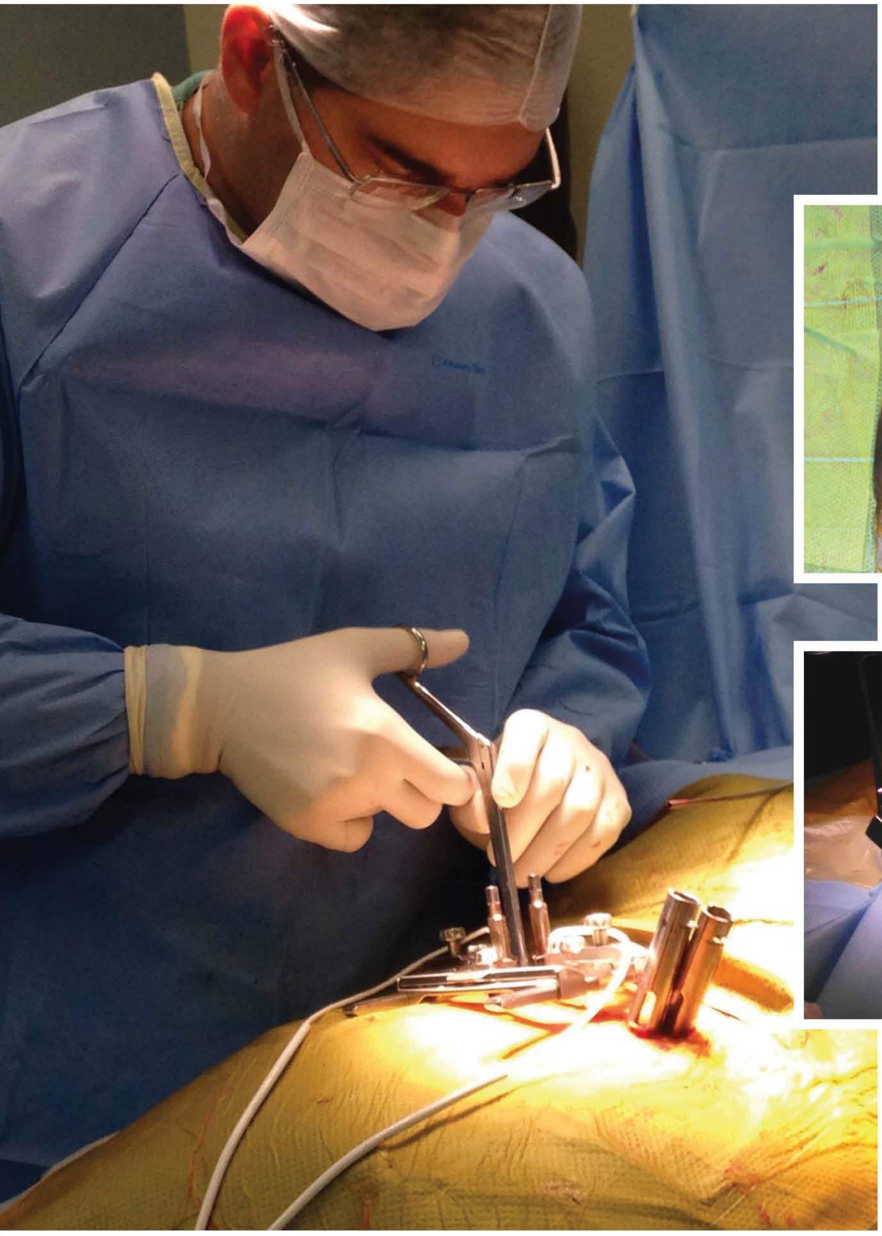
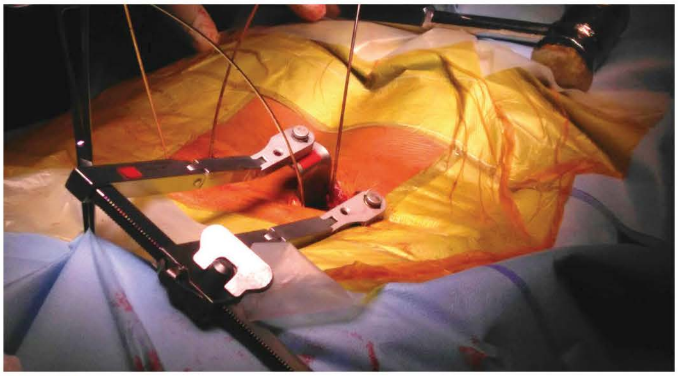
Mastering
MIS TLIF

Rodrigo Miziara Yunes





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RODRIGO MIZIARA YUNES was born in 1976 in Ribeirão Preto/Brazil, and lives in São Paulo with his wife and two daughters.

In 2000, he finished Medical School at the Federal University of São Paulo and attended the neurosurgery residency between 2002 to 2006.

He has been working in the field of Spinal Surgery since then, treating degenerative diseases of the spine, including child and adult deformities, in addition to spine trauma and vertebral spinal tumors.

Whenever possible, he applies minimally invasive techniques to treat chronic spinal pain.

He is the clinical staff of numerous hospitals in São Paulo, working routinely at AACD Hospital, where he performs most of his surgeries.

“

I often tell younger doctors that the MIS TLIF is a challenge: “Show me a spine surgeon operating MIS TLIF, and only then I will tell you his qualities”.

”

Mastering MIS TLIF is a compilation of the operative technique MIS TLIF *(Minimally Invasive Surgery – Transforaminal Lumbar Interbody Fusion).*

In this work, I approach the surgical indications, complications, and surgical procedure described step by step, with anatomical details explained preliminarily, in a relaxed and well-illustrated way, making learning quite pleasant.

The target audience is spine surgeons and resident physicians (orthopedists or neurosurgeons) interested in the spine field, mainly in the MIS TLIF technique. On the other hand, mastering MIS TLIF gives the spine surgeon solid foundations for numerous other spinal techniques, such as endoscopic discectomy, pedicle subtraction osteotomy, and vertebrectomy, as they require extensive anatomical knowledge.

In addition, the MIS TLIF helps the surgeon master the excellent indication regarding disc disease as a source of axial and radicular pain, widespread in medical practice, improving results by empowering the best candidate for the technique.

MIS TLIF is a recent technique and requires a lot of knowledge and skills from the spine surgeon since discectomy and spinal instrumentation are performed through a working channel of only 2 cm. It certainly is a procedure with its limitations, and the experienced surgeon will respect the technique's indication limit and his own within his learning curve.

I often tell younger doctors that the MIS TLIF is a challenge: "Show me a spine surgeon operating MIS TLIF, and only then will I tell you his qualities." However, I have been practicing this technique for ten years. Therefore, I have acquired the necessary knowledge and experience to master this surgery with immersion and passion for Human Anatomy since my first years of medical school.

Over the years of medical residency, I practiced spine dissections aimed at spinal surgery, creating solid and essential foundations for the MIS TLIF. However, there was no compendium dedicated to this subject at that time, which motivated me, with mastering and solidifying my learning curve, to write this work on the MIS TLIF technique.

My satisfaction in seeing the patient rehabilitated with the technique performed correctly motivates me to continue improving my knowledge in this technique. It is a powerful weapon that solves the vast majority of cases of degenerative disc disease prevalent in the office.

My passion for Human Anatomy led me along this path that I took with great care, pride and satisfaction. Now I can contribute to the scientific community by transmitting my knowledge to the young.

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Acknowledgment

To my parents, Dr. Paulo and Mrs. Rita made me who I am and were examples with all their love and dedication.

I dedicate this book also to my beloved wife, Catherine, who provided me with a family and a home.

Especially to my daughters, Lisa and Lilian; they are my little pieces and my reason to live. I dedicate, in return, my infinite and unconditional love.

Mrs. Jaqueline Garcia and Mr. Eduardo Silva kindly provided MIS TLIF surgical instruments to illustrate the technique; then, I registered my eternal gratitude.

I acknowledge the illustrator Vinícius, who gave life to my ideas in his drawings, and to photographer Wagner, who showed his brilliance.

I thank those who once were among us and still contribute to my learning. The Human Anatomy Laboratory is where the dead teach the living. Thus, I thank those anonymous who allowed me to walk through this journey of knowledge.

Finally, I am immensely grateful to all my patients I had the opportunity to operate on and for their trust. Without them, I would never have improved my knowledge and skills in MIS TLIF.

DR. RODRIGO MIZIARA YUNES M.D.

Disclosure

Some of the MIS TLIF implant instruments demonstrated are Spine Art® brand. They were kindly provided to compose the illustrations by Mrs. Jaqueline Garcia Ribeiro, owner of Spine Level Company, and its commercial manager, Mr. Eduardo Silva Júnior, who represents the brand in São Paulo.

I have no business relationship between the representatives and manufacturers, and their illustration was only for educational purposes. There is no better way to demonstrate the technique without illustrating the instruments, as the method depends on the implants exclusively developed for that purpose. Other brands were contacted to compose the compendium, but none was ready to contribute.

Without their cooperation, this work would be incomplete, and in this way, I register my eternal gratitude.

There are no other conflicts of interest to be registered. This literary work is a compendium for future spine surgeons who intend to improve and master the MIS TLIF technique.

DR. RODRIGO MIZIARA YUNES M.D.

1 About This Book

Mastering MIS TLIF is a compendium about the operative technique Minimally Invasive Surgery – Transforaminal Lumbar Interbody Fusion.

In this book, I describe the indications, complications, and surgical technique explained step by step, with anatomical details related, in a relaxed and well-illustrated way, making learning very pleasant.

The target readers are spine surgeon residents (orthopedics or neurosurgeons) interested in improving the MIS TLIF technique.

On the other hand, mastering MIS TLIF gives the spine surgeon solid foundations for numerous other spinal surgical techniques, such as discectomy, spinal canal tumor resection, and anterior spinal column surgery via a posterior approach, such as pedicle subtraction osteotomy and vertebrectomy, as it requires extensive anatomical knowledge and anatomic-radiological correlation.

In addition, knowledge of MIS TLIF helps the surgeon master the excellent indication of the technique regarding discopathy as a source of axial and radicular pain, which is very common in medical practice, improving the results by potentializing the best candidate for the technique.

MIS TLIF is a recent technique and requires much knowledge and skills from the spine surgeon since discectomy and vertebral column instrumentation is performed by a tiny working channel 2 cm wide. However, it sure is a technique with its limitations, and the experienced surgeon will respect the indication limits within his learning curve.

I often tell younger doctors that MIS TLIF is a challenge: "Show me a spine surgeon operating by MIS TLIF, and only so I will tell you his qualities."

I have been practicing this technique for ten years. Since my first years of medical school, I have acquired the knowledge and experience necessary to master this surgery with immersion and passion for Human Anatomy.

My satisfaction to see the patient rehabilitated by MIS TLIF performed correctly is a great motivation to continue improving my knowledge in this technique. It is a powerful weapon that solves most degenerative disc disease cases widespread in outpatient clinics.

I applied my anatomical laboratory studies to spinal surgery during my medical residency. At that time, there was no compendium about MIS TLIF, which motivated me, with the domain and solidification of my learning curve, to write this book about MIS TLIF.

My passion for anatomical studies walked me along this pathway, which gives me great pride and satisfaction. Now I can contribute to the youngest and transmit my acquired knowledge over these years of research and training.

Remember that this book should be used as a reference, and It will not dispense your learning curve. The complete technical domain will take a few years of practice. Respect your patient, respecting primarily your limitations. A good doctor recognizes his weakness.

2 Preface

Posterior interbody fusion was described by Cloward[1] in 1952 and has evolved tremendously since then as a result of the emergence of modern surgical instruments and new methods that allow for better technical quality in its execution. In 1982, Harms[2] described TLIF (transforaminal lumbar interbody fusion), a known effective spinal fusion weapon.

In 2002, Foley and Lefkowitz[3] introduced the term MISS (minimally invasive spine surgery), later extended to TLIF and is currently known in the medical literature as MIS TLIF.

The open and conventional TLIF technique, described in the mid-1980s, underwent a substantial technical improvement to perform disc removal, bony decompression, deformity correction, and spine stabilization by a single working channel, as slight as the channel used for a microdiscectomy.

MIS TLIF, since its introduction, has shown fewer complication rates than the conventional and open technique, less bleeding, minor muscle detachment, shorter hospital stays, less postoperative analgesics, and early return to activities, whether social, physical or labor. Furthermore, the paravertebral muscle is neither detached nor devascularized, and consequently, it is not atrophied or denervated, thus preserving its natural stabilizing and motor function.

The MIS TLIF has characteristic vital points that define it: (1) minor tissue damage (muscle and bone) and, therefore, less segmental iatrogenic instability and less postoperative pain, (2) direct and indirect anterior and posterior column decompression in a single-stage approach, (3) correction of segmental deformity (disc flattening, olysthesis and segmental kyphosis) and, last but not least important, the (4) stability of the operated segment. These objectives are possible by two small working channels, defined on average by 2 cm (1 inch) of skin incision over the facet joints for each operating segment.

Since the working channel is narrow, the surgeon must respect some essential key features before indicating MIS TLIF. I will discuss in-depth these points listed below:

- 1st Choose the patient correctly
- 2nd Have the proper surgical instruments
- 3rd Master the nerve root anatomy
- 4th Respect your learning curve

When the surgeon performs MIS TLIF correctly, he has in his arsenal a powerful weapon to solve the vast majority of cases present in clinical practice, especially the most common degenerative disorders of the lower lumbar region, such as disc herniations with segmental deformity and instability, spondylolisthesis, and spinal stenosis without using more invasive approaches such as ALIF, and necessarily supplement spine fixation with posterior instrumentation in a double-stage.

3 The nerve root pathway anatomy

The previous domain of the anatomy of the lumbar nerve root is essential before indicating surgical treatment by MIS TLIF. The working channel is narrow, and removing bone structures is minimal, so a thorough knowledge of the nerve root anatomy is imperative. In addition, adjacent neural structures are not fully visualized, and therefore, mastering their exact location is necessary to remove the disc without injuries.

The nerve root that emerges in the foramen is intradural, and only in the region close to the dorsal root ganglion (DRG) has a dural reflection. However, in its extraforaminal portion, it is wholly extradural.

It follows a caudal course around the pedicle and emerges through the foramen, leaving a small neural free disc area (triangular safe zone), where we perform the discectomy in the TLIF. (fig. 1)

The nerve root follows a recurrent pathway in the lumbar spine, from L1 to L5. Between L5 and S1, there is a slight difference in the emergence of the S1 nerve root, which I will detail later.

For surgical purposes, the nerve root pathway is divided into four different anatomical levels (fig. 2 A-C).

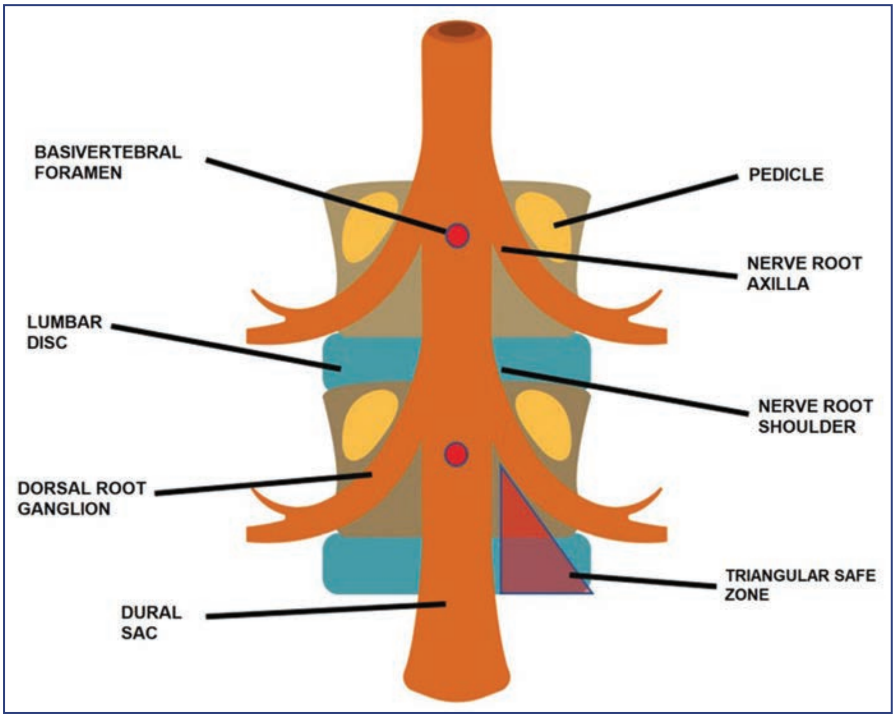


Figure 1 – Illustration of the nerve root pathway inside the lumbar spinal canal (L1 to L5)

THE LUMBAR NERVE PATHWAY LEVELS

1. Disc Level
2. Foraminal Level
3. Pedicular Level
4. Suprapedicular Level

NOMENCLATURE

The lumbar vertebrae are numbered L1 to L5. The discs receive the nomenclature corresponding to the upper vertebra on which they rest. For example, L1 disc in which L1 vertebra is cranial to, L2 disc in which L2 vertebra is cranial to, and so on successively. The L1 disc is not named "L1-L2 disc".

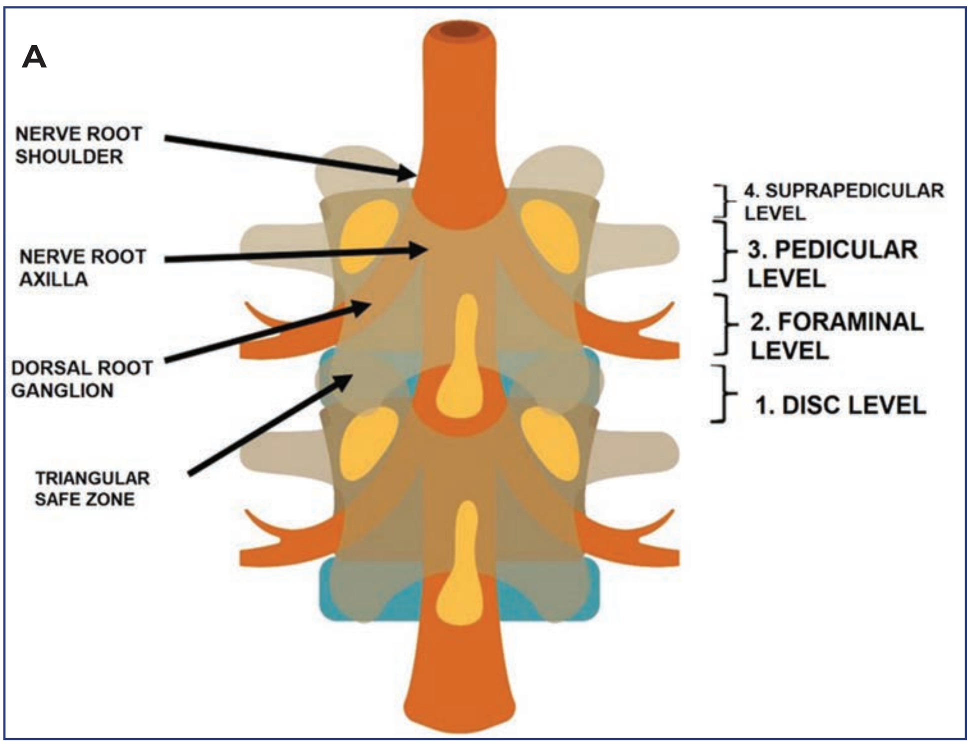


Figure 2A – Illustration of the nerve root levels from L1 to L5 inside the spinal canal

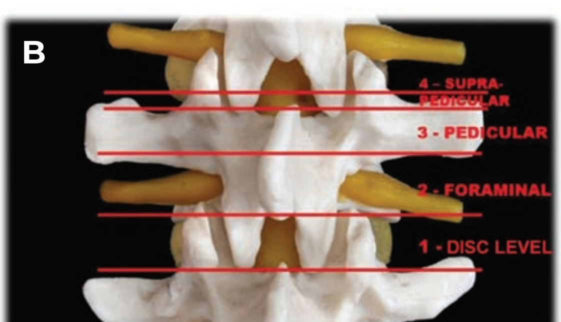


Figure 2B – Posterior view

Figure 2C – Lateral view

The emerging nerve roots and the corresponding foramina are given the name of the disc adjacent to them: the L1 root emerges through the L1 foramen adjacent to the L1 disc (fig. 3) and so on.

1: Disc Level

The first level comprises the core of MIS TLIF. The intervertebral disc is bare of neural structures at this level. The disc level is between the superior and inferior endplates of the vertebrae that form the disc space.

It is on this level that we perform the discectomy. The anatomical bone structure corresponding to the disc level is the facet joints.

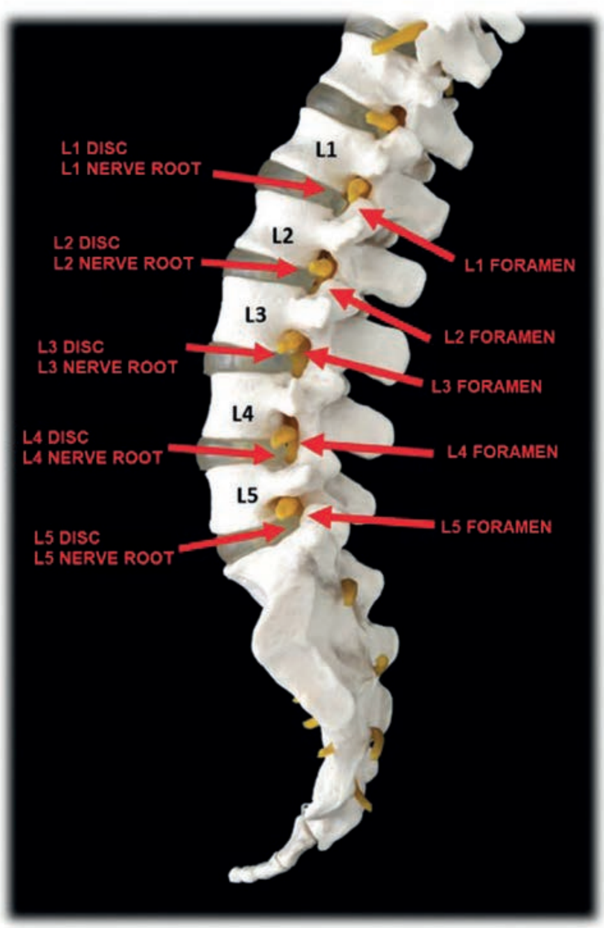


Figure 3 – Lumbar spine – basic nomenclature

From an anatomical point of view, the disc level corresponds, in part, to the intervertebral foramen. However, for didactic and surgical purposes, the foramen is subdivided into two levels to facilitate understanding of the importance and target of the disc level, the main issue addressed by the MIS TLIF surgeon.

At the medial edge of the disc level (inside the spinal canal), the nerve root shoulder can be seen, and it marks from the L1 to L5 nerve roots, the disc level and is the best intracanal reference to the intervertebral disc.

2: Foraminal Level

This level corresponds to the nerve root region emerging from the lateral recess and here lies the dorsal root ganglion (DRG) (fig. 1).

It is vital to report that this region should never be approached by the surgeon who executes MIS TLIF. The manipulation of this area causes one of the leading acute complications of this technique, transient dysesthesia. Furthermore, it is unescessary expose this level, as there is no disc in the emergence of the ganglion in addition to the existence of voluminous venous plexus in this area, worthy of massive bleeding.

