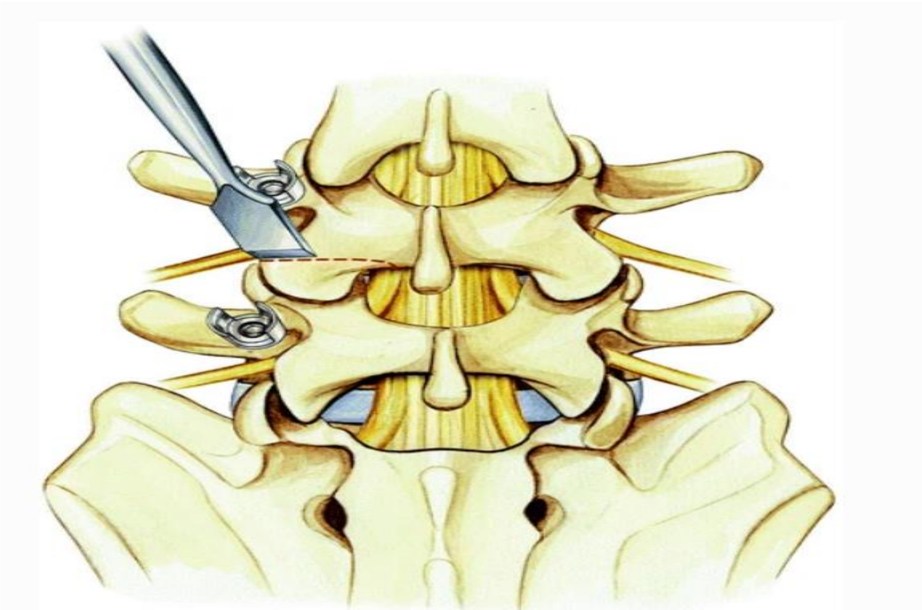

Figure (5): Using a big bone rongeur, the top of the facet joint is removed until the gap of the facet joint is clearly. With an osteotome, the inferior articular facet is removed. The direction of the osteotome is from medial to lateral and from cranial to caudal orienting on the gap of the facet joint [31]

- A sharp incision is made into the annulus of the disc, which is removed. The nucleus of the disc is removed using a combination of pituitary and Ferris Smith rongeurs.
- Complete removal of the disc to the anterior annulus is necessary, as is removal of the cartilaginous endplates of the disc. Ring curettes are helpful in the removal of the endplates.
- Further distraction of the disc space may be accomplished by placing an intervertebral distracter within the disc space to reduce pressure on the pedicle screws. It is important to remove the superior aspect of the vertebral bodies.
- Because of the concave anatomy of the vertebral body, it is necessary to osteotomize the posterior aspect of the vertebral bodies adjacent to the disc space to allow appropriate exposure and placement of an appropriate size cage.
- If this is not done, cages that are too small are placed and anterior column support is not achieved. Cages are sized and prepared for insertion by filling the cage with autogenous bone. It is necessary to use a 13- or 14-mm diameter cage and size the cage 1 mm less than the width of the intervertebral space.
- Appropriate ‘‘lollypops’’ designed to measure the width of the disc space are available. By placing a cage 1 mm smaller than the size measured, the cage is allowed to ‘‘roll’’ over to the opposite side.

Endplate preparation and fusion [30]:

- The anterior half of the vertebral endplates are then decorticated using a combination of straight and angled osteotomes. It is important to osteotomize as close to the anterior longitudinal ligament as possible. It may be helpful to check the depth of the osteotomy using laterally positioned fluoroscopy.

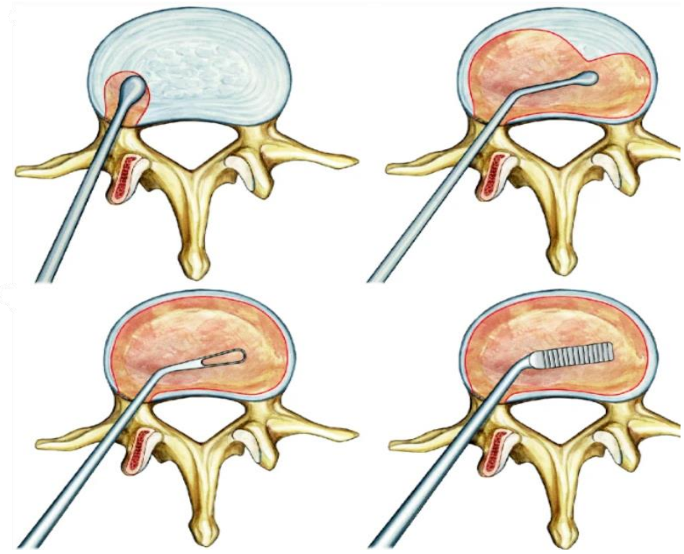

Figure (6): Disc space and end plate preparation [31].