From my point of view, the manipulation of the foraminal level by the surgeon operating MIS TLIF is due to a lack of experience and intraoperative spatial disorientation. Therefore, assiduous and prior knowledge of this anatomy is paramount for its correct execution.

The corresponding bone structure posterior to this region is the *pars interarticularis*. It is subdivided into the *isthmus* and the lateral *pars*. The *isthmus* corresponds to the posterior wall of the lumbar pedicle; it is the "neck" of the Scotty Dog. The lateral *pars*, in turn, corresponds to the nerve root exit door through the foramen, close to the extraforaminal zone, inferiorly to the pedicle. It is the upper limit of inferior facetectomy (figs. 8 and 9).

3: Pedicular Level

The pedicular level corresponds to the region that encompasses the top and bottom edges of the pedicle. Therefore, the pedicular level is the pedicle region from an anatomical point of view. The posterior wall of the pedicular level corresponds to the *isthmus* (fig. 9).

Figure 4 – Basivertebral foramen at the pedicular level – lumbar vertebra

In this region, lies the axilla of the nerve root medially to the pedicle (fig. 2A). In the center of the posterior surface of the vertebral body at the pedicular level, medial to the nerve root axilla lies the basivertebral foramen (fig. 4). From this foramen emerges the vein of the basivertebral plexus drainage system, the anterior epidural venous plexus. The inadvertent manipulation of the axillary region of the nerve root causes massive bleeding and should never be explored in disc approach surgeries.

4: Suprapedicular Level

The suprapedicular level corresponds to the superior endplate and the upper pedicle border. The emerging nerve root from the dural sac and its shoulder is located at this level (fig. 2A).

The nerve root shoulder is of paramount importance, as it marks the edge of the superior vertebral endplate and the lower edge of the

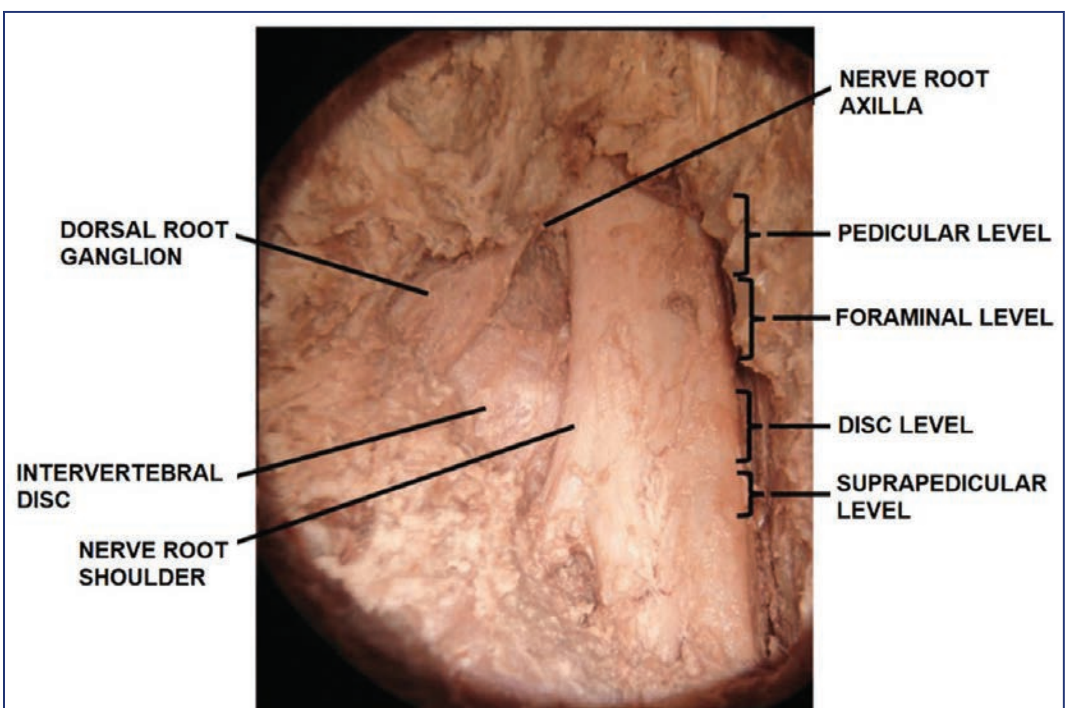


Figure 5A – Microsurgical view of the safe triangle intervertebral disc. It is the best anatomical intracanal landmark to find the intervertebral disc.

During discectomies, finding the nerve root shoulder, we can infer that we are at the disc level. However, in surgeries, epidural fat interspersed with the venous plexus makes it challenging to find the disc without bleeding. Therefore, we can see the disc space with little neural manipulation and venous plexus bleeding by identifying this anatomical repair.

In vivo, unlike figure 5 anatomical picture, the dural sac is filled with cerebral spinal fluid, further facilitating nerve root shoulder identification.

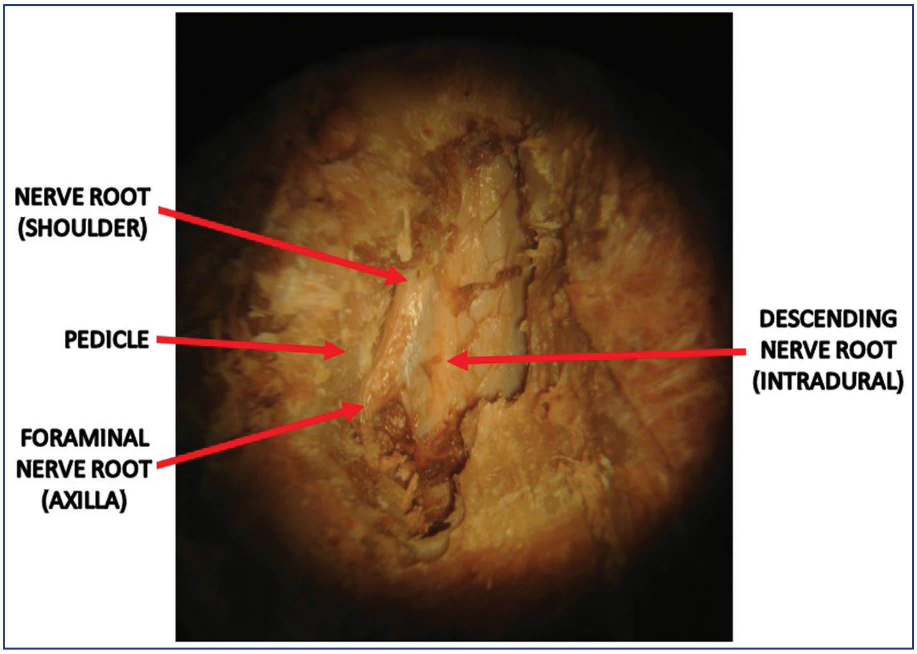


Figure 5B – The nerve root pathway anatomy

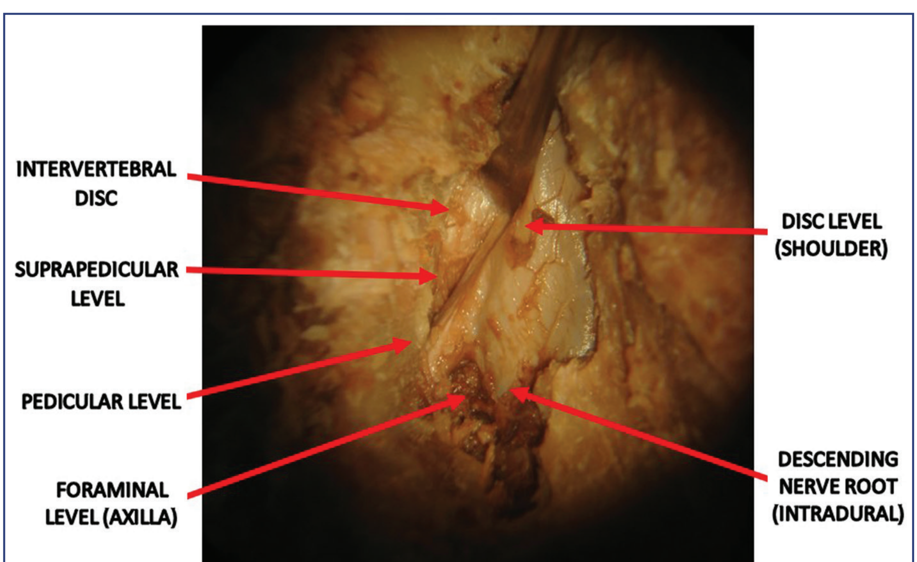


Figure 5C – The nerve root pathway and its levels

BONE LANDMARKS ANATOMY

The correlation between the nerve roots and the bone structures is also essential (fig. 6). Otherwise, the surgeon misses intraoperative orientation when minimal epidural bleeding occurs due to manipulating an inappropriate site.

The disc level is the main target in the TLIF approach and is precisely located at the level of facet joints. The disc bare of neural structures lies anterior to the articular facets, and here it is possible to remove the disc content without manipulation of nerve roots.

The inferior articular facet is located medially relative to the superior facet. Both facets have an

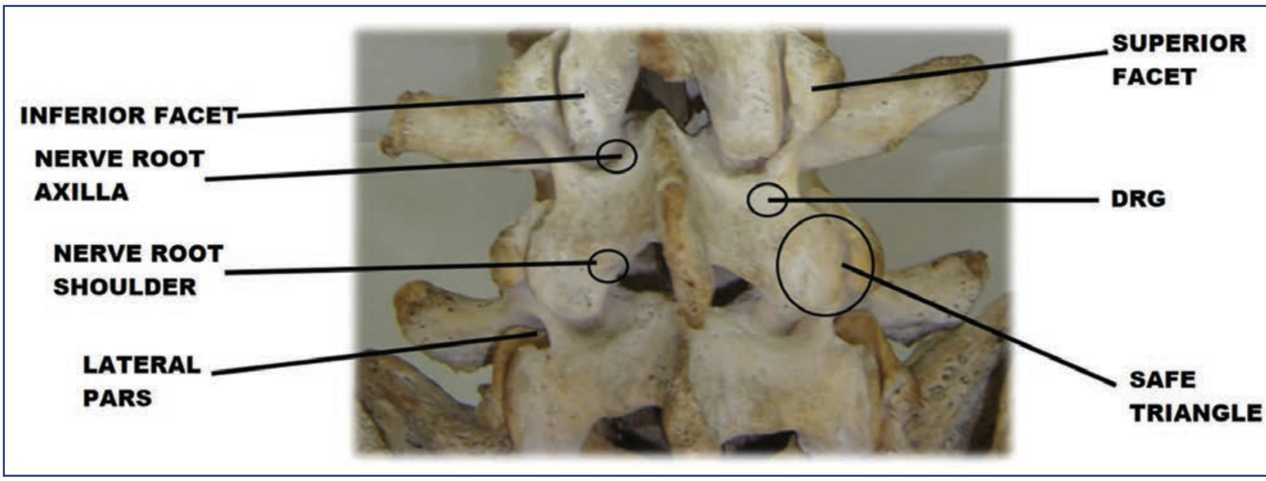


Figure 6 – Lumbar posterior surface – L4-L5 segment

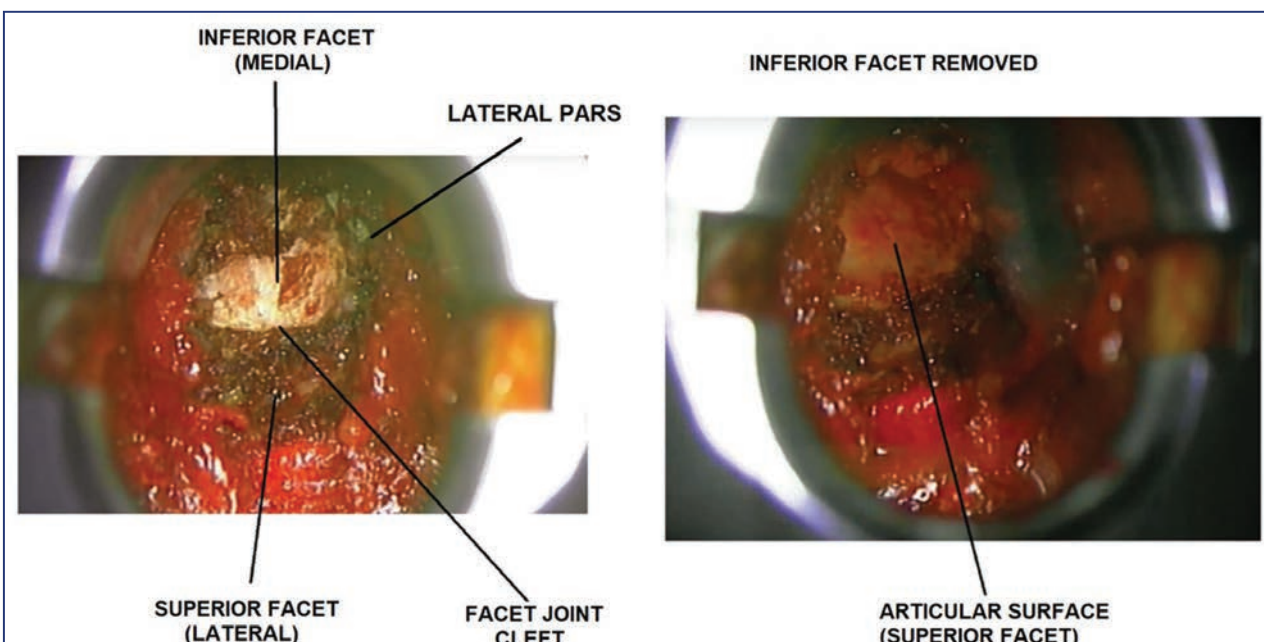


Figure 7 – Microscopic view of the facet joint (patient's right side) – the cranial region is at the right side of the image

articular surface facing eachother and laterally rotated.

In this way, removing the inferior facet joint exposes the superior facet articular surface (fig. 7). The inferior facet is the first bone structure removed in TLIF and is directly related to the lateral pars and the lamina. Therefore, the lateral pars marks the upper limit of the inferior facet cut for its complete removal, without injuring the dorsal root ganglion, superiorly located, which will be demonstrated in chapter 6. On the other hand, the medial limit is the lamina-inferior facet junction (LIFJ) (figs. 8 and 9).

Remember that these bone structures are named and divided for educational purposes. The transition between them is subtle and should be visually accustomed by the surgeon to recognize its correct location intraoperatively.

The articular surface of the superior facet joint, in turn, is identified after removal of the inferior facet medially. It relates directly to the pedicle.

The recognition of this correlation is fundamental, as it avoids accidental breakage of the pedicle during superior facetectomy. Its inferior portion continues with the pedicle and must be recognized by the surgeon. See the relationship between them in figures 10 and 11. This relationship is of utmost importance for MIS TLIF surgeons.

The transverse process continues with the pedicle in its medial extension. Thus, it should be used as a guide to finding the exact location of the pedicle intraoperatively. Note this close relationship between those structures in figures 10 and 11.

The lateral recess comprises the region between the pedicle, the intervertebral disc, and the superior facet. It is an imaginary area within the spinal canal (figs. 12 and 13A), where lies the nerve root shoulder emerging from the dural sac. The lateral recess corresponds to the nerve root entry into the intervertebral foramen, and it is also the target of bony stenosis of the spinal canal. Therefore, in facet hypertrophy and disc degeneration, the patient's neurological symptoms are mainly due to stenosis of this area. Think of the lateral recess as the entry door of the nerve root pathway in the spinal canal and the foramen, while the exit door is the lateral pars.

Finally, the spinal canal is delimited between the medial edges of the pedicles. The region between the lateral and medial borders of the pedicle is the foraminal zone, and the area lateral to the outer edge of the pedicle is the extraforaminal zone (fig. 13A). The facet joints are the anatomic landmark for delimiting the foramen and the

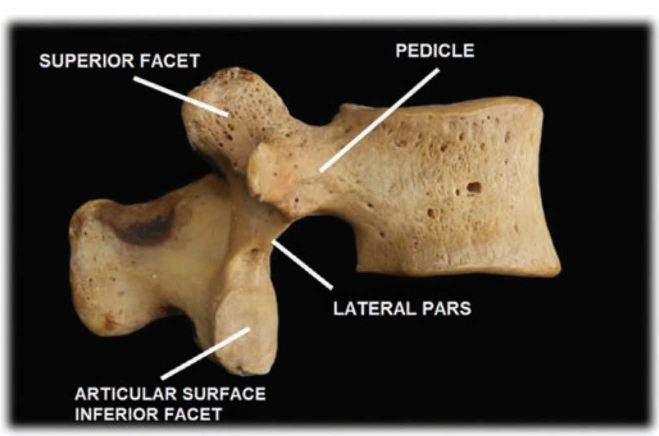


Figure 8 – Lateral view (lumbar vertebra)

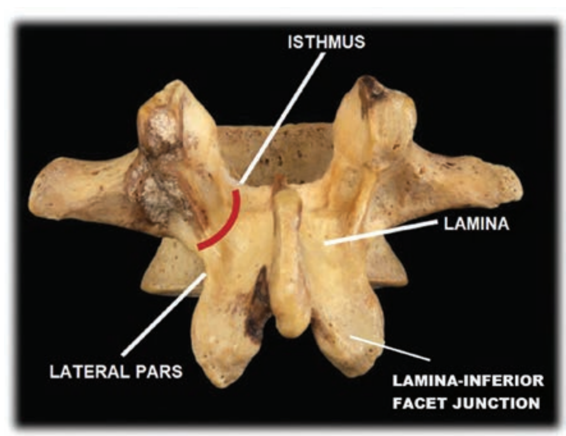


Figure 9 – Posterior view (lumbar vertebra)

spinal canal limits, shown in the same figure. The spinal canal lateral limit landmark is the lamina-inferior facet junction (LIFJ) on both sides. In figure 13B, the nerve root complete pathway is seen to facilitate comprehension.

The triangular safe zone

A triangle is delimited between the nerve root shoulder medially that traverses the disc level (descending nerve root), the edge of the superior endplate, inferiorly, and laterally, the foraminal nerve root and DRG. It is known as Kambin´s triangle. Some authors call it the "triangular safe zone" because it is the disc region that is bare of neural structures, and the disc may be safely removed in this area (fig. 14).

The width of the triangle safe zone[5] (distance between the dural sac and foraminal nerve root) in adults is, on average, 10 mm for the L2 and L3 discs, 13.72 mm for the L4 disc, and 18.87 mm for the L5 disc. Once the L4-L5 and L5-S1 segments correspond to the vast majority of degenerative changes of the lumbar spine in adults, we can infer that the triangle region to be approached measures between 13 and 18 mm on average. In this way, given the small disc space area bare of neural structures, the correct knowledge by the surgeon of this area is essential before approaching this region. The base of the triangle

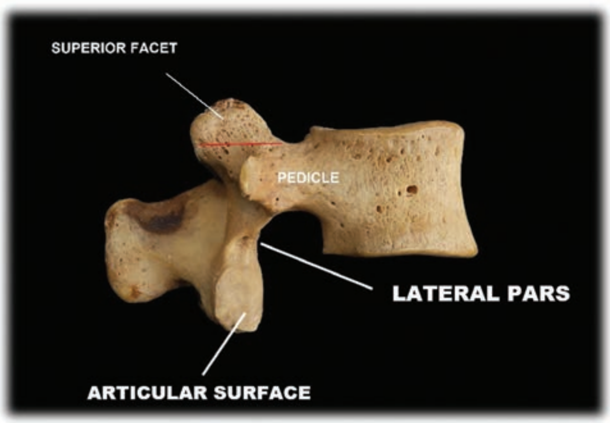


Figure 10 – Lateral view

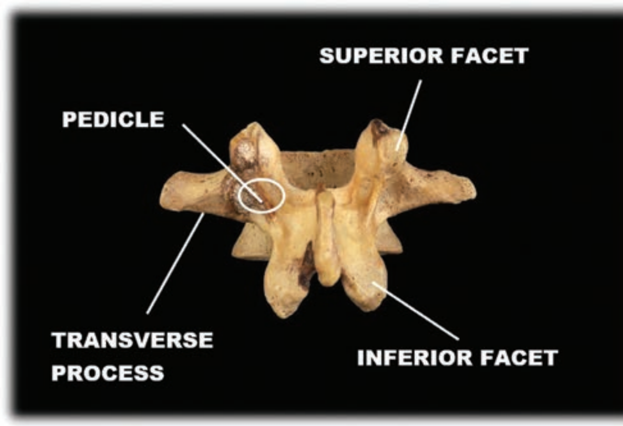


Figure 11 – Posterior view

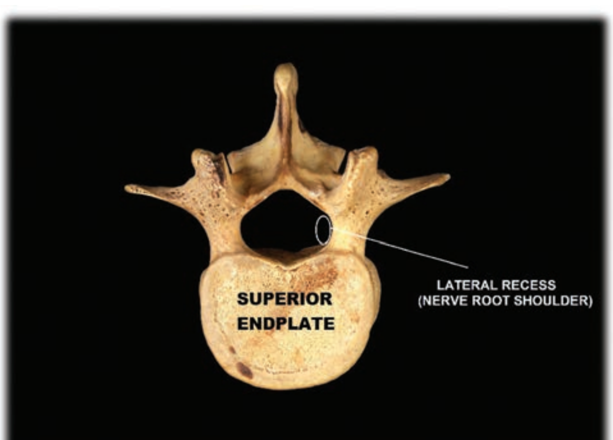


Figure 12 – Lumbar vertebra superior view

lies on the suprapedicular level and the remaining lies through the disc and foraminal level. The triangular safe zone is located in the foraminal zone. Because figure 14 is in two dimensions, it gives the erroneous impression that Kambin´s triangle is located in the extraforaminal zone.

CORRELATION WITH FLUOROSCOPY

Knowing the lumbar nerve root pathway within the foramen is no more important than correlating all that knowledge with the fluoroscopy image, an indispensable weapon for the spinal surgeon.

Recognition of bone landmarks and their corresponding neural structures in the fluoroscopy image at different angles helps the surgeon locate himself intraoperatively without large incisions and direct vision.

The correct fluoroscopy view

Lumbar anatomy

The correct image view allows the exact visualization of the structures and avoids trajectory errors (figs. 15 to 18). In the posteroanterior (PA) view, the endplates and pedicles were aligned as follows:

- Endplates as parallel as possible
- Spinous process symmetrically between the pedicles

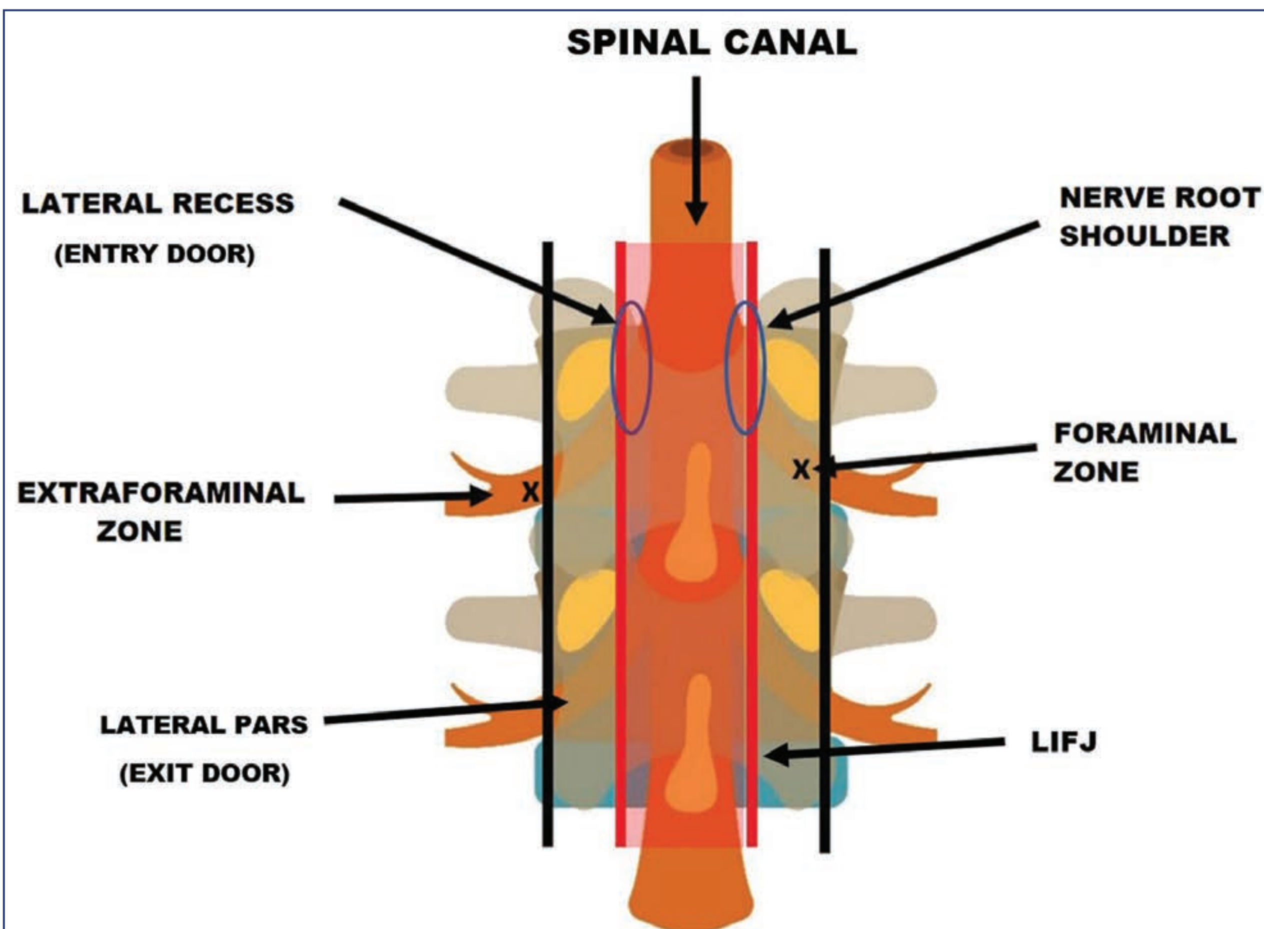


Figure 13A – The spinal canal and foramen limits

In lateral view, vertebral endplates, pedicles, and facet joints were aligned, and the structures were superimposed as a single image (fig. 16). Oblique incidence allows direct vision into the pedicle trajectory. Finally, in PA view, tilt fluoroscopy arc until the spinous process meets the contralateral pedicle. In this way, X-rays target directly into the pedicle trajectory, and the surgeon can see "inside" the pedicle (figs. 17 and 18).

In the oblique view, we can see the pedicle "as a tunnel" when checking for any accidental rupture into the lateral recess is necessary. A guidewire is inserted into the pedicle for demonstration purposes (figs. 19 to 22).

Sacral anatomy

The sacral anatomy is slightly different from the lumbar region regarding the facet joints and the pedicle. The sacrum has only the superior facets, and the transverse process is the sacral ala itself. The S1 lateral recess is narrower than in the lumbar region, and therefore, additional

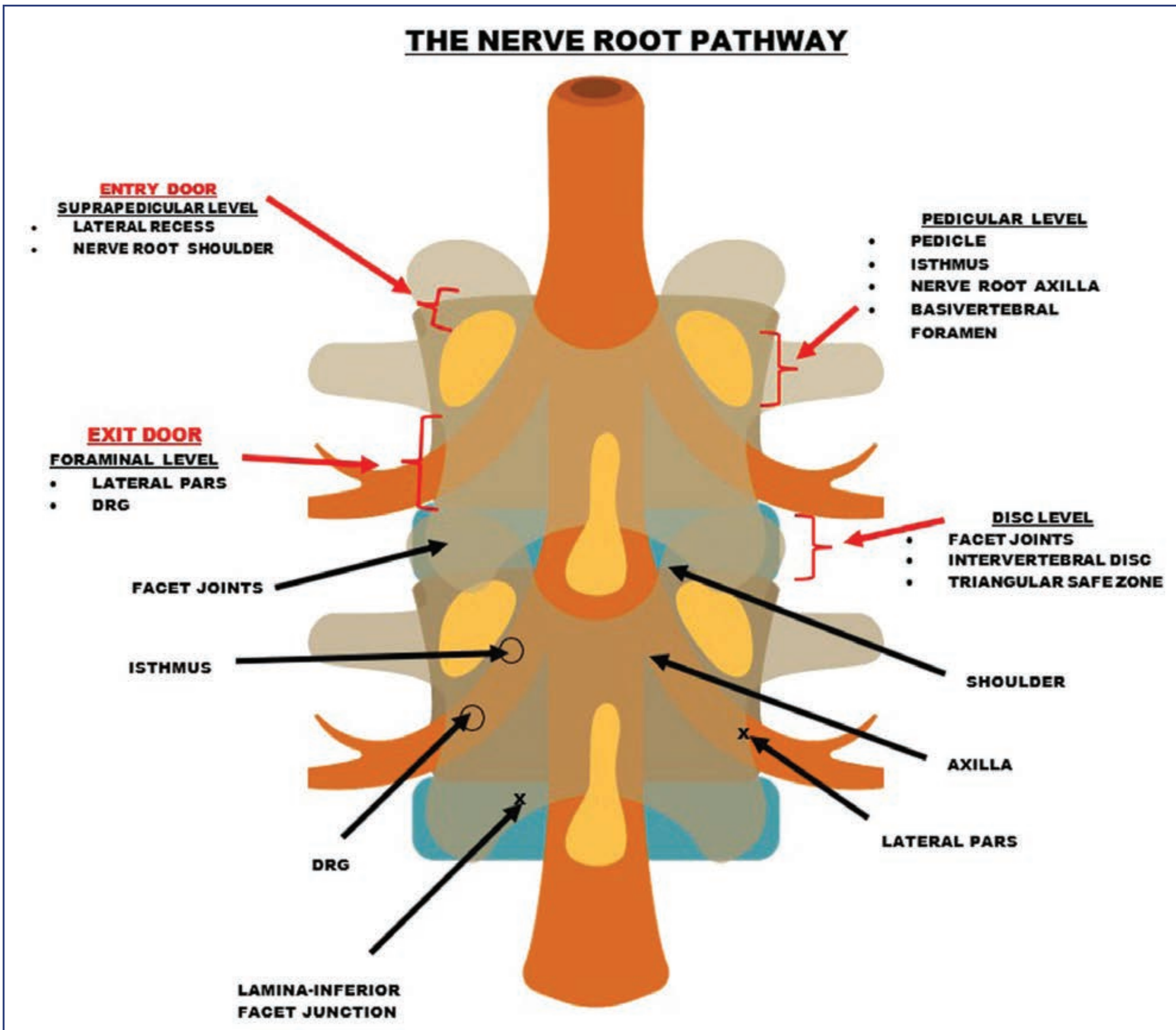


Figure 13B – The nerve root pathway inside the lumbar spinal canal care must be taken not to perforate the pedicle medially.

The most appropriate entry point for the S1 pedicle is at the intersection between the lateral and inferior edges of the S1 superior facet joint (fig. 24). Its pathway is craniomedial toward the promontory, with an average of 15° cranial and 25° medial (figs. 28 to 30). The same care must be taken to stop the needle introduction when its tip reaches the medial edge of the S1 pedicle on Ferguson fluoroscopy view (fig. 27). Remember that the S1 pedicle medial border is not always clearly visible on X-ray due to the large volume of cancellous bone in that region.

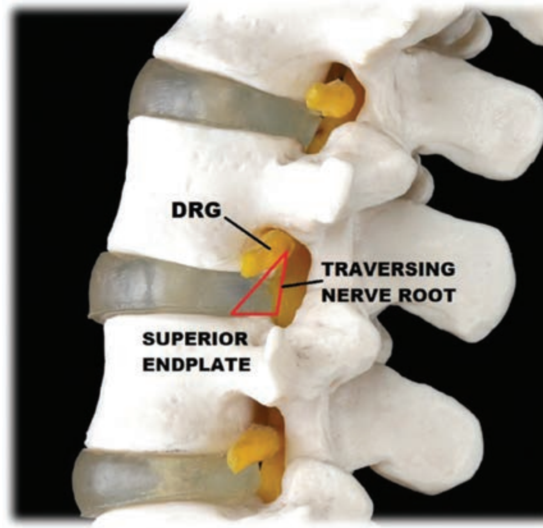


Figure 14 – Triangular safe zone – lateral view

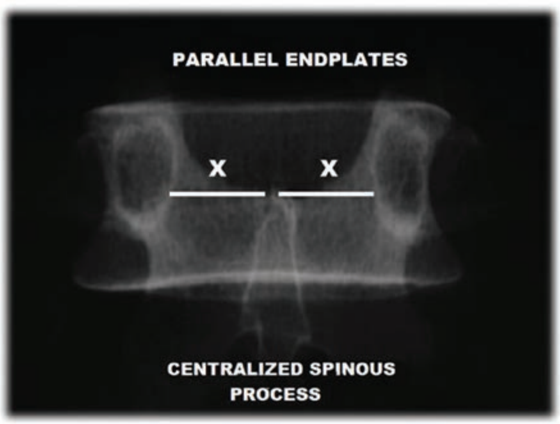


Figure 15 – PA View

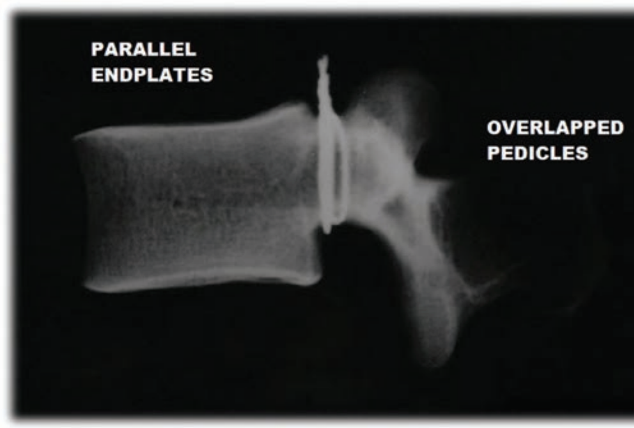
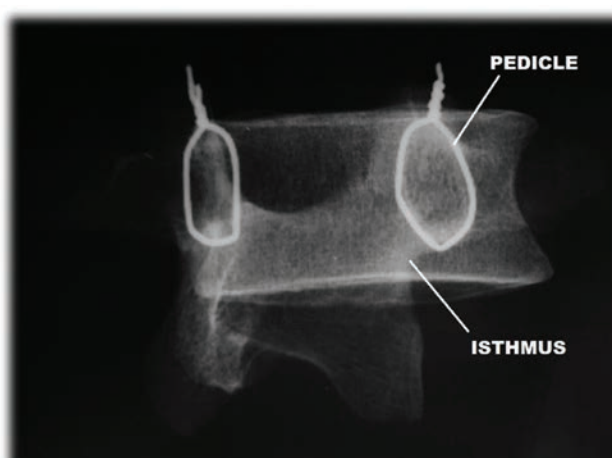


Figure 16 – Lateral view



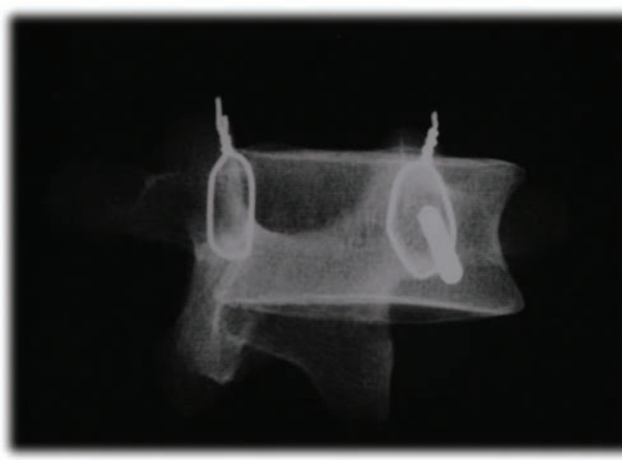
Figures 17 and 18 – Right side oblique view – Note the spinous process superimposed to the contralateral pedicle

The S1 to S4 nerve roots exit through the anterior sacral foramina. The anterior surface of the promontory is safe to place bicortical screws if necessary. In its lateral portion, facing the sacral ala, lesions can occur in the lumbosacral plexus and the artery-iliac vascular complex, the sacral ala unsafe zone (fig. 23 A-B).

Radiological anatomy

The pedicle does not change due to disc degeneration and rests beside the nerve root (figs. 31 and 32). To facilitate understanding, I marked the lumbar pedicles with a metallic marker, the main target in arthrodesis (figs. 33 and 34). The transverse process is superimposed on the pedicle in lateral view, but the lateral pars and facet joints are well visible. Remember that the nerve root rests medial and caudal to the pedicle, anterior to the isthmus and the lateral pars, heading toward the extraforaminal zone, just cranial to the safe triangle.

The PA view does not allow the correct visualization of the pedicle path since it angulates 25° at L4 pedicles and 30° at L5[6] pedicles. In this way, we must not insert the Jamshid needle beyond the medial limit of the pedicle edge before checking its correct location in the



Figures 19 and 20 – A guidewire is placed in the pedicle. The more oblique views there are, the greater the wire looks like a dot (the target sign)

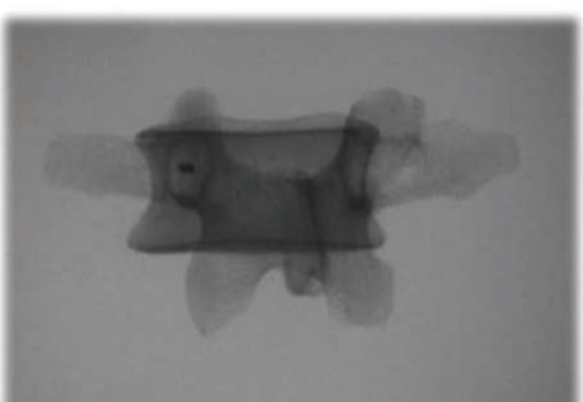


Figure 21 – Target sign (left side oblique view)

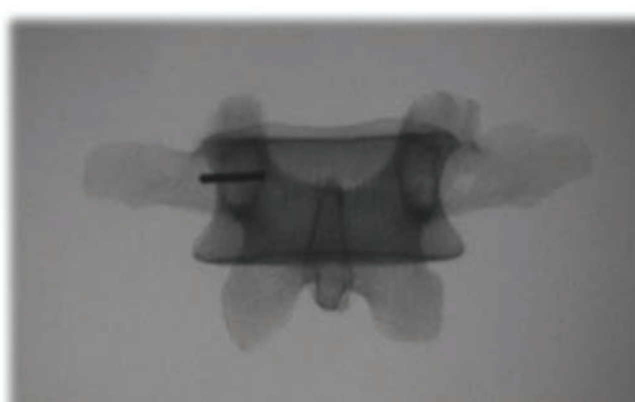


Figure 22 – Same image in PA view

lateral view; otherwise, the lateral recess or the anterior vertebral cortex could be compromised. The lateral view, in turn, provides vertebral body anterior limit and the depth of the pedicle trajectory. Therefore, in this view, the anterior safe place to rest the needle is the anterior third

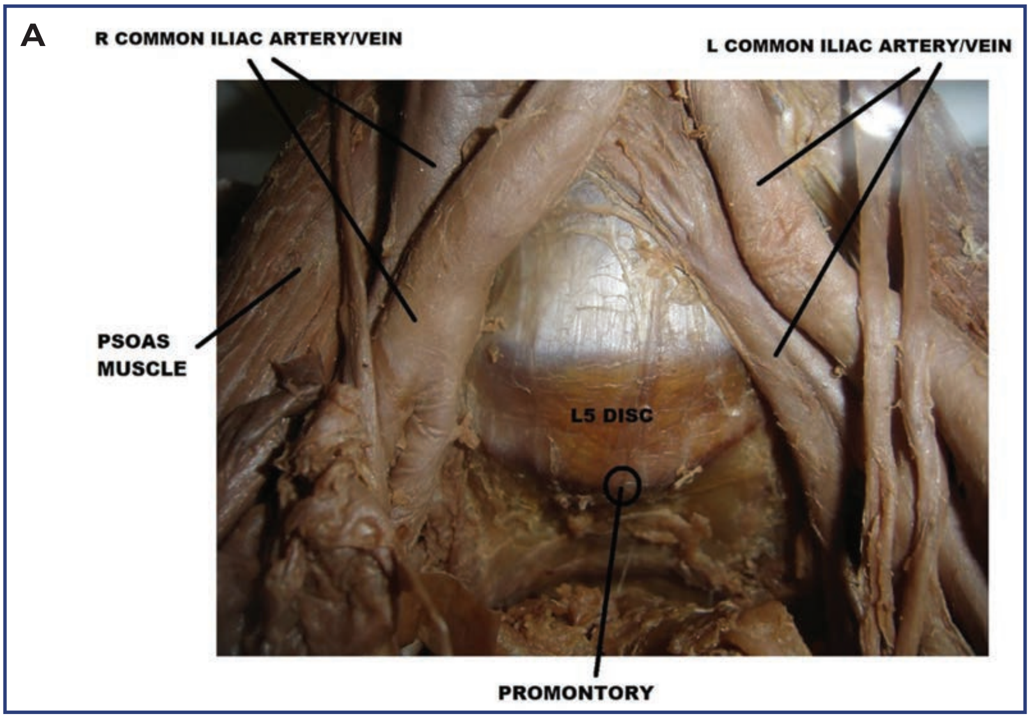


Figure 23A – Anterior pelvis and sacral ala (unsafe zone)

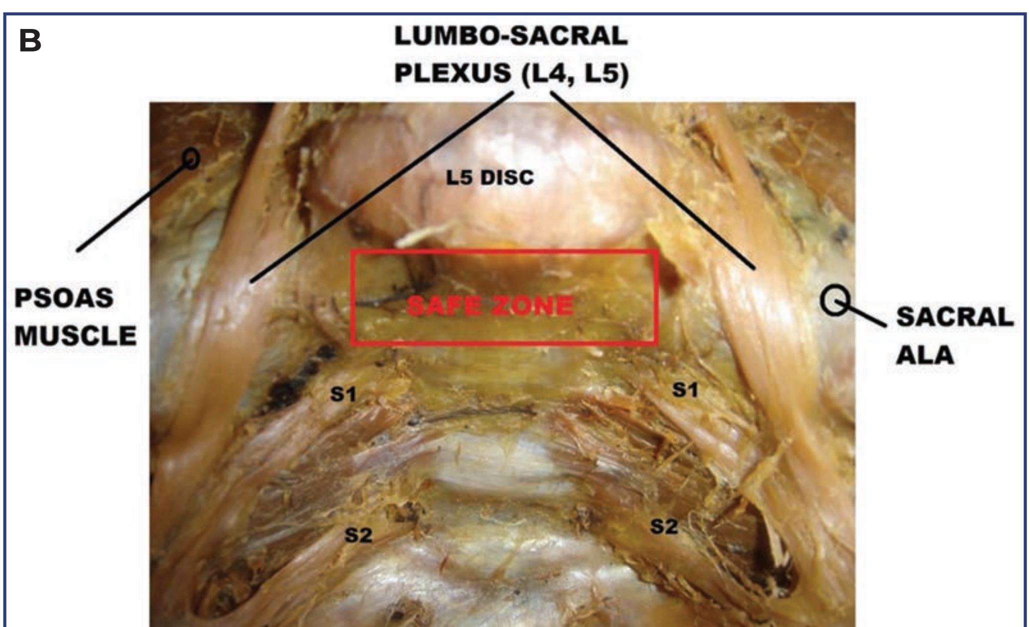


Figure 23B – Anterior pelvis and the safe promontory zone. Vascular complex removed of the vertebral body, as shown in the figures 37 and 38.

The pedicle trajectory follows an angulation for each level in PA view, as already described. The correct trajectory, seen from PA, ends slightly before the spinous process and never crosses the midline. If a screw crosses the midline, there is a high probability of breaching, inadvertently, the lateral recess (figs. 39 and 40). The same image, in oblique view, demonstrating the guidewire placed inside the pedicle, can be seen in figures 19 and 20. In this way, following the pedicle trajectory, the midline should never be crossed or reached by the guidewire or screw, with the screw inserted in its entirety, because this demonstrates pedicle violation into the lateral recess (fig. 41).

S1 NERVE ROOT PATHWAY

As already stated, the trajectory of the lumbar nerve root in the four levels follows a recurrent

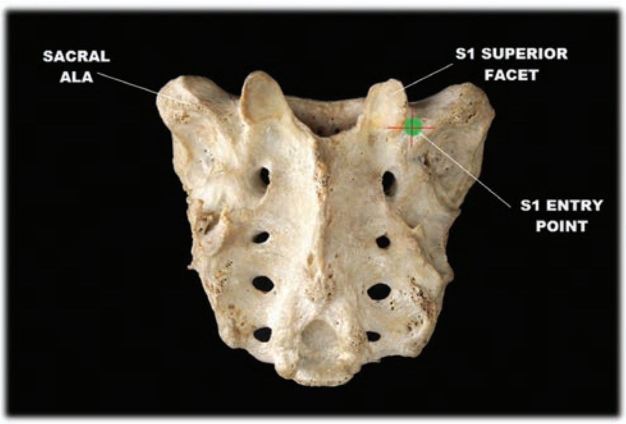
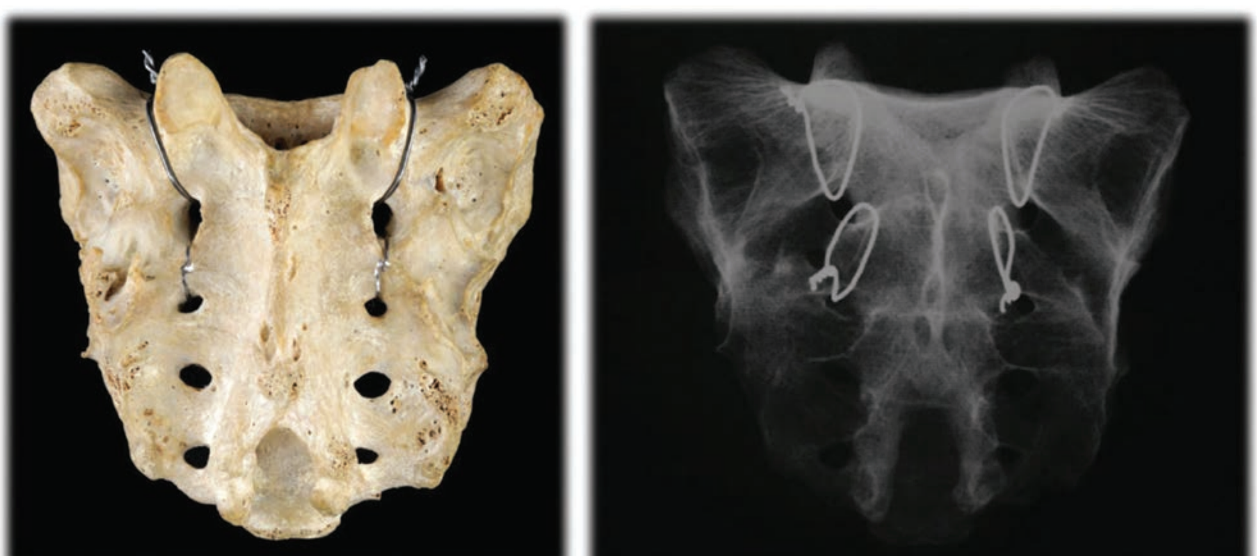


Figure 24 – Posterior sacral surface

Figure 25 – Anterior (pelvic) sacral surface



Figures 26 and 27 – Identification of the S1 and S2 pedicles – posterior surface and radioscopic Ferguson view pattern from L1 to L5, being slightly different for the S1 nerve root.