- After decortication of the vertebral bodies, the anterior aspect of the disc space is packed firmly with cancellous bone using straight and angled bone impacters. After adequate placement of the graft, both cages are placed from one side.

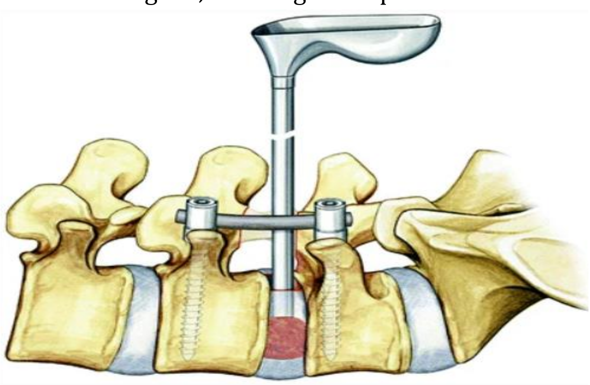

Figure (7): Insertion of cancellous bone graft or bone substitute into the disc space using a funnel [31]

- Round titanium mesh cages are best suited for this purpose, although cortical bone and conceivably small threaded cages may be used. The round titanium mesh cage is placed and then rolled to the opposite side using straight and angled pushers and is followed by placement of the second cage.
- It is important to keep the cages under the vertebral endplates so as not to protrude potentially against the exiting nerve root. After placement of the cages, the tightening mechanisms of the screws are loosened, and the spine is placed into compression.

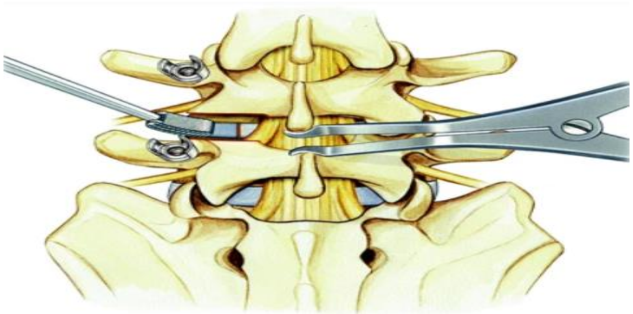

Figure (8): Introduction under interspinous distraction of a boomerang cage (TLIF Cage) with an implant holder into the disc space. Alternatively, distraction with an angled distraction forceps over the ipsilateral side fixed on the pedicle screws [31]

- If the table or frame is in a flexed position, it is important to extend the table or frame to create lordosis before tightening the implants. The cages are checked again for position and tightness within the disc space.
- The lateral transverse process fusion is then performed. The incision is closed in standard fashion, and a drain is placed in the subcutaneous tissues.

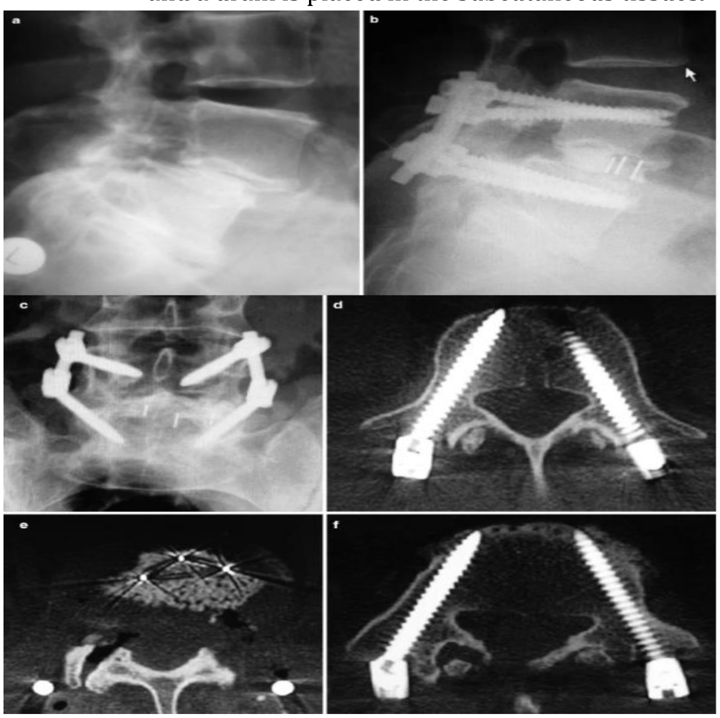

Figure (9): X-ray of a patient with a spondylolisthesis L4/L5 (a), postoperative final construct with bilateral pedicle screws and TLIF cage and additional bone substitute (anterior, posterior, and inside the cage) (b, c); CT scans: level L4 (d), disc space level L4 (e) and level L5 (f) (f) **[30]:**