Learning human anatomy is based on repetition. Therefore, from L1 to L5, the nerve root emerges from the dural sac (root shoulder) in the suprapedicular level, entering the foramen through the lateral recess (the foramen entry door). Next, the nerve root runs caudally in the pedicular level, where the nerve root axilla can be seen. Finally, the basivertebral foramen is located medially inside the spinal canal at this same level.

Caudal to the pedicle lies the dorsal root ganglion (DRG) at the foraminal level. The DRG is located slightly cranial to the intervertebral

Hint:

- If the needle's tip in PA view lies at the pedicle medial border but in lateral view it is still inside the pedicle, not inside vertebral body, you made a trajectory towards the lateral recess.

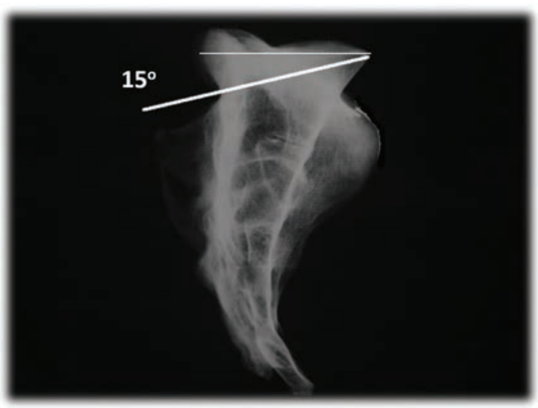


Figure 28 – S1 pedicle sagittal trajectory is 15° cranial

Figure 29 – S1 pedicle axial trajectory is 25° medial toward the promontory safe zone

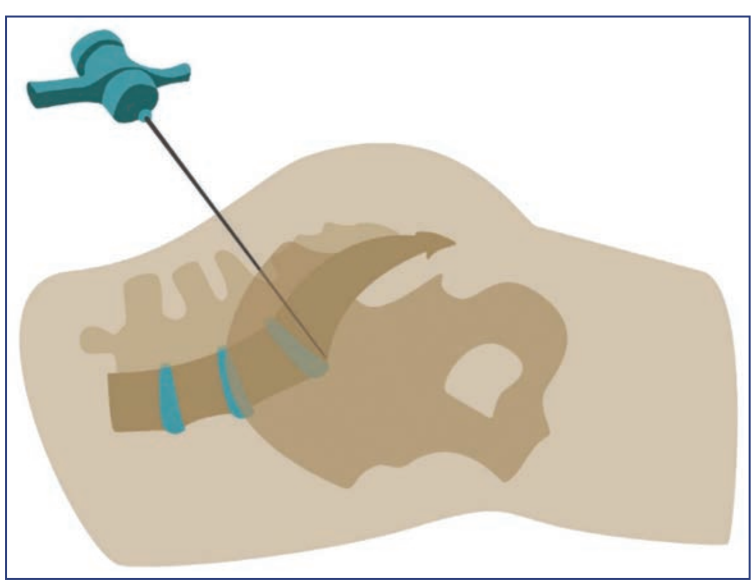


Figure 30 – The ideal trajectory of the S1 pedicle aims to the promontory safe zone in the lateral view

disc and anteriorly to the nerve root exit door, the lateral pars.

The S1 nerve root, in turn, emerges from the dural sac, not at the 4th level, such as the L1 to L5 nerve roots, but in the foraminal level (fig. 42). In virtue of this slight anatomical variation in the L5-S1 segment, the surgeon finds the disc through the axilla of the S1 nerve root during discectomies. This slight variation induces him to intraoperative disorientation. The ignorance of this variation often makes the surgeon move the S1 nerve root laterally, thinking it to be the L5 root, causing neurological damage or even dural tears because of working the discectomy through the S1 nerve root axilla. The most appropriate is identifying the S1 nerve root, moving it medially against the dural sac, and removing the disc lateral to the S1 nerve root.

On the other hand, complete facet joint removal opens the surgeon the triangular safe zone. In this way, the nerve root is in its normal anatomy, the L5 ganglion cranial to the disc, and the S1 nerve root medially.

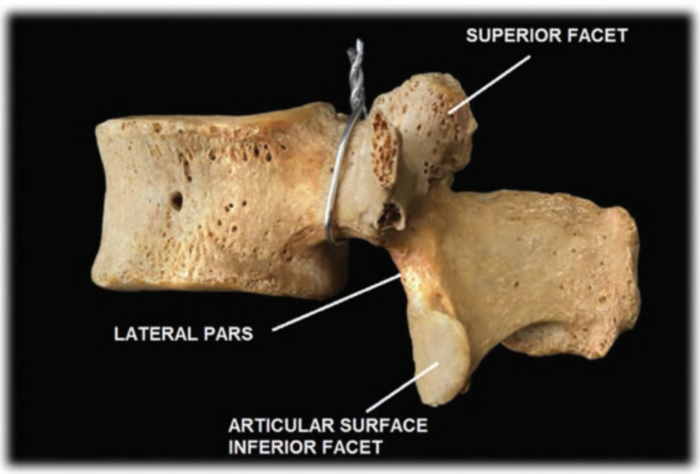


Figure 31 – Lumbar vertebra (lateral view)

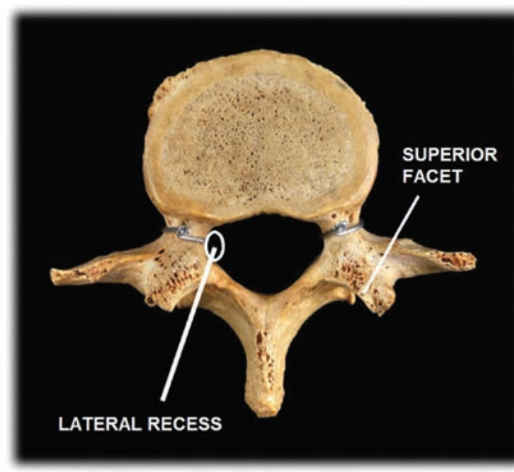


Figure 32 – Lumbar vertebra (superior view)

Figure 33 – Lumbar vertebra with a marker (lateral view)

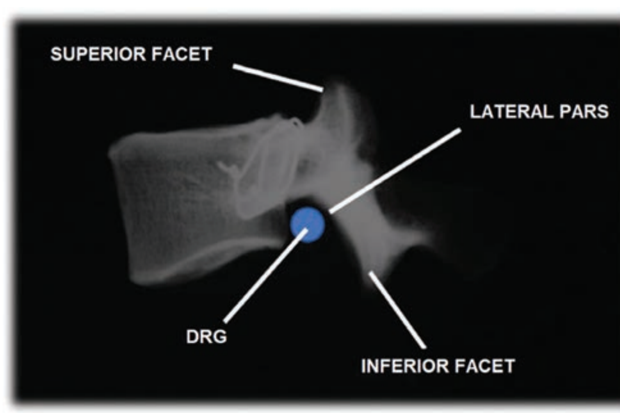


Figure 34 – Figure 33 X-ray projection

The prior domain of the nerve root trajectory from L1 to S1 within the vertebral canal is of fundamental importance for the spinal surgeon, especially for those who treat degenerative diseases, and manipulation of the disc is performed routinely.

Figure 35 – Lumbar vertebra with pedicle marker

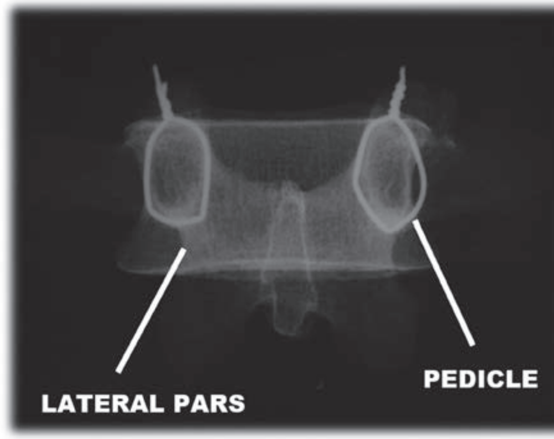


Figure 36 – X-ray view

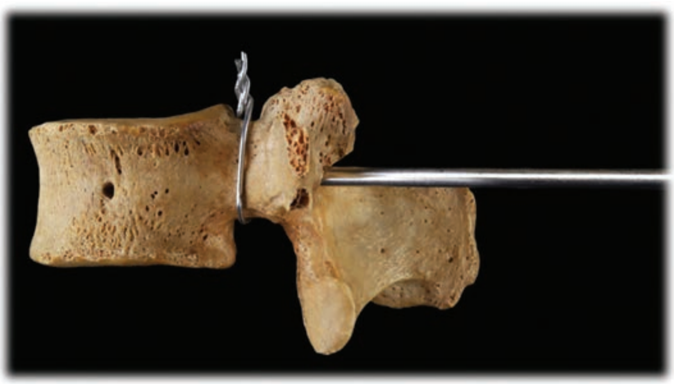


Figure 37 – Guidewire inserted – lateral view

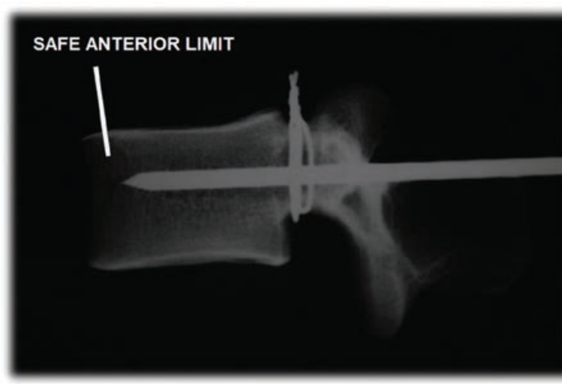


Figure 38 – X-ray view

Figure 39 – Guidewire inserted – PA view

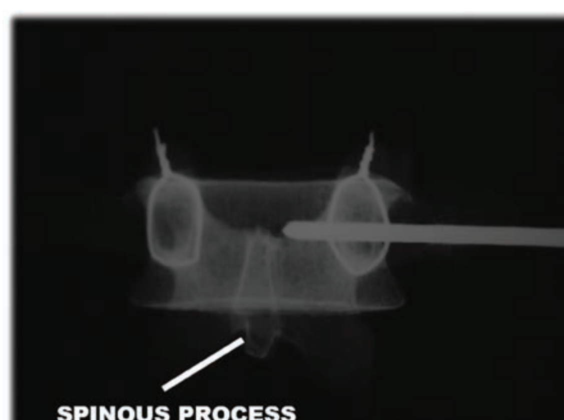


Figure 40 – X-ray view

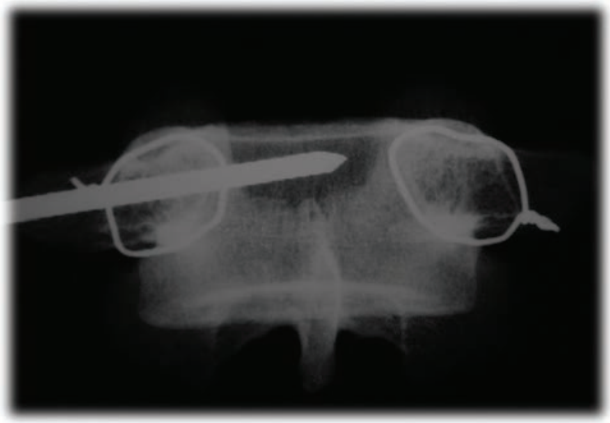


Figure 41 – Guidewire crossing the midline, indicating breaching the pedicle into the lateral recess

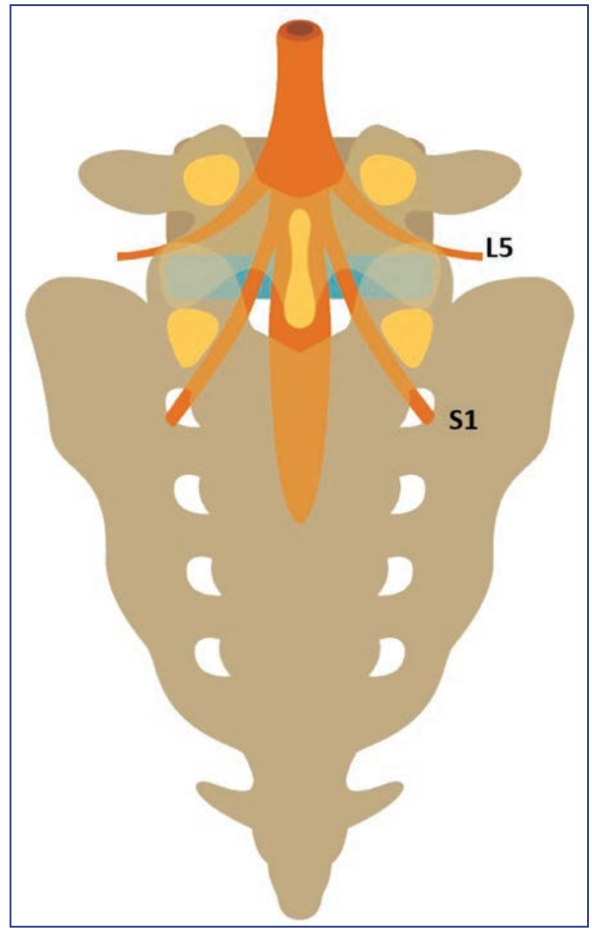


Figure 42 – Note the emergence of the S1 nerve root on the foraminal level and its axilla crossing the disc level

4 Indications

As a general rule, one should not indicate MIS TLIF for more than two levels, and the height of the disc space should not be less than 50% of the original height compared with the normal adjacent levels. This minimum of the remaining disc space is paramount to successfully restoring disc height, completely emptying the disc space, bone graft implantation, and correctly positioning the intersomatic cage in the disc space.

The proper study of the sagittal balance of the spine is also essential. The MIS TLIF is geared toward degenerative segmentary deformities without a global imbalance of the spinal column in the sagittal plane. In this way, the surgeon must remember that significant deformities with sagittal plane imbalances, such as degenerative scoliosis and flatbacks, should be treated by another technique, preferably the anterior approaches, where height gain and balance correction are best achieved. All global deformities of the spine must be respected.

The surgeon should never operate a single stenotic segment in an imbalanced spine by MIS TLIF. The patient will later suffer the consequences of not correcting the deformity and its imbalance, attributing this failure to the MIS TLIF technique. Therefore, the experienced surgeon must respect the limits of the method.

The MIS TLIF, in general, corrects the lumbar curvature when there is no deformity in the sagittal plane. The height gain is small, usually between 5° and 10° per segment, and only aims to restore the original disc height and prevent degeneration of the adjacent disc. There is a recent concept that is deformity prevention. It is known that segmental deformity, especially in the most caudal segments, such as L4 and L5, is the reason for significant global deformities and chronic low back pain. Based on this concept, preventing disc flattening is a goal of modern spine surgeon. Simple decompression entails segmental instability, even if minimal, and late deformity due to loss of disc height and segmental kyphosis. Chronic glacial instability leads to global[7] deformities as well.

Extreme care must be taken before indicating MIS TLIF in patients with compensated balanced lumbar deformities. As long as the height restoration is small using this approach, the experienced surgeon should study other treatment options in those situations.

The three goals of spine surgery that must be respected in all operations are decompression, correction and prevention of segmental deformity (flattened disc and olysthesis), and segmental stabilization. The MIS TLIF respects these goals when correctly indicated. When decompression is performed correctly, anterior elements, such as the disc, are directly (discectomy) and indirectly reached (through height gain and kyphosis restoration). Posterior structures can also be decompressed when indicated, such as central spinal canal stenosis, which can be easily done through additional facetectomies. High intersomatic cages restore disc height and prevent later deformity. Furthermore, they prevent adjacent disc overloads and segmental iatrogenic kyphosis (as discectomy does)—the theory of the instant axis of rotation[8,15]. The simple loss of one segment height can upset the global spinal balance and degenerate the adjacent discs.

Simple discectomies and laminectomies cause minimum iatrogenic instability and leads to chronic glacial instability. Stabilizing the segment with arthrodesis allows the patient early mobility, protects the neural structures and allows bone fusion of the intersomatic implant. In this way, the MIS TLIF must be chosen as a form of treatment when the cause of the symptomatology is neural compression and not the global deformity. When the primary cause of the pain and symptomatology of the patient is the global deformity, for example, in degenerative scoliosis and flatback, the use of another approach is a rational option. Attempting to perform MIS TLIF on flattened disc spaces does not allow adequate cleaning of the vertebral endplates and the implantation of high cages. Cage placement in these circumstances fractures the endplate ("intraoperative subsidence") and is subject to misalignment, migration, and severe nerve damage. The attempt to correct the collapsed disc space will be frustrating, leading to long-term treatment failure and intractable pain due to the lack of correction of segmental kyphosis and lumbar lordosis. The restoration of the original disc height is the primary goal of MIS TLIF, and the correct selection of the discs levels to be operated on must be respected, considering the limitations of the technique.

Due to marginal osteophytes, significant disc flattening challenges restoring the disc height by the transforaminal route. The major contraindications, therefore, for this technique are flattened discs. When lumbar or global deformities are the main reason for the pain source, and deformity correction is the main reason for the surgical treatment indication, for example, in patients with "flatback" or sagittal plane imbalance, MIS TLIF should be contraindicated. Anterior approaches, such as (anterior lumbar interbody fusion) ALIF, are more rational in these situations. In this way, I suggest using the Pfirrmann classification to guide the best MIS TLIF indication since global spinal balance is within normal limits. The ideal indication is Pfirrmann grades I to III. Grade IV should be judged depending on surgeon experience, and grade V should be contraindicated for MIS TLIF.

Nevertheless, the subject of great discussion in the literature is the indication of intersomatic arthrodesis for discogenic low back pain. I must emphasize that degenerative disc disease (DDD) is the main indication for chronic low back pain arthrodesis in clinical practice. Unlike herniated discs, which are more acute events, DDD is an entity apart, chronic, with lingering symptoms, and only in its late stages it causes sciatica-like nerve root pain. Therefore, the criteria for arthrodesis for degenerative discopathy as the primary cause of low back pain should be carefully analyzed before indicating MIS TLIF surgery.

As a general rule, I recommend lumbar fusion by MIS TLIF for patients with chronic low back pain, located in a manner compatible with the radiological findings, which present daily living activities restrictions, social, sports and labor. Patients must take pain medication regularly, perform frequent physical therapy, and score, on the numeric rating scale (NRS), an index greater than 5 for at least six months and without interruption. In these situations, performing at least one epidural nerve block during the follow-up period should be routinely performed before the indication of surgery. Numerous studies in the literature demonstrate the excellent effectiveness of epidural blocks[19], with various periods of symptomatic improvement. On the other hand, routine use to confirm symptomatic levels and exclude psychological factors is essential before indicating MIS TLIF.

Another indication for MIS TLIF is spondylolytic and degenerative spondylolisthesis with or without central canal stenosis. In these cases, one must consider the disc height as the main factor to indicate MIS TLIF. Spondylolisthesis can be treated optimally by this technique. The previous disc space must be wide open enough to be handled appropriately during discectomy and implantation of the intersomatic cage. Grade I and II Meyerding spondylolisthesis can be appropriately reduced by MIS TLIF. I have already carried out cases of grade III, with subtotal reduction and complete symptomatic improvement, as long as bilateral facetectomy and disc space distraction are performed using disc shavers to open the intersomatic space to reduce the vertebra and allow proper handling disc removal.

Intraoperative neurophysiological monitoring (IOM) is routinely used. The motor function of the L5 and S1 nerve roots is monitored, especially during distraction and reduction of the olisthetic segment. Spondylolytic spondylolisthesis has spinal canal enlargement; thus, its decompression is not required. Furthermore, facetectomy is performed only on the symptomatic side (ipsilateral to the radiculopathy, thus avoiding unnecessary manipulations of the asymptomatic DRG).

In degenerative spondylolisthesis with central canal stenosis, bilateral facetectomies are preferred. TLIF approaches the symptomatic side, and laminectomy is not required. In contrast, the preservation of the central elements, in addition to promoting natural segmental stability, prevents epidural fibrosis, a well-known reason for surgical treatment failure and intractable neurological pain[9]. When bilateral facet decompression is performed, we observe motor evoked potential improvement intraoperatively, confirming proper direct decompression. After cage implantation and vertebral distraction and reduction, a more significant increase in motor potentials is seen due to indirect decompression of the disc space and olysthesis correction.

MIS TLIF can also treat herniated discs. Should the experienced surgeon take proper care of central disc extrusions and migrated fragments. Protruded discs are the most suitable for the indication of arthrodesis by MIS TLIF. In central bulky disc extrusions, the midline approach is limited by the less invasive MIS TLIF technique since access is through a paramedian incision, which makes it difficult to approach, manipulate, and visualize the central spinal canal even with the aid of the surgical microscope. Therefore, only experienced surgeons should choose this access as a form of treatment in these situations.

Migrated discs, depending on their location, due to the small working channel focused on the facet joints, may have limitations of access and impediments to removing them, mainly when they occur caudally or cranially. Therefore, the surgeon's experience and judgment should be considered before indicating MIS TLIF surgery under these circumstances.

Finally, in elderly patients, especially menopausal women, bone density testing should be routinely requested before MIS TLIF is indicated. Low bone density delays the spinal fusion process and overloads the adjacent levels, causing compression fractures and aggravating the clinical condition of these patients, who are often already debilitated. Patients with osteoporosis should be discouraged from performing this technique due to the short and medium-term failure risk, reserved only for cases intractable by other methods. There are indications for adjuvant treatment with zoledronic acid in osteoporotic patients undergoing spinal fusion. Compared with placebo, some studies demonstrate the prevention of compression fractures and the reduction of spinal fusion time in osteoporotic patients treated with zoledronic acid[16]. Therefore, I treat osteoporosis patients with zoledronic acid before surgery and delay the procedure for as long as possible to prevent bone fusion failure and fractures. Furthermore, the concomitant use of polymethylmethacrylate (PMMA) to reinforce the screw's pullout strength and avoid osteolysis, while bone fusion occurs, is helpful in numerous studies and can be used in a reserved manner in osteoporotic patients[17,18].

In summary, the ideal case for indicating MIS TLIF can be summarized below, always considering normal spinal global balance:

- Single or two symptomatic adjacent segments;
- Symptomatology compatible with radiological findings;
- Failure of conservative treatment, including epidural blocks;
- High pain score (>5 on the NRS);
- High disc space or with no more than 50% height loss;
- Protruded discs facing lateral into the foramen
- Patients with normal bone density

Judging by the surgeon's experience:

- Bulky disc extrusion with fragment migration;
- Bulky central disc herniation;
- Flattened or collapsed discs with no global spinal imbalance;
- High-grade spondylolisthesis
- Patients with poor bone quality

5 Complications

MIS TLIF is not exempt from complications like any other technique. In my opinion, the leading and most common complication is wound border necrosis (fig. 43). Because of limited access, usually between 2 and 3 cm wide, the compression caused by the retractor hurts the edge of the wound and may cause suture dehiscence. The carelessness of this event by the patient and, mainly by the surgeon, can eventually lead to deep infections and severe discitis, compromising the result belatedly.

This complication is common, especially with experienced and qualified surgeons. When mastering the technique, the incisions decrease in size. However, the limitation of access is not limited by the surgeon's skills but by the auxiliary equipment and the working channel (the retractor). Usually, tubular retractors available on the market are broader than 2 cm in diameter and, therefore, do not allow small incisions to the taste of experienced surgeons. For this reason, I suggest checking beforehand which retractor will be in your surgery and making a skin incision compatible with the width of the retractor available. Larger incisions do not compromise the result, only the aesthetic appearance while preventing skin edge injuries and later severe complications.

Another complication, not so frequent, hovering approximately 5.3% of cases, is transient dysesthesia[10]. Other references[11] show higher rates, different from our sample, perhaps because of major manipulations (post-laminectomies). In any case, dysesthesia symptoms may occur. It is caused mainly by excessive manipulation of the region of the dorsal root ganglion[12], mainly by the use of electrocautery at high intensity in the facet joints, and by bipolar thermal injuries, close or inadvertently to the dorsal root ganglion (DRG). During venous plexus coagulation to disc exposure, the correct identification of the traversing nerve root and the DRG, medially and cranially to the disc, respectively, is imperative. The constant use of normal saline helps maintain the foramen's temperature low, avoiding thermal injuries. The use of bipolar in low potency also mitigates thermal damage to adjacent nerves.

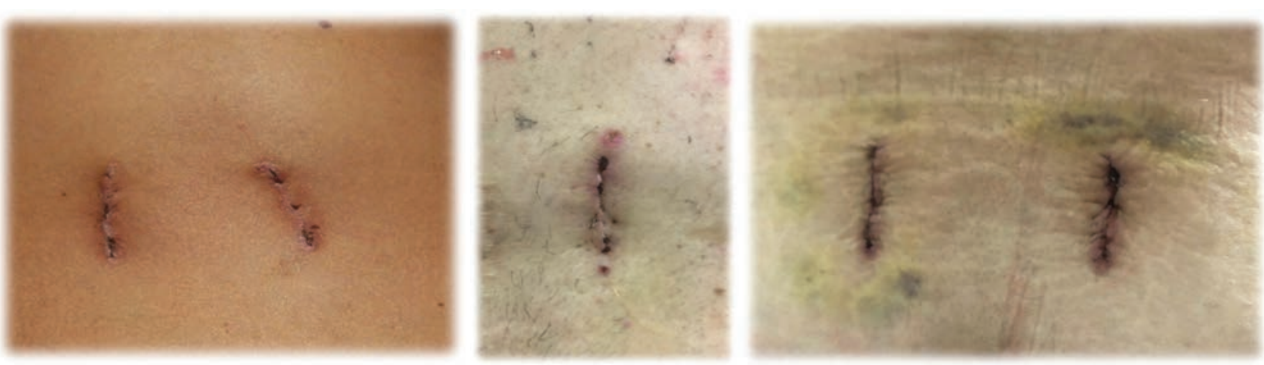


Figure 43 – MIS TLIF incisions with wound edge necrosis, without dehiscence

Keeping a clean and dry operative field is the main factor in avoiding transient dysesthesia. In this way, therefore, the rational and correct use of the bipolar allows a clean view without bleeding and, at the same time, prevents nerve damage from inadvertent manipulation of nerve structures during discectomy and cage implantation in a bloody field.

The symptoms usually occur a few days after surgery and between 3 and 7 days post op. It starts with neuropathic pain on the corresponding manipulated dermatomes and is extremely painful and difficult to control even with opioids. Some cases require readmissions and anesthetic nerve blocks, including continuous infusion through an epidural catheter. It is not infrequently, in severe cases, the appearance of signs of dysautonomia, such as edema and hyperemia. Usually occurs on the dorsum of the foot, anterior surface of leg and toes, site of L4 and L5 dermatomes, corresponding to the nerve roots most often manipulated (fig. 44). The recovery period is varied and typically lasts 3 to 4 weeks in mild cases and 6 to 8 weeks in severe cases. Therefore, the best scenario for this complication is prevention, which has already been described.

Transient dysesthesia treatment must be performed aggressively. Over-the-counter analgesics should be avoided; neuromodulators such as pregabalin, amitriptyline, and pericyazine are the most effective and can be used alone or in combination, depending on the severity of the symptoms. I prescribe topical anesthetics on small areas as well.

Dural tears are not frequent, as the correct access is limited to the foramen, not the spinal canal. They usually occur in wider openings and laminectomies toward the spinal canal. In addition, fat tissue and fibrin sealant correction associated with medications and bed rest is often enough to avoid external fistulas. The surgical incision is always tiny. There is no dead space for collecting CSF between paravertebral muscles; I have had no case thus far of externalized cerebrospinal fluid fistulas. Exposure of the central canal and the descending nerve root is unnecessary and should be avoided in MIS TLIF. Laminectomy and flavectomy near the lateral recess expose the nerve root shoulder, allow for dural tears, and cause transient dysesthesia,

Figure 44 – Area of dysautonomia, with hyperemia and edema and tenderness to the touch, as a result of postoperative transient dysesthesia

Technical Note:

- Despite all care during surgery, there are cases after adequate decompression, olisthesis reduction, and disc space distraction that transient dysesthesia signs and symptoms still may occur, mainly in patients with exuberant previous nerve root symptoms, which serve as a predictive factor for its occurrence especially during disc removal and implantation of the intersomatic cage due to inadvertent nerve root manipulation.

Furthermore, laminectomy predisposes undesired later epidural fibrosis. Therefore, TLIF must be performed exclusively through the foramen; there is no need to identify the nerve root shoulder and the DRG to MIS TLIF proper realization. The correct technique will be demonstrated in a separate chapter.

Nerve root injuries are usually related to facetectomy, discectomy, and cage implantation. Less frequent cases may occur during the passage of guidewires, inappropriately, through the lateral recess, or just below the pedicle. The mastery of anatomy described in Chapter 2 prevents nerve root damage during facetectomy and discectomy. During cage implantation, extreme care must be taken. Observing its correct positioning by fluoroscopy before impacting also prevents nerve root damage.

In most cases, these injuries are transient, as they cause only neuropraxia. However, complete and irreversible damage usually occurs with inadequate identification of the disc space and inadvertent sectioning of nerve structures. In these cases, the surgeon perceives the untimely outflow of CSF with the loss of motor nerve evoked potential when available. Accidents can occur because the small working channel is aimed at the disc level without directly visualizing the Kambin´s triangle´s nerve structures. The passage of guidewires through the pedicles, less frequently, when performed improperly, rarely causes permanent damage, and they are generally sensory and temporary.

Pseudarthrosis, an unusual late complication, can occur. It is usually related to inadequate cleaning of the disc space due to the surgeon's lack of experience or insufficient surgical instruments. Incomplete nucleus removal can be seen immediately after the impaction of the intersomatic cage, which does not fit properly in the most disc anterior half and does not rotate freely into the coronal plane.

Another frequent reason that leads to pseudarthrosis is the incorrect use of bone grafts. Never use bioceramics alone. The bone removed from the facet joints is used routinely as an autologous bone graft. As a general rule, the joint bone content is enough to fill the cage and the remaining disc space. When the bone graft volume is not enough in some patients, I mix bioceramics with the autologous grafts to increase its volume, thus allowing proper osteoconduction.

The diagnosis of pseudarthrosis is not easy. Usually, the patient goes very well after surgery for between 6 months and one year, feeling mechanical pain and eventually nerve root sciatica after this period, similar to those before surgery. X-rays and CT scans of the lumbar spine are usually enough to clarify the diagnosis. Slight displacements of the cage or even significant dislocations strongly suggest the diagnosis of pseudarthrosis. More common, however, is the cage endplate subsidence (**fig. 45 A-C**), and it is, from my point of view, pathognomonic of pseudarthrosis. Screw osteolysis does not appear at first on X-ray of the lumbar spine, only in late cases, or on CT scans with a bone window, which must be requested routinely in symptomatic patients. As a general rule, pseudarthrosis must be suspected if the well-indicated and well-operated patient complains of relevant symptomatology recurrence more than 12 months postoperatively. Finally, the correct preparation of the bone implantation site, with the proper disc content and cartilaginous endplate removal through complete curettage, is imperative for good bone grafting, thus preventing pseudarthrosis.

Severe intersomatic cage dislocations into the foramen are an infrequent complication that usually happens acutely and is related to incorrect cage implantation. The leading cause lies in the incomplete removal of the disc core, thus not creating a space suitable for the implant and choosing the wrong cage size, usually shorter than necessary. The locking of screws in compression also prevents migration, keeping the anterior border of the disc higher than the posterior edge in a "fish mouth" shape.

Pedicle palpation is not performed in MIS TLIF, and this vital step is skipped thus, opening the opportunity for pedicle trajectory errors. In MIS TLIF, the surgical technique must be systematically followed because minor deviations of the pedicle pathway toward the lateral recess can occur and deceive the most trained eye and may cause exuberant neurologic symptoms in the immediate postoperative period. For this reason, I recommend using intraoperative electroneuromyography monitoring (IOM) routinely to double-check the placement of the screws correctly and not rely only upon the fluoroscopic image.

Figure 45A – L5-S1 Cage subsidence indicating pseudoarthrosis

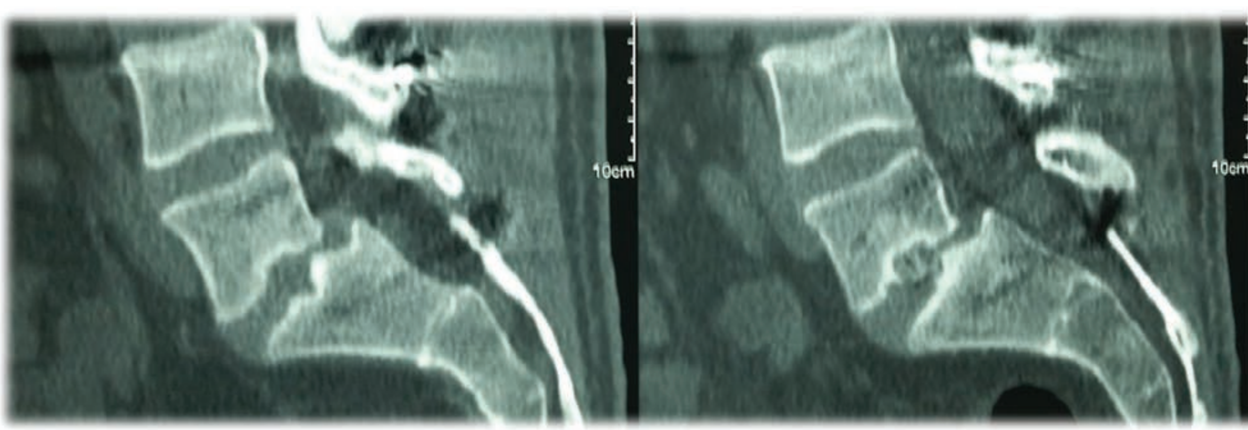


Figure 45B – CT spine shows cage subsidence at the L5-S1 segment.

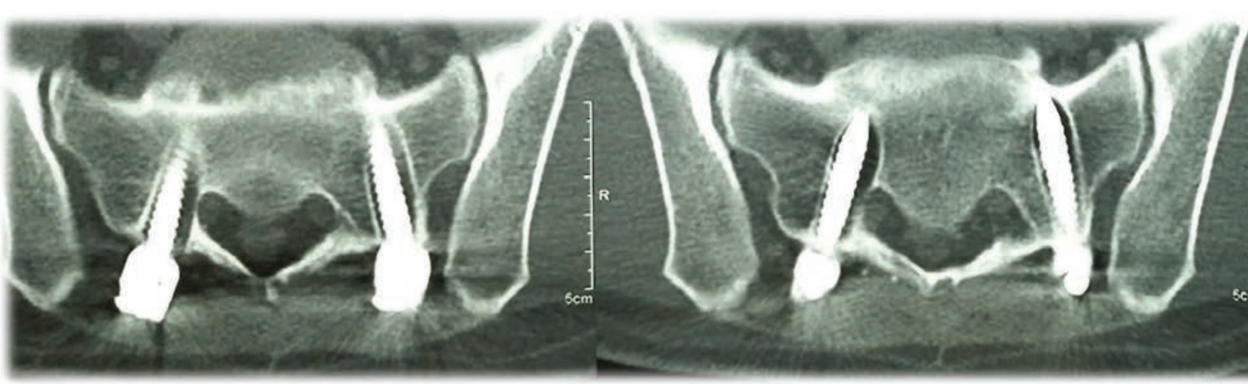


Figure 45C – Osteolysis halo between S1 pedicle screws.

6 The surgical technique

MIS TLIF INSTRUMENT SET

For the MIS TLIF to be appropriately performed, the surgeon must follow steps systematically to minimize errors. The first step is the correct patient selection, considering the method's limitations, as detailed earlier.

In general, the instruments used in MIS TLIF are listed below and must be present in all surgical procedures.

- Jamshid needle and guidewires
- Cannulated torque screwdriver
- Screw clipping tube (screw tower)
- Caliper
- Set screw holder
- Percutaneous rod inserter
- Rod persuader
- Compression/distraction forceps
- Counter torque wrench
- Tower release wrench
- TLIF retractor

Remember, the scrub nurse has an essential role in the surgical procedure, and she must be trained according to the surgery steps. In addition, she must know the correct assembly and disassembly of the entire system to support the surgeon during the surgical procedure.

Another essential step is to check the screw's size and the quantity available by the supplier. Not infrequent, there may be a lack of some screw sizes, and the most commonly used ones are usually missing. I typically use 45x6 mm screws in adult patients' L4 and L5 pedicles. For the sacral pedicles, I use 40x7 mm screw sizes. Intersomatic cages must have numbers from 8 to 12 mm in height. The imaging exams should not estimate the cage's correct size. Instead, the cage´s correct size must be estimated intraoperatively compared with the adjacent normal levels and its acceptance by intervertebral space distraction.

The lack of an implant of the correct size or any surgical tool may compromise the surgery result. Therefore, check the instrument tray list routinely before taking the patient to the operating room.

EXTRA INSTRUMENTS SET

The MIS TLIF is performed in a narrow field (on average 2 cm wide) regardless of the patient's body type. In tall, short, thin, or obese patients, the skin incision and the working channel have an exact width of 2 cm. The depth varies from patient to patient. Generally, obese patients have the spine deeper, ranging from 10 cm between the skin and the facet joint. In this way, the surgeon must acquire the essential instruments for the proper execution of the procedure.

For those reasons, the cautious surgeon must have a small list of instruments to perform the surgery comfortably for any patient size.

- ### Long bipolar forceps

The ideal bipolar is 20 to 22 cm in length. It is essential in MIS TLIF because bleeding, even if minimal, floods the operative field and makes it impossible to remove the disc nucleus and cage implantation. Therefore, working in a dry field is essential. Unfortunately, short bipolar does not have enough length in obese patients. It blocks the surgeon’s field of view, and one cannot coagulate the epidural veins.

- ### Toothed disc rongeur

The ideal rongeur size is 24 cm long, with 4 and 5 mm toothed bites (fig. 46 A and B). Disc rongeurs larger than 5 mm in width do not freely enter the intervertebral space in flattened discs. As the working channel is narrow, I use the disc rongeurs to bite the free facet fragment after cutting it. I suggest having at least one straight and one bite up toothed disc rongeur. Then, the surgeon can use them in anterior approaches as well.

- ### Multiple size suckers

I suggest a set of Frazier-like suckers in different diameters, not too long (fig. 47). The operative field must be clean and dry at all times. Since the surgical field is narrow, even minimal bleeding covers the operative area and makes safe manipulation of the foramen region impossible.

- ### Bayonet scalpel handle for blade type 11

The annulus fibrosus incision must be done with extreme care. Therefore, good visibility of the surgical field is necessary. A straight scalpel handle blocks the surgeon´s field of vision since the MIS TLIF approach is narrow and deep. In this way, a bayonet-shaped scalpel handle allows the surgeon to have a better field of view (fig. 48).

- ### Osteotomes

The facet joints may be removed using osteotomes (fig. 49). The first advantage is a short time. Safely remove the inferior facet joint with two cuts and one in the superior facet. Another advantage is to use of the removed bone as an autologous graft.

- ### Curettes and disc shavers

Complete and proper disc nucleus and cartilaginous endplate removal is the surgery’s

Figure 46A – 24 cm long 4 or 5 mm width

Figure 46B – Toothed mouth

most crucial step. Thorough and correct disc cleaning, creating a bare bony surface, is the essential step for the late success of spinal fusion, preventing pseudarthrosis. The disc shavers (fig. 50) allow the complete removal of the nucleus pulposus and cartilaginous endplate and disc space distraction. Curved and straight curettes (fig. 51) allow gentle cleaning of the superior and inferior endplates, removing any disc and cartilage remnant inside the disc core. Systematic cleaning of the disc contents is also essential to open ample space for intersomatic cage placement.

• Muscle retractor

Current MIS TLIF brands provide different types of retractors. Access to the foramen is the noblest part of the procedure, and the muscle retractor is the instrument that allows the procedure's success. Thus, the surgeon needs to use the same retractor during his learning curve, making each surgical step easier over time.

A good retractor must present the facet joints and the foraminal zone. A bad retractor does not hold the paravertebral muscles properly and does not allow adequate visualization of the bone structures. In addition, the retractor must remain in place during the entire TLIF step. A retractor that escapes and constantly loosens the muscles also impairs the operative time. I use a lumbar Caspar retractor with a socket for fiber optic lighting. This retractor has four blade sizes for the most varied body types (fig. 52).

• Trephine

Autologous bone grafts are by far the best option for implants. In this way, when bone removed from the facet joints is not enough or is sclerotic, such as in elderly patients with hypertrophic facets, I suggest harvesting iliac cancellous bone with a trephine (fig. 53). A good trephine allows the removal of enough bone to fill a disc level and the cage, with minor damage to the patient, consequently, less pain. Removing

Figure 47 – Multiple size suckers

Figure 48 – A bayonet-shaped scalpel handle allows a better field of vision

Figure 49 – Multiple sizes and shapes osteotomes

small bone "corks" is easy and not painful (fig. 54). When approaching the L5-S1 segment, a bone graft can be harvested through the same skin incision used for TLIF. There is the drawback of graft removal; on the other hand, in the long term, I minimize pseudarthrosis as much as possible, a complication that is difficult to treat.

The iliac tuberosity (fig. 55) is the most appropriate site for bone graft harvesting in spinal surgery. In addition to being lateral to the L5-S1 segment, it has a large area and bulky cancellous bone and is poorly innervated compared to the anterosuperior iliac crest. Therefore, make a 1 cm^2 decortication to facilitate the introduction of the trephine. Next, introduce trephine one centimeter into the iliac cancellous bone with a surgical mallet. Next, with hands, rotate it to allow the cancellous bone to enter its lumen. Thus, it is possible to harvest the bone without breaking the lateral cortex of the iliac bone crest. Finally, the bone is filled with wax, and the periosteum is sutured.

Figure 50 – Multiple-size disc shavers

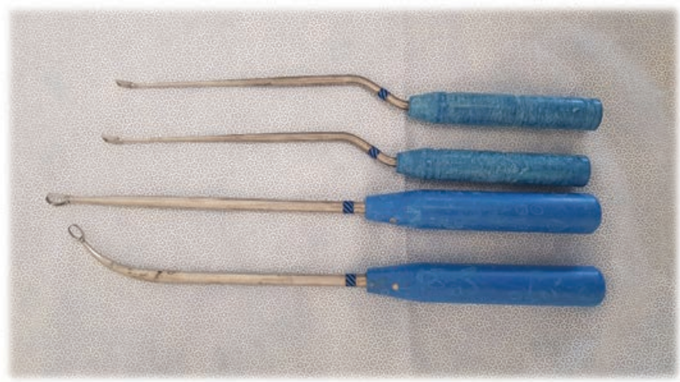


Figure 51 – Long and curved curettes allow contralateral disc removal, creating room for cage implantation

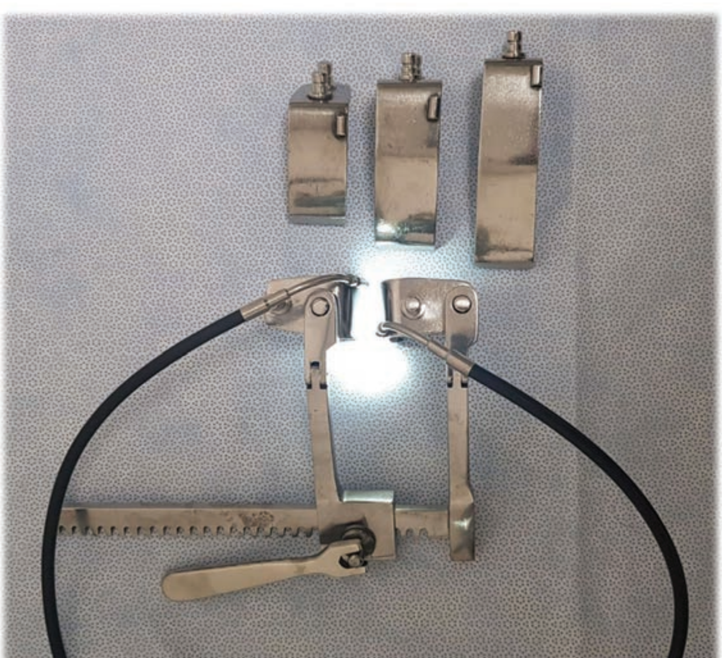


Figure 52 – Lumbar Caspar retractor with a fiber optic light source

Figure 53 – Trephine used to remove iliac bone graft

THE MIS TLIF STEP BY STEP

Anesthetic care

Intraoperative neurophysiological monitoring (IOM) during screw placement requires neuromuscular activity. On the other hand, during TLIF, complete muscle relaxation is necessary. Thus, interaction with anesthesiologists and neurophysiologists is essential. In addition, the working channel is limited (2 cm wide

Figure 54 – Iliac cancellous bone "corks"

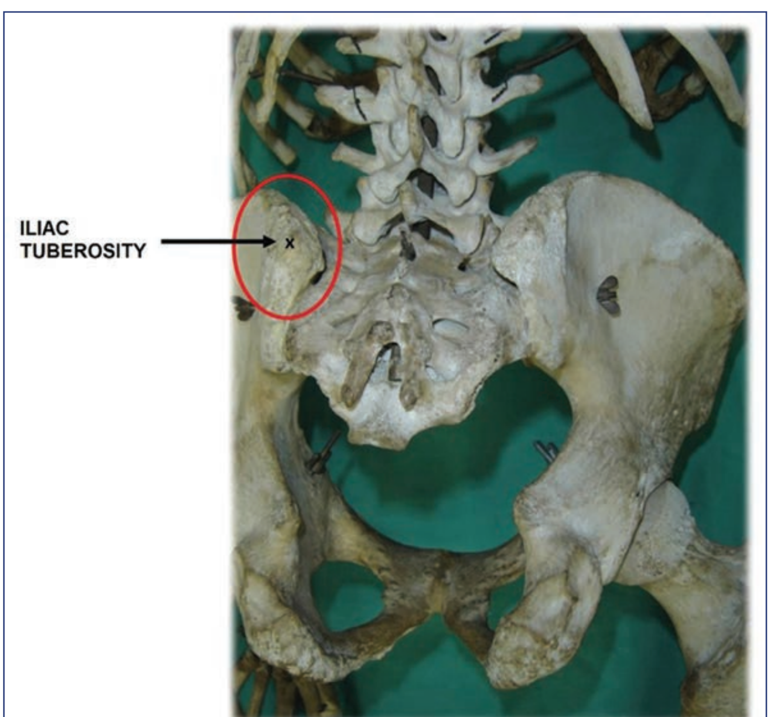


Figure 55 – Lumbosacral region identifying a suitable location for bone graft harvesting

incision), and for this reason, the tense muscle does not allow adequate muscle retraction, expels the retractor, and makes it unfeasible to perform the TLIF step. For this reason, I suggest checking guidewires' correct placement using intraoperative electromyography (EMG) before the neuromuscular blockade. During TLIF, the neurophysiologist does not have control of motor potentials, which, on the other hand, does not change the course of the surgery. In the end, neuromuscular blocking naturally reverses, and the surgeon can recheck the motor potentials at the end of the procedure.