- Postoperatively, the patient is kept in bed overnight and ambulated the next day with a corset. The drain is removed 48 hours after surgery, and the patient is generally discharged on average 4 days after surgery.

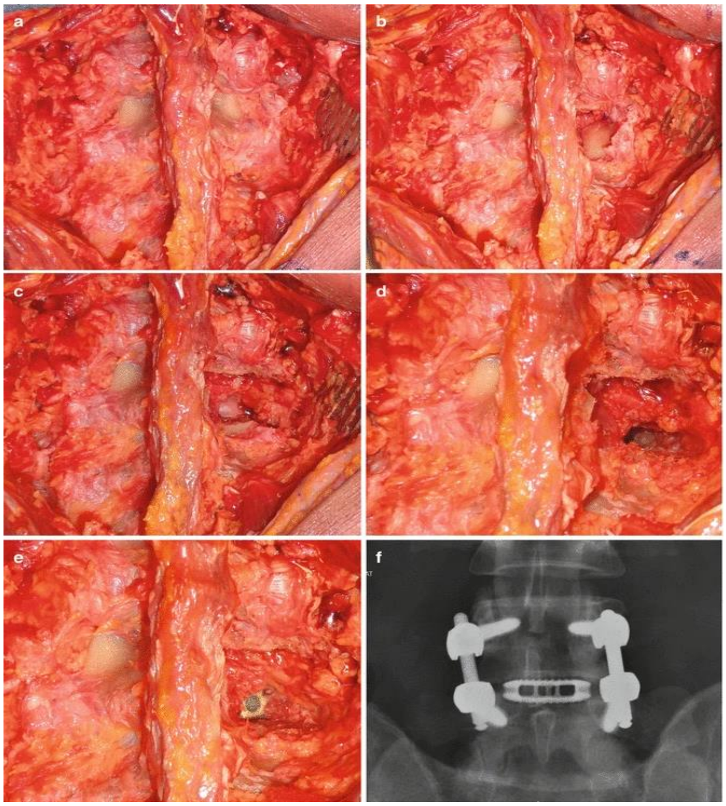

Fig. (10): Steps for an open right L4–L5 TLIF. (a) Exposure of the lamina and articular and transverse processes. (b) Osteotomy at the level of the right L4 pars interarticularis. (c) Resection of the right superior L5 articular process exposes the L4 nerve root and the L4–L5 disk. (d) Thorough diskectomy is performed without retraction of L4 nerve root. (e) Insertion of the cage is performed at a 45° angle and positioned across the midline. (f) Postoperative radiograph demonstrates ideal cage position and pedicle instrumentation. [32]

Complications

Transforaminal lumbar interbody fusion is a major procedure and, as with other such procedures, requires complete understanding of normal pathologic anatomy of the spine and neurologic structures. Complete understanding of spinal biomechanics and fusion technique is mandatory. General complications common to any major spine surgery, such as urinary infections, thrombophlebitis and deep venous thrombosis, pulmonary atelectasis, and abdominal ileus, are not discussed. The following complications are specific to a TLIF [33]:

- **Bleeding:** It is important to be meticulous with vascular control. This starts initially with positioning of the patient with the abdomen hanging free, using hypotensive anesthesia, and, most importantly, using a meticulous technique in which all bleeding points are cauterized. At the time of disc exposure, it is important to cauterize epidural vessels using bipolar cautery. When decorticating the vertebral bodies, increased bleeding may occur [34].
- **Neural injuries:** Injuries to the dura, theoretically, should not occur with a standard TLIF approach, because the dura is not exposed. Potential injury to the exiting nerve root may occur, and knowledge of the appropriate anatomy and protection is necessary [35].

Pseudarthrosis: should be minimized by appropriate endplate preparation with complete removal of the disc and cartilaginous endplates, use of an autogenous bone graft with stable anterior construct, and posterior fixation that creates appropriate tension band and anterior column support [36]

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