The arrangement of tables, equipment, and personnel in the room also dramatically influences the smooth running of the procedure. I suggest the following configuration in the operating room:

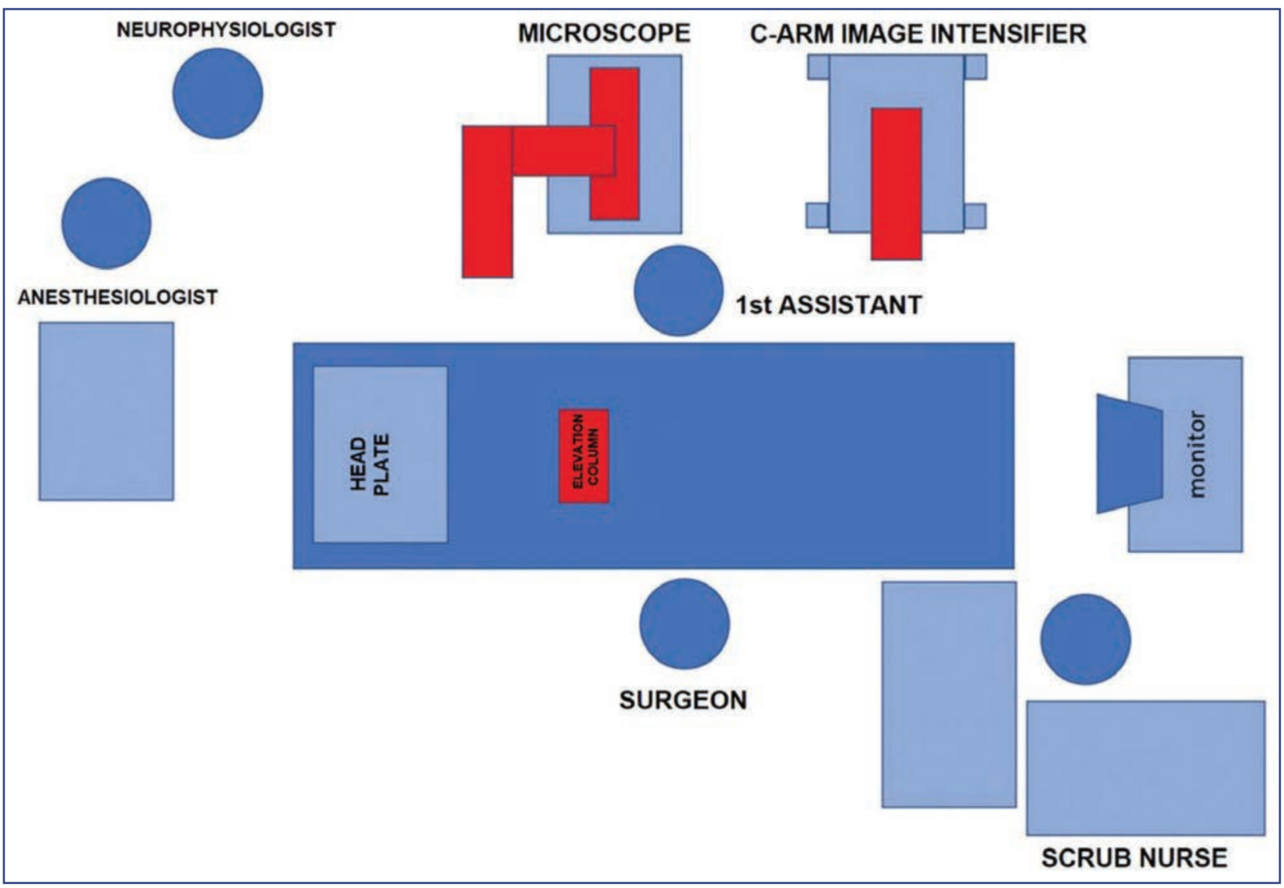


Figure 56 – The operation room

The correct X-ray view

In the PA view align the superior endplates as parallel as possible and center the spinous process between the pedicles to insert the Jamshid needle (fig. 15).

I. To compensate for the distance from the skin toward the spine, the Jamshid needle entry point over the skin corresponds to the radioscopic projection of the midpoint of the transverse process (fig. 58 A and B).

II. First, make a tiny skin incision sufficient to fit the needle (fig. 59), which keeps it

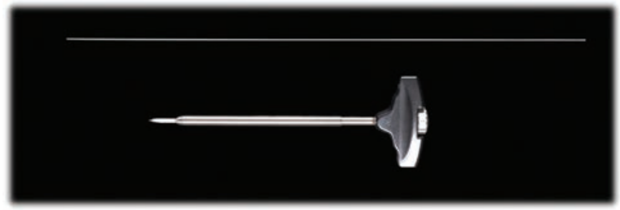
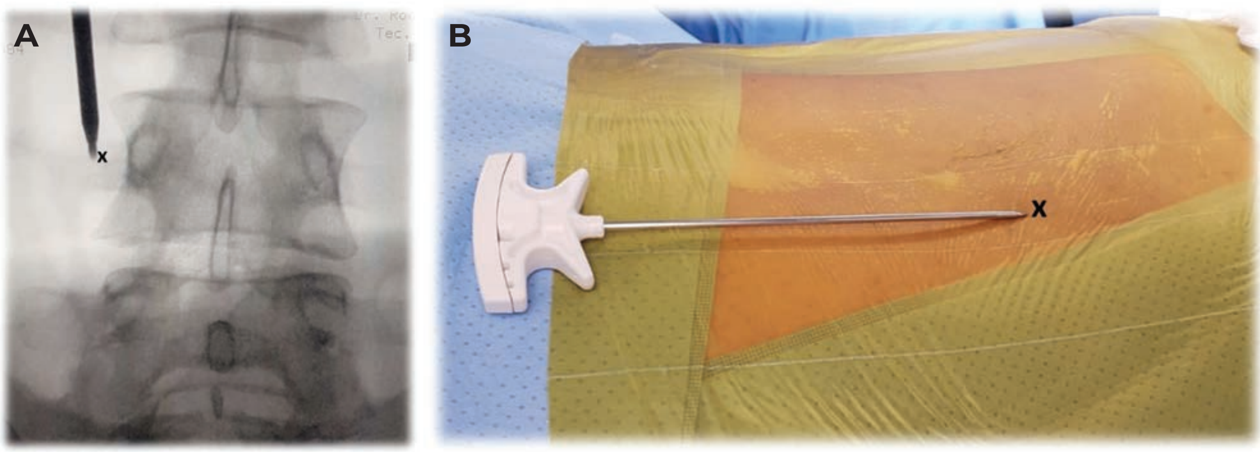


Figure 57 – Jamshid needle



Figures 58 A and B – The entry point over the skin: the midpoint of the transverse process

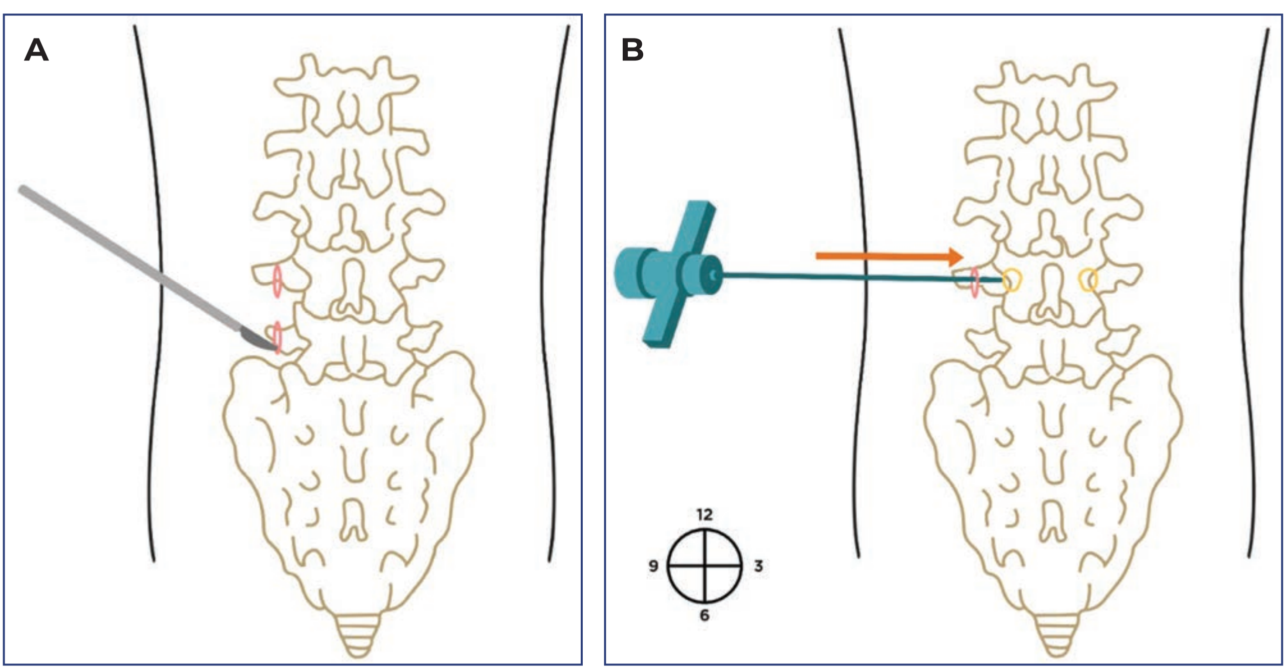


Figure 59 A – Skin incision wide enough to fit the needle; **B** – Pedicle entry point

tight, as soft tissue is not dissected. The skin incision is enlarged at a later time. Then, the pedicle entry point corresponds to the lateral edge of the superior facet and the transverse process midline intersection (fig. 60 A to D).

III. The pedicle entry points start in the lateral pedicle border at 3 o'clock on the right side and 9 o'clock on the left side and stop insertion point is at the pedicle medial border (fig. 61 A to D).

IV. The needle is introduced parallel to the superior endplate as far as it reaches the medial border of the pedicle in the PA fluoroscopy view (fig. 62). The guidewire is introduced gently through the needle, checking for the existence of cancellous bone at its end; otherwise, the wire may perforate retroperitoneal structures. If the surgeon feels soft tissue at the wire tip end, the needle must be removed, and the whole process must be restarted. The guidewire must reach the cancellous vertebral body bone at this stage. Pushing the wire must be possible, with some resistance, with the surgeon´s hand, indicating that the wire is inside the vertebral body. However, it is impossible to push it by hand when the guide is still inside the pedicle because of its cortical bone. In this case, the needle must be removed and restart the process; otherwise, the needle may breach the

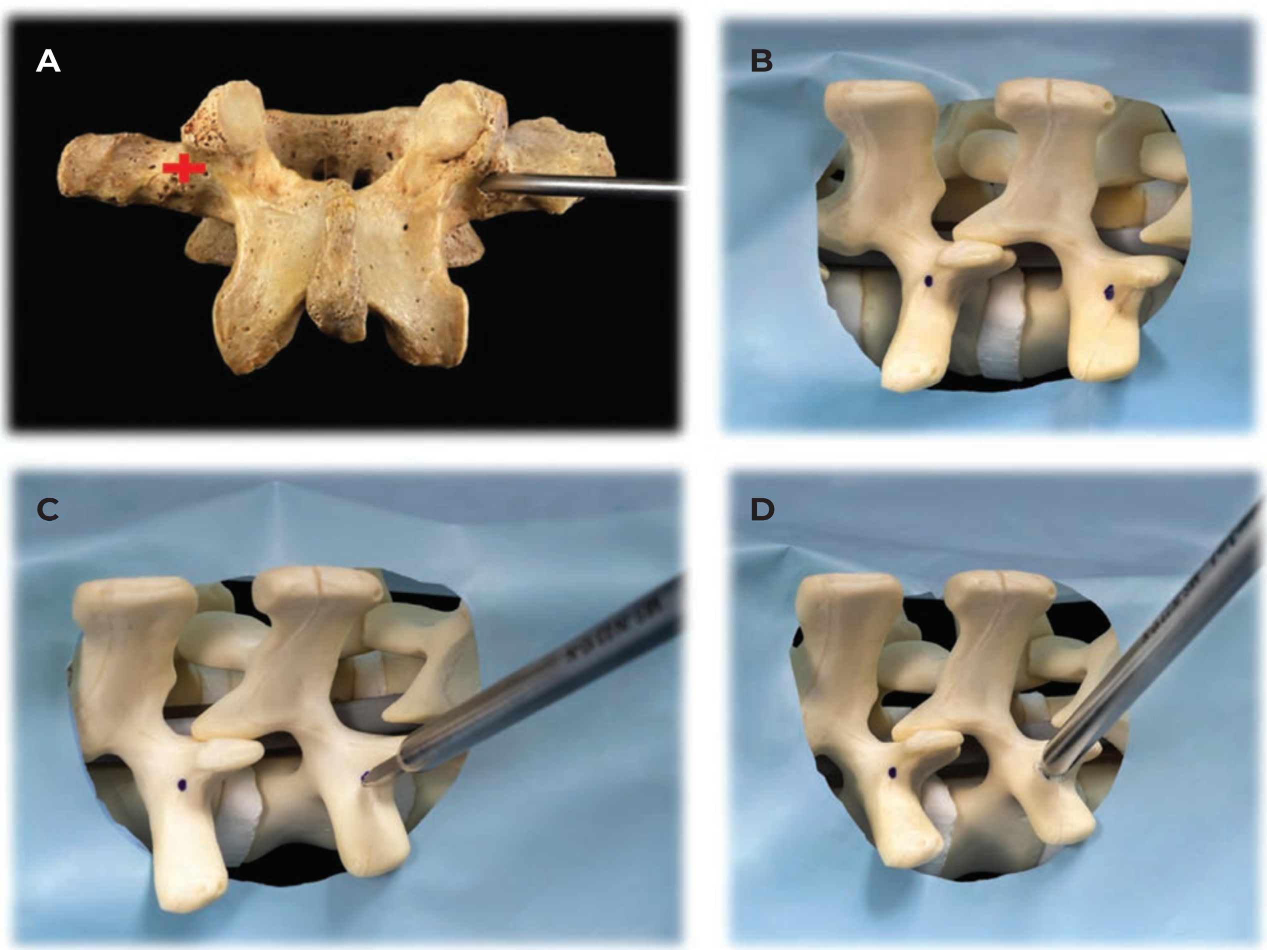


Figure 60 – Lumbar pedicle needle entry point

pedicle into the lateral recess. Check needle and guidewire placement with intraoperative EMG monitoring test at this stage. (fig. 63). At any nerve root signal, restart needle introduction.

V. In the PA fluoroscopy view, this step is repeated in every target pedicle. Next, switch the fluoroscopy arc to the lateral view to check the depth of the wires into the vertebral body. All guidewires must be in the half posterior vertebral body (fig. 64 A and B).

VI. After inserting the guidewires, implant the screws in the contralateral side to which discectomy and TLIF will be performed (fig. 66). Modern MIS TLIF brands allow interbody distraction through towers connected to the screw's head providing a more significant working space for the disc removal facilitating the intersomatic cage placement.

The cannulated screw is implanted through the guidewire. Extra care should be taken not to bend the wire; otherwise, its removal may

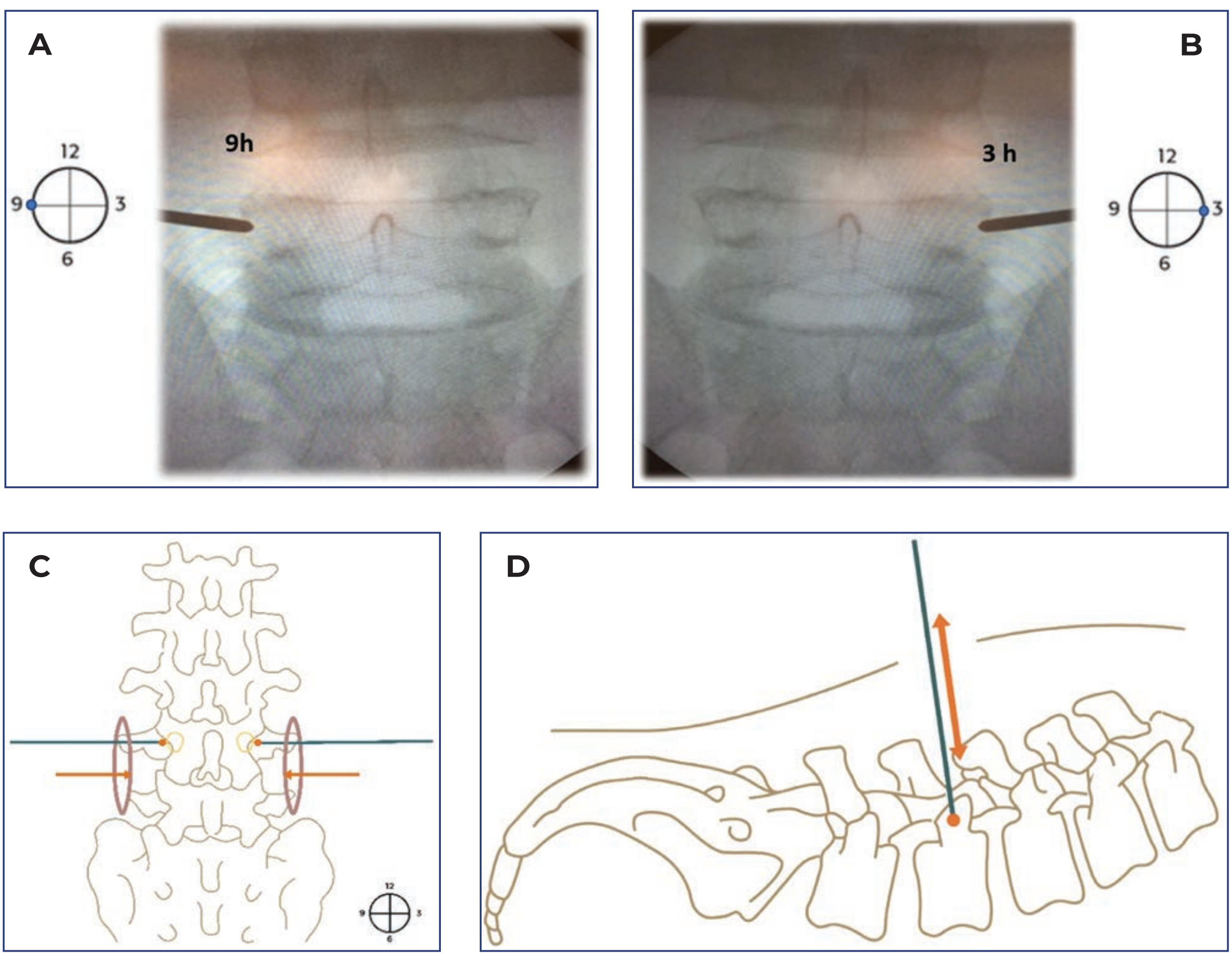


Figure 61 – Pedicle entry point. **A**: 9 o´clock left side; **B**: 3 o´clock right side; **C**: Lateral pedicle border entry point; **D**: Entry point lateral illustration

be difficult. The vast majority of MIS TLIF brands have tubular soft tissue retractors in their instrument arsenal for screw placement, which in my opinion, are unnecessary and time-consuming. Additionally, dispensing tubular retractors during screw placement does not cause harm to the patient´s muscle tissue at all. Inadvertent escapes of the guidewire from the pedicle happen with minor frequency, and the surgeon can easily find the pedicle entrance through the muscle tissue with care and patience. The connection towers facilitate the introduction of the rods through the screw's head between the paravertebral muscles.

The minimally invasive TLIF

The skin incision

Two paramedian skin incisions connecting the guidewires on both sides are made, facilitating the rods placement and muscular fascia suture at the end of the procedure (fig. 67). Typically 2 to 3 cm is sufficient for one level of TLIF. This incision is usually 3 cm lateral from the midline; however,

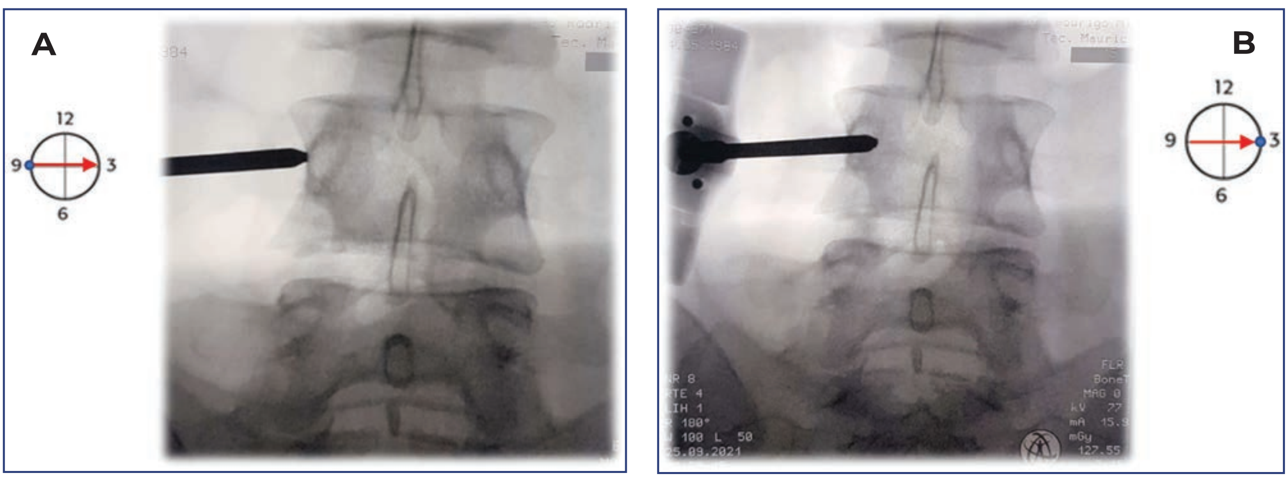


Figure 62 – **A**: Lateral border Jamshid needle entry point; **B**: Medial border Jamshid needle stop point

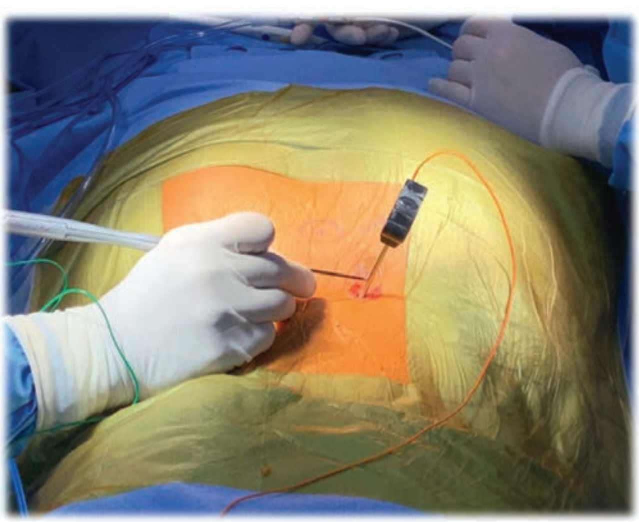


Figure 63 – Intraoperative EMG monitoring after the figure B step

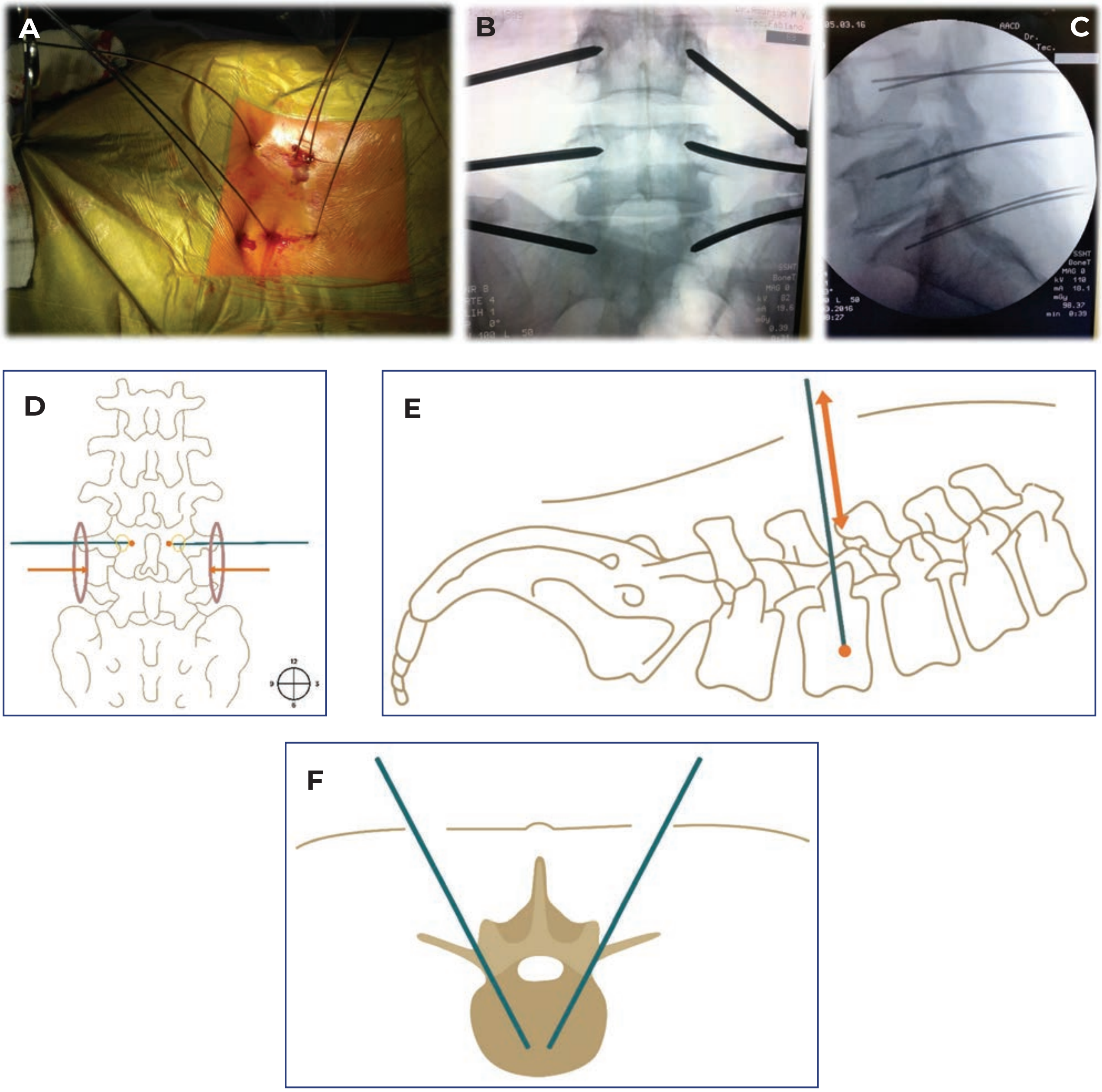


Figure 64 – **A**: Two-level needle insertion. **B**: Needle at the pedicle stop point (medial border). **C**: Corresponding guidewire location. **D**: Guidewire at the pedicle medial border. **E**: Guidewire in the posterior half safe place. **F**: Axial view illustration.

the exact location is found by fluoroscopy during needle insertion.

The facetectomy

The TLIF is performed on the more symptomatic side (radiculopathy). Incise thoracolumbar fascia and muscular aponeurosis and bluntly dissect the muscular planes using the index finger (fig. 68). Dissect between the multifidus and the longissimus dorsi muscles until you feel the articular facets. The facets are easily found. This approach causes very little postoperative pain and does not devascularize or denervate the muscles.

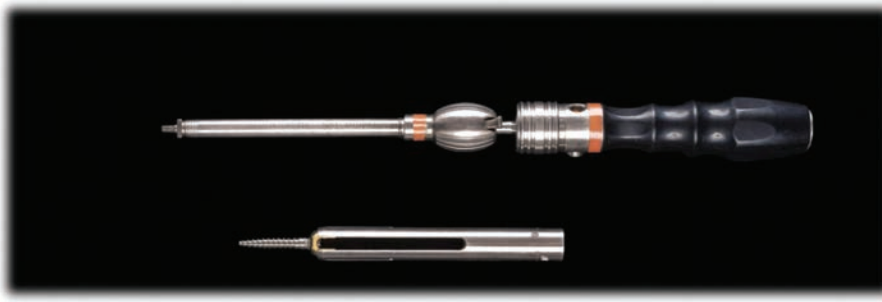


Figure 65 – Cannulated screw attached to the connecting tower and cannulated screwdriver

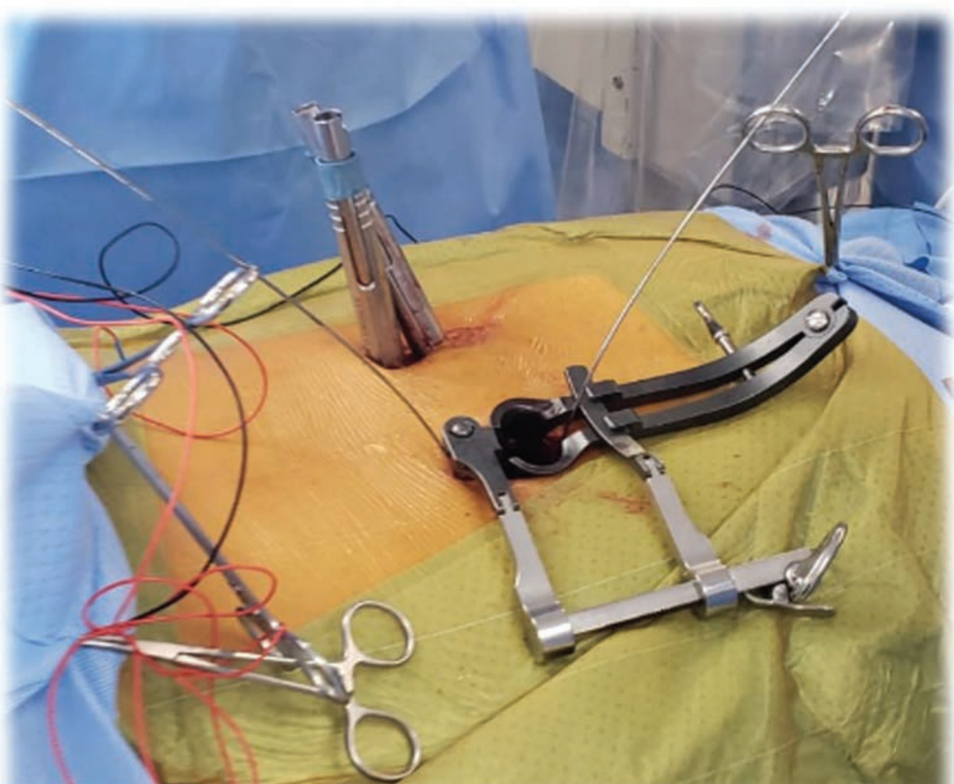


Figure 66 – TLIF is made before screws implantation, leaving the guidewires attached to the surgical drape. In the contralateral side, screws are implanted to distract the intersomatic space

Using the Cobb elevator, remove all remaining loose soft tissue attached to the facet joints. A complete neuromuscular blockade is essential for the next step: retractor placement. Tense paravertebral muscles do not allow the retractor blades proper opening, impairing the operative field visualization. At this moment, I ask the anesthesiologist for a complete neuromuscular

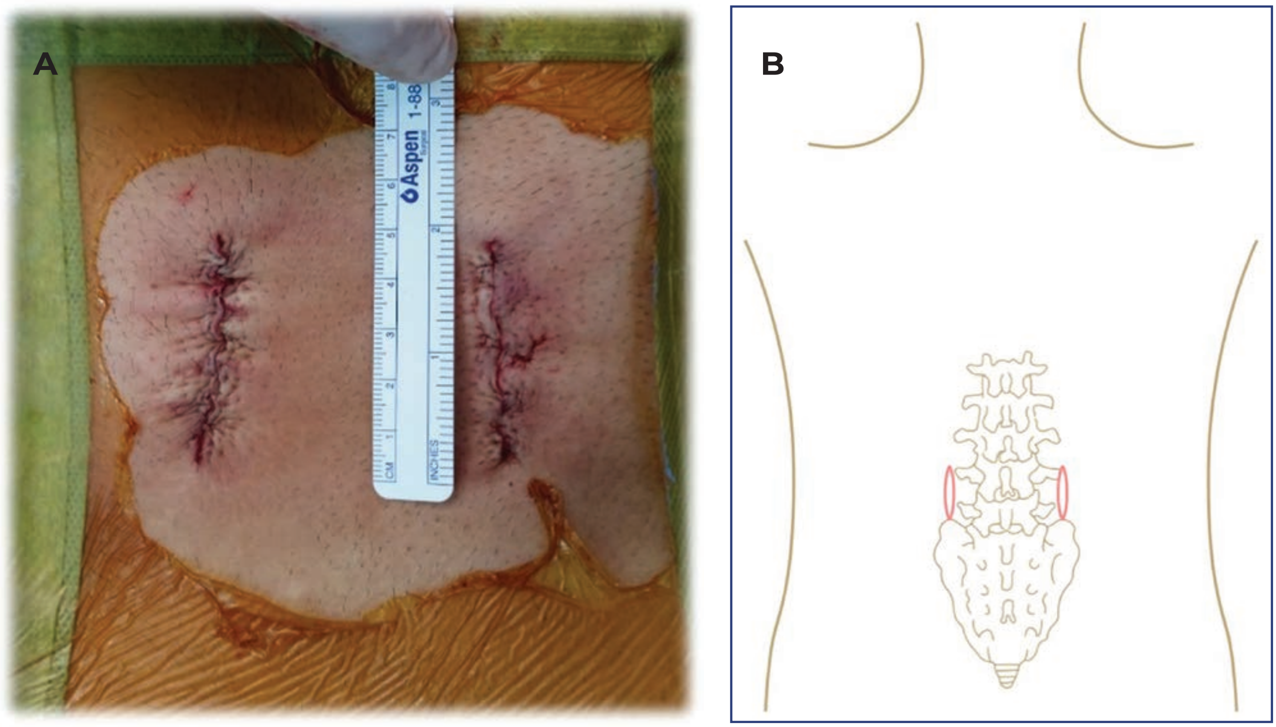


Figure 67 – **A**: Two-level TLIF skin incision; **B**: Skin incision illustration

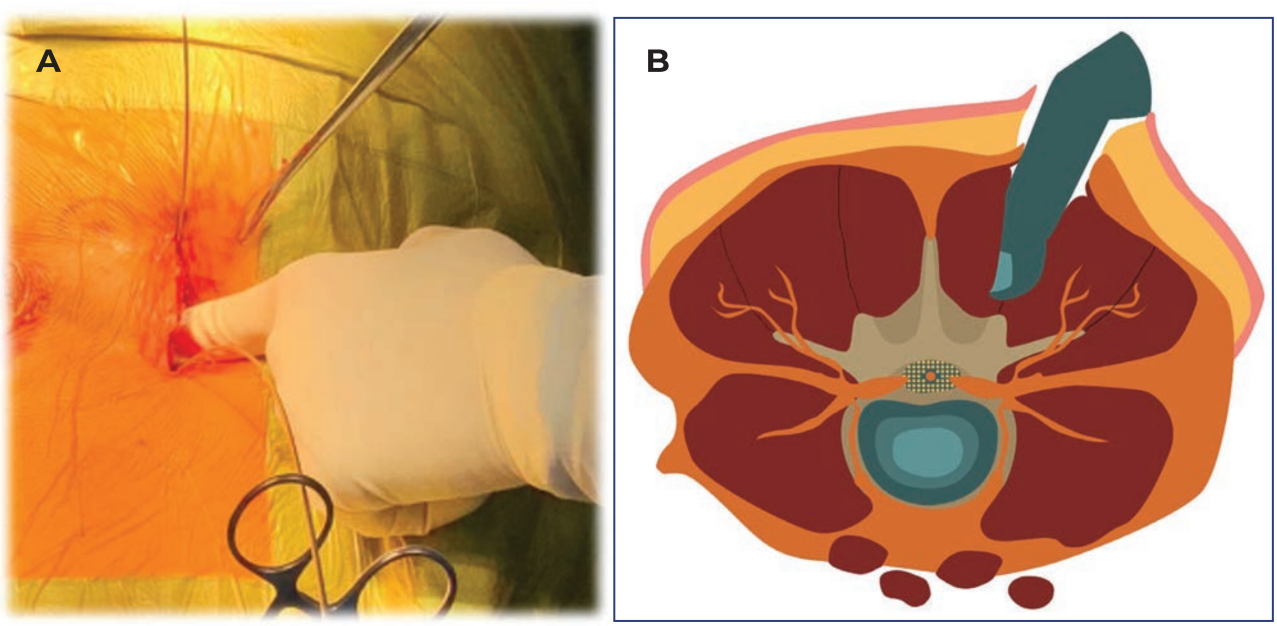


Figure 68 – Blunt dissection of the paravertebral muscles

blockade. Next, insert the retractor, ensuring that no muscle fibers enter the field of vision.

Elderly patients, not infrequently, have paravertebral muscle lipodystrophy, and it is more evident in the lumbosacral region (fig. 69). Therefore, it is unnecessary to have neuromuscular blockade for adequate removal and exposure of the facet joint in those cases.

Using a low voltage monopolar electric scalpel, skeletonize the facet joints. Irrigate from time to time to not cause thermal injury to the nearby DRG. Finally, the remaining tissue is removed with the toothed disc rongeur. Remove the joint capsule altogether. Hypertrophy facet joints usually present calcified capsules and even so need complete removal. The surgeon sees the joint cleft after skeletonization. Inferior (medial) and superior (lateral) facets are seen at this stage. The surgeon must also perform proper cleaning of the lateral pars to reference the upper limit of medial facetectomy.

Over time, the surgeon gets used to the restricted access and learns to use only the necessary references. The bony landmarks are the facet joints, the lateral pars, and the joint cleft. Greater tissue exposure is unnecessary. A surgeon approaching the disc from the patient´s left side finds the lateral pars on his left side; on the other hand, coming from the right side, he sees the lateral pars on the right side.

Facetectomy is performed with a 5 mm osteotome. If done correctly, dural tear or nerve root damage do not occur. Imagine how glazier cuts the glass, breaking the pieces after a delicate diamond cut. Inferior facetectomy is done with a transverse cut over the lateral pars (upper limit) and a longitudinal one at the lamina-inferior facet junction. Superior facetectomy is performed with only a single transverse cut. However, the surgeon must not cut too much downward; otherwise, the pedicle will be violated. The inferior facet is the first

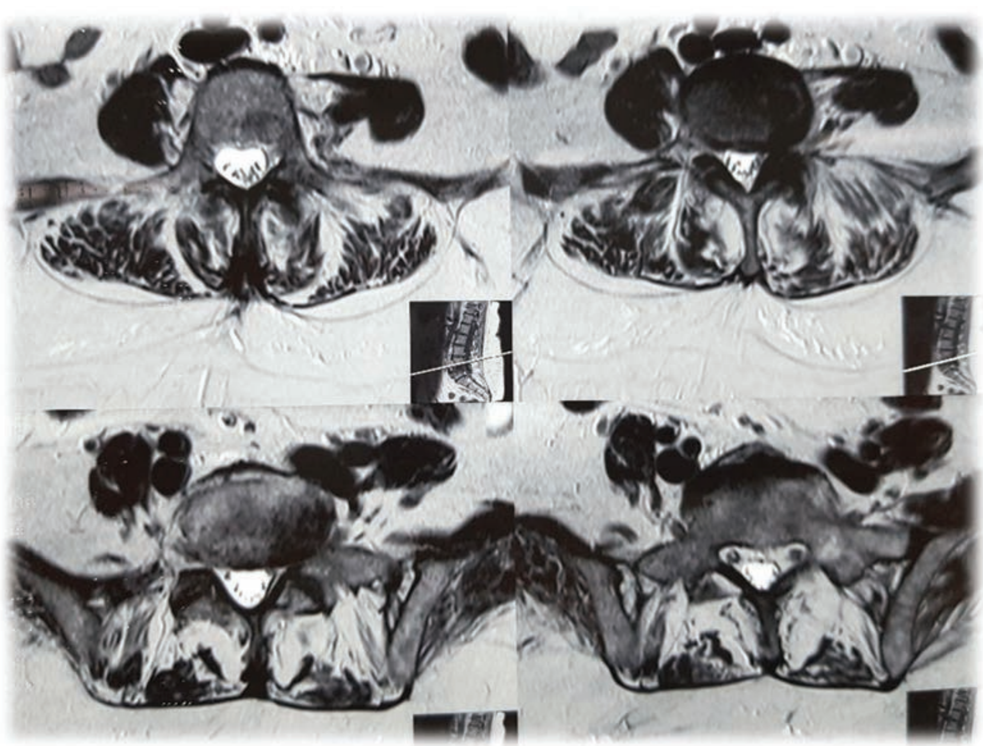


Figure 69 – Severe muscle lipodystrophy in the lumbosacral region

to be removed. Make a smooth cut line using the osteotome and feel the loss of resistance of the outer cortex of the inferior facet. The inner cortex must never be violated; otherwise, dural tear or nerve root injury may occur. Therefore, make an L-shaped cut, as shown in figures 71 and 72A. Rotation of the osteotome between its cutting line easily releases the facet joint. Remove the bone with a toothed disc rongeur. It is firmly attached to the ligamentum flavum.

The superior facet is removed with only a single transverse cut (fig. 72B), approximately 2/3 of the joint's length rotating between the bone cutting line with the osteotome as well. It is also firmly attached to the ligamentum flavum. The DRG and the traversing nerve root are not always seen since the lateral pars and lamina are preserved to prevent unnecessary exposure (fig. 72C). Thus, the discectomy area (triangular safe zone) is open and bare of neural structure, minimizing root damage (fig. 72D). The joint removed is used as an autologous bone graft (fig. 73A).

Removed facets are milled into small fragments (fig. 74A) and implanted in the disc space and the intersomatic cage (fig. 74B). An entire facet, in general, is enough to adequately fill one cage and the remainder of the disc space.

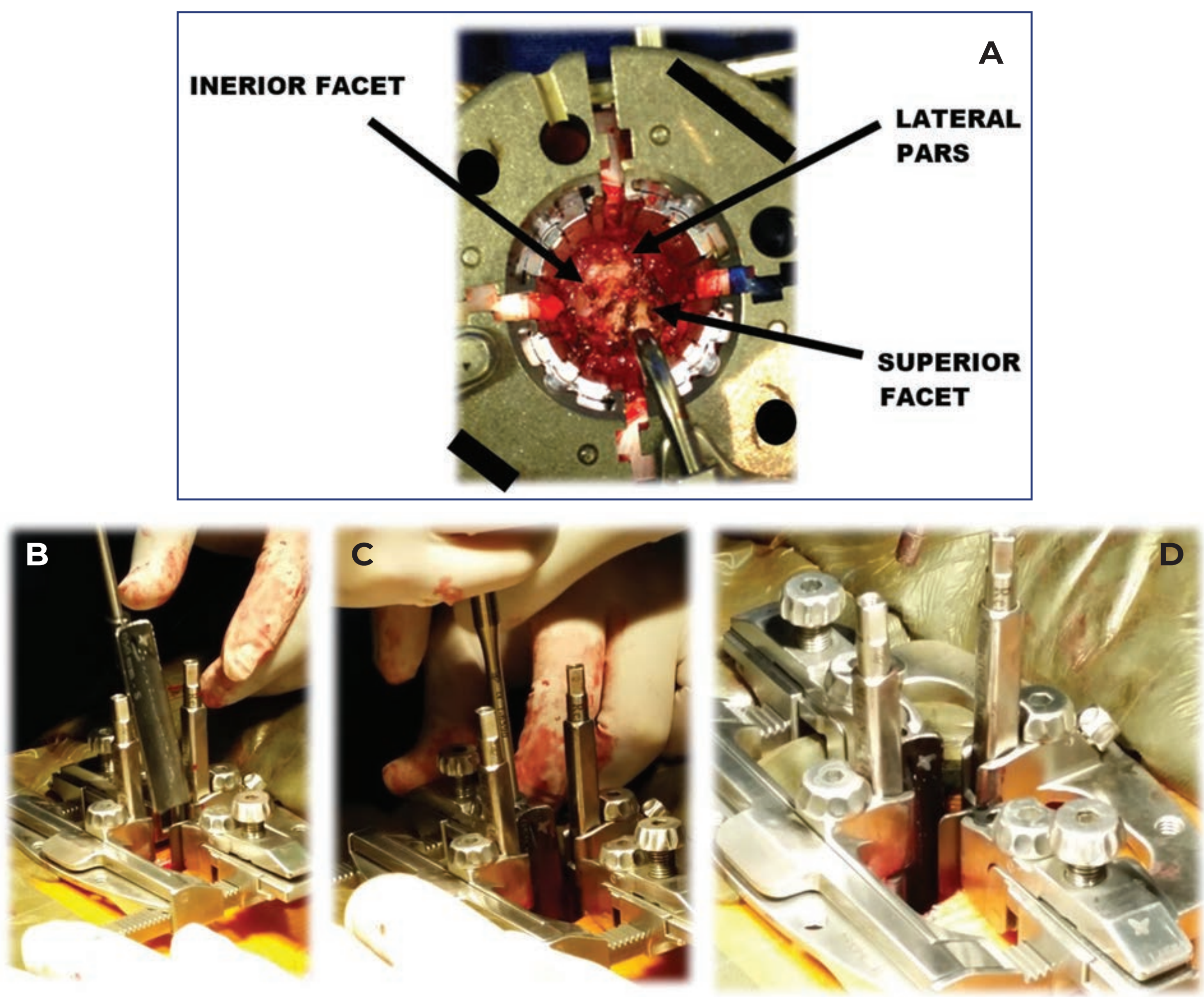


Figure 70 – **A**: Right side approach TLIF view. **B-D**: Romeo MIS retractor placement

Elderly patients with facet hypertrophy often have facet joint bone sclerosis. This type of graft is unsuitable, as its cancellous layer no longer has vitality compared to young patients. I harvest a small iliac cancellous bone to substitute the facet graft in these cases. The surgeon must always examine facet bone quality before implantation to establish the vitality of its cancellous layer (fig. 73B).

FINDING THE DISC

The facetectomy is performed under the naked eye. I always use the surgical microscope to find the disc inside the triangular safe zone. Depending on the extent of facetectomy, some facet bone remnant is removed with the Kerrison rongeur. In addition, the ligamentum flavum needs to be removed to visualize the triangular safe zone properly.

The next step is venous plexus coagulation. Using low voltage bipolar forceps, keep the region as devascularized as possible. The surgeon must not injure the DRG, which lies cranial to the disc and anterior to the lateral pars. Therefore, constant irrigation with normal saline at room temperature is essential to maintain foramen temperature low. The DRG, eventually, lies more caudally than usual, depending on the disc height and the severity of disc degeneration. DRG lies downward close to the disc in these situations, and consequently, extra care must be taken.

After complete coagulation of the venous plexus, the cauterized remnant must be removed to leave the disc area visible to the surgeon. The annulus fibrosus appears to have an opaque white appearance with no shining. The dural sac and descending nerve root are never displaced into the foraminal region, even with bulky herniations. The dural sac and the descending nerve root appear in the microscopic field in facetectomies larger than usual. They look very similar to the disc, distinguishing themselves by their brightness. I suggest the correct and undoubted identification of the disc before incising it. Otherwise, irreversible nerve root damage may occur.

Without bleeding, a dry microsurgical field is essential to perform a good discectomy and, consequently, a good bone grafting. Any bleeding, however slight, can make it difficult for the surgeon to find the disc and carry out the

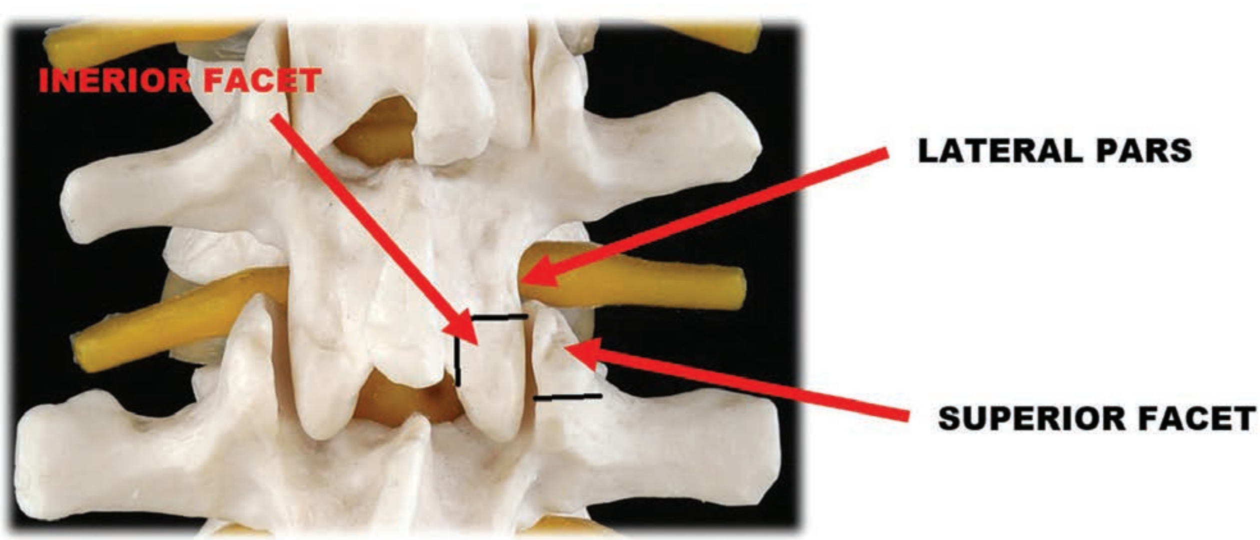


Figure 71 – Facet joint cutting lines

discectomy and intersomatic bone grafting. MIS TLIF operative field, as already said, is narrow and deep. Even if minimal, bleeding floods the working area, making it hard to visualize the nerve roots, leading surgeons to mistakes.

Routinely, I do not incise the disc before coagulation of the entire visible venous plexus in the microsurgical field. By doing so, I can perform the discectomy without suction. Therefore, the careful surgeon should not ignore the correct disc preparation for the discectomy. The time spent at this stage will be recovered in the following steps.

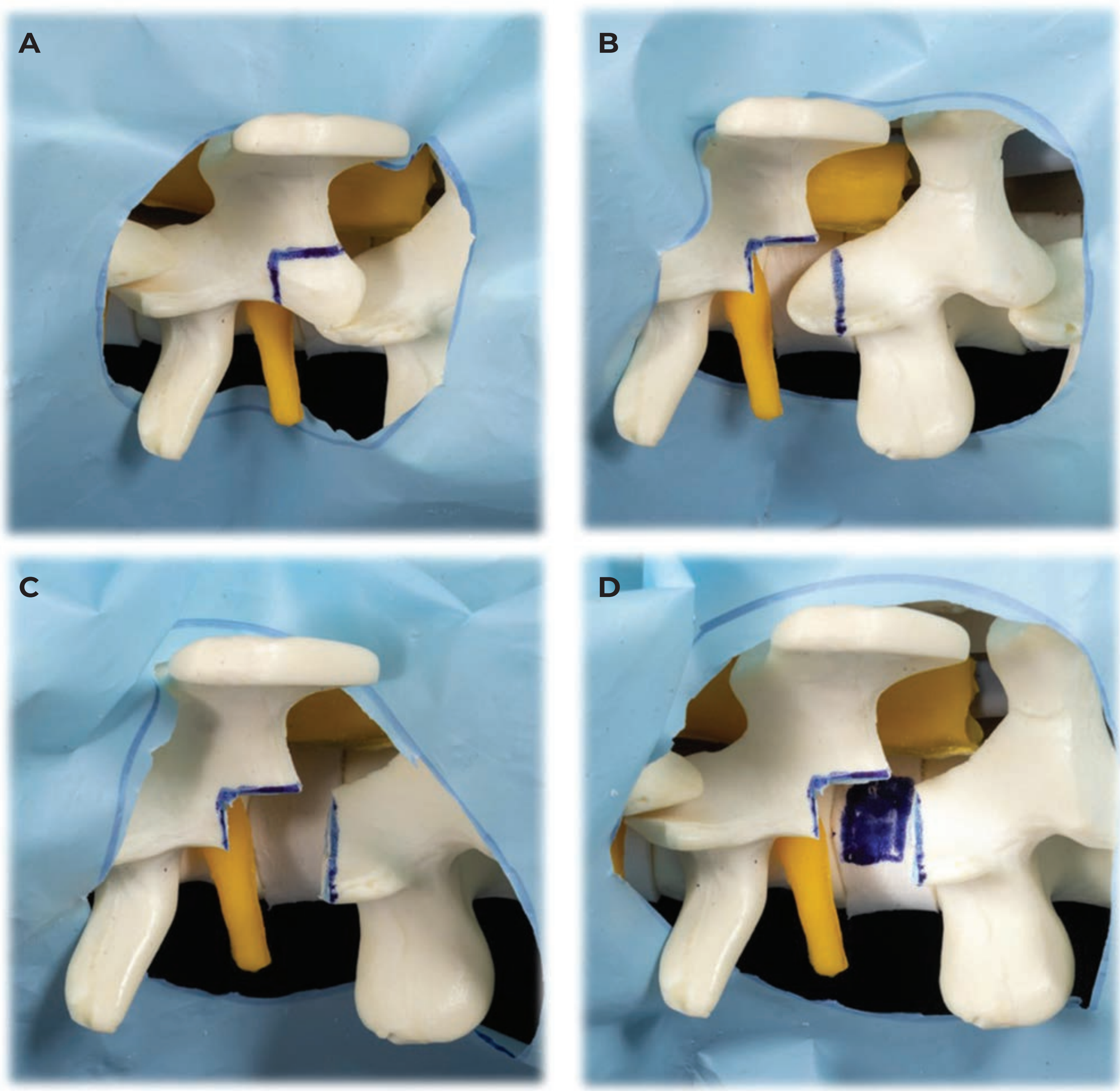


Figure 72 – **A**: Inferior facet cutting lines; **B**: Superior facet cutting line; **C**: Open foramen; **D**: Discectomy area

THE DISCECTOMY

The annulus fibrosus is incised with an 11-blade bayonet scalpel handle. Disc shaver helps the complete detachment of the disc nucleus, plus it helps to distract the disc space (fig. 75A).

Initiate discectomy using disc shaver 8 mm wide and, depending on the degree of distraction

> **Hint:**
> - The safest place to find the disc is beneath the superior facet cut surface; it is the base of the safe triangle (fig. 75B).

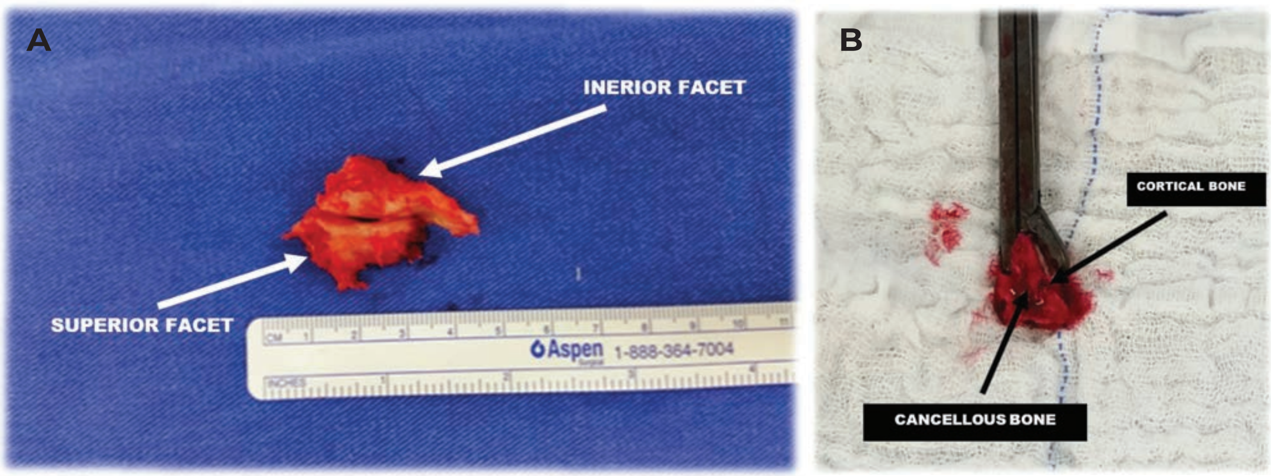


Figure 73 – **A**: Facet joint removed; **B**: Viable cancellous bone

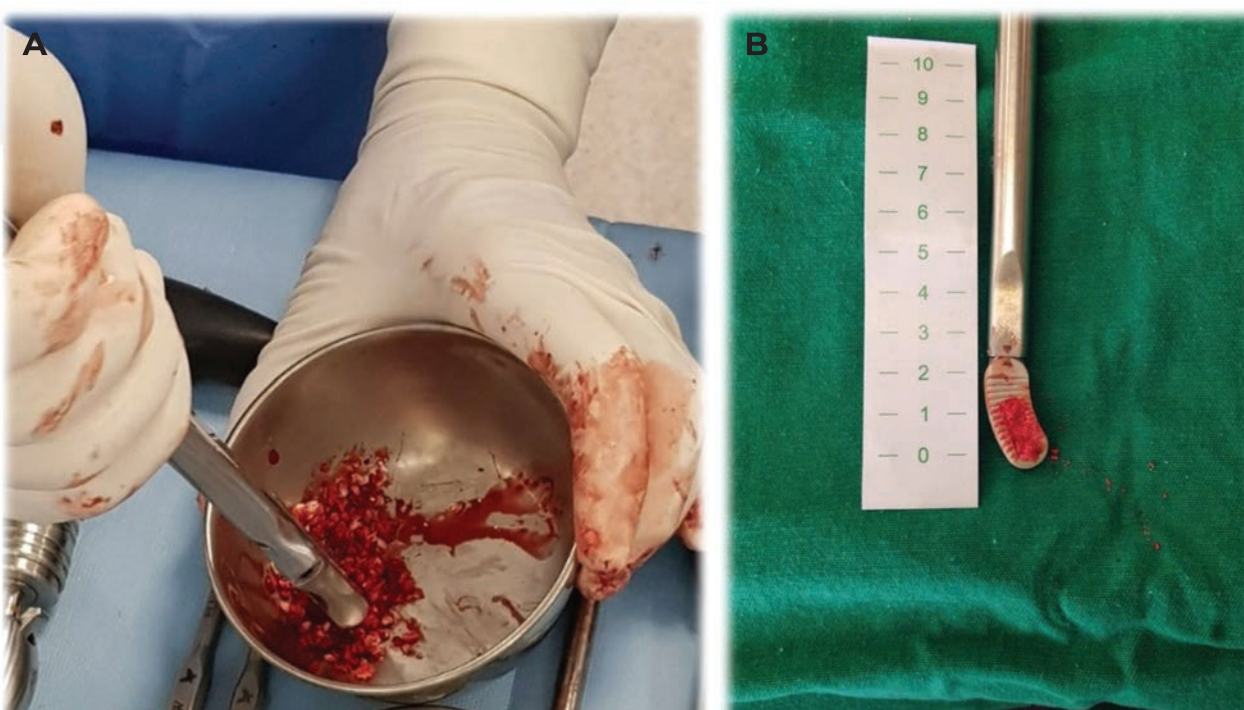


Figure 74 – **A**: Bone graft preparation; **B**: Cage filled with bone graft

and acceptance of the patient's disc space, gradually increase shaver size to number 10 and 12, respectively. Remember to distract the contralateral segment, facilitating the procedure and avoiding endplate fractures (fig. 76).

Before placing the disc shaver, use fluoroscopy guidance initially for its correct introduction into the intersomatic space without fracturing the endplates. Another essential care not to perforate the anterior edge of the annulus fibrosus must be taken; otherwise, severe vascular or retroperitoneal structures lesions may occur. Therefore, handle the instruments smoothly and cautiously.

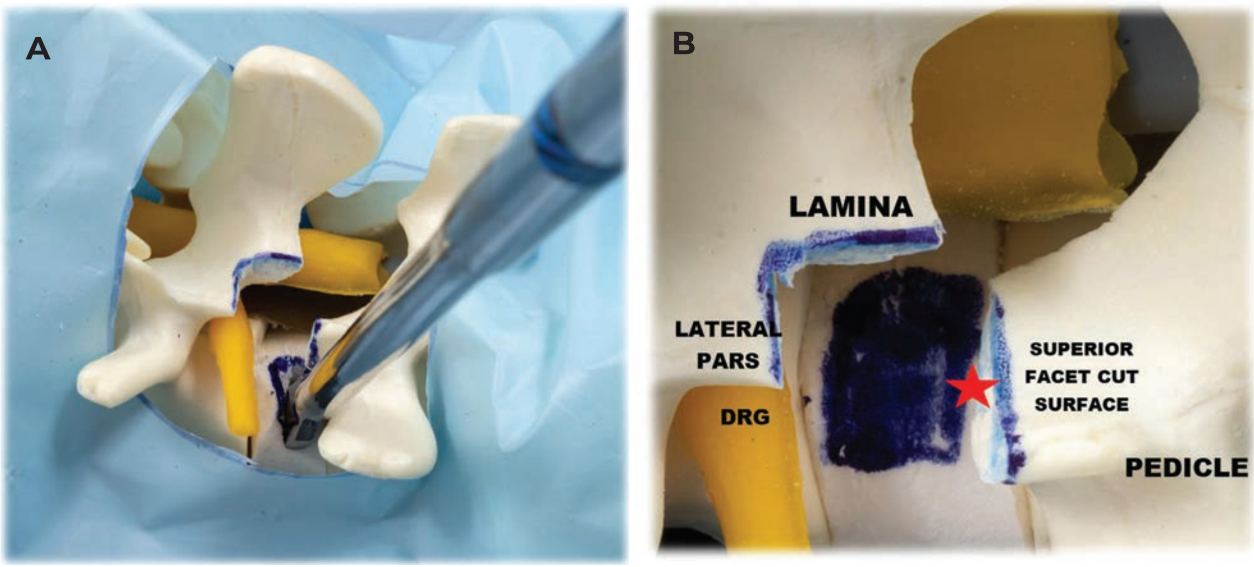


Figure 75 – **A**: Use the disc shaver to discectomy and disc space distraction; **B**: ★ Safest place to find the disc is the base of the triangle safe zone on the suprapedicular level

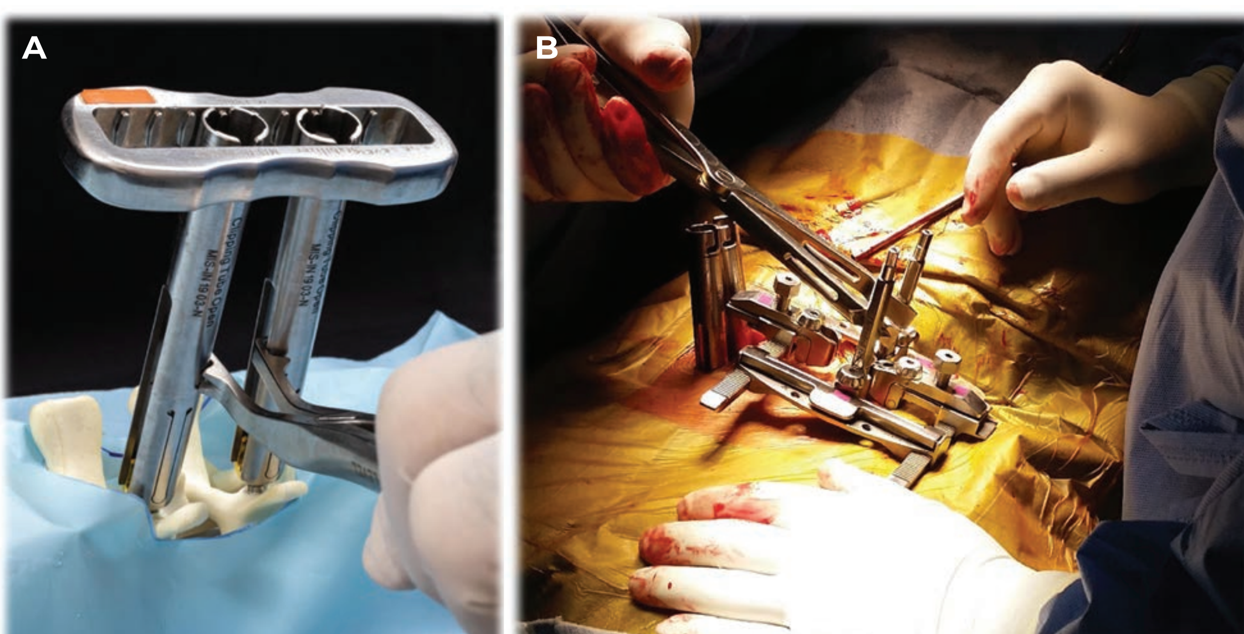


Figure 76 – **A**: Contralateral disc distraction; **B**: In situ ipsilateral disc space distraction (Romeo® MIS)

Shaver rotation should not be aggressive. Instead, continuously evaluate the degree of the disc space distraction. Significant resistance offered by vertebral bodies to distract the disc space should not be forced; otherwise, endplate fractures occur, making it impossible to place the intersomatic cage correctly, in addition to causing massive bleeding.

The cartilaginous endplate is shaved with curettes to prepare the vertebral body's surfaces for bone grafting. Using curved curettes, shave the opposite side to remove some remnant of the nucleus or endplate cartilage. This step is essential because the intersomatic cage must be placed towards the contralateral side.

The incorrect cleaning of the disc space does not allow an adequate cage placement and does not rotate it properly to the coronal plane. Furthermore, the TLIF cage positioned too posteriorly without proper rotation into the coronal plane predisposes to migrations and undesired catastrophic effects.

Endplate curettage must be done exhaustively and at the same time carefully. The surgeon must feel and listen to the bare bone sound during scraping movements to ensure that the superior and inferior vertebral body surfaces are ready to receive the graft.

The surgeon must take extreme care not to injure the descending nerve root medially placed; otherwise, severe injuries may happen if the instrument enters directly into the spinal canal.

Save the removed disc to measure its volume and send it for anatomopathological examination. In general, the disc weighs between 2 and 4 g; however, the volume is best verified intraoperatively by visual inspection (fig. 77). In addition, with rare exceptions, only the cartilaginous endplate is removed in patients with flattened and very degenerated discs. Therefore, appropriate disc volume removal should be analyzed individually.

INTERSOMATIC CAGE PLACEMENT

Measure the proper cage size using the cage trial and fluoroscopic imaging (fig. 78). The cage must not fit too loose, or it is at risk of posterior migration. In the same way, it cannot be aggressively impacted. In this way, placing a cage too high makes it hard to rotate to the coronal plane and may fracture the vertebral endplates, leading to iatrogenic cage subsidence.

After discectomy, implant the milled bone graft inside the disc space, and the remaining fill the cage(fig. 79).

It is important to note that the bone needs to be chopped entirely. The placement of large bone pieces hinders the correct positioning of the cage

TLIF cage, cage trial, cage holder, and TLIF curette and delays the process of bone fusion by reducing the contact surface.

The disc space is distracted with the aid of contralateral screws to facilitate cage placement and its rotation in the coronal plane (fig. 80). Again, take extreme care not to injure the descending nerve root, just medial to the foramen while placing the cage inside the disc space (fig. 81).

With the aid of fluoroscopy in the lateral view, place the cage with successive light taps, constantly checking on fluoroscopy. A slight medial direction tilts the cage towards the contralateral side. (fig. 82). At any sign of nerve impingement, the procedure is interrupted, and the cage removed. Once impacted as far anteriorly as possible, remove the cage holder and rotate the cage to the coronal position (fig. 83). If it does not turn properly, remove the cage under vertebral distraction and re-inspect the disc space looking for remaining disc fragments. The main reason for cage misplacements is incomplete cleaning of the disc space.

Some degree of cage eccentricity is acceptable as long as it fits inside the disc space and does not go beyond the vertebral body lateral limits. The ideal cage site is in the anterior vertebral body half, rotated in the coronal plane. A posteriorly placed cage does not allow adequate disc space compression,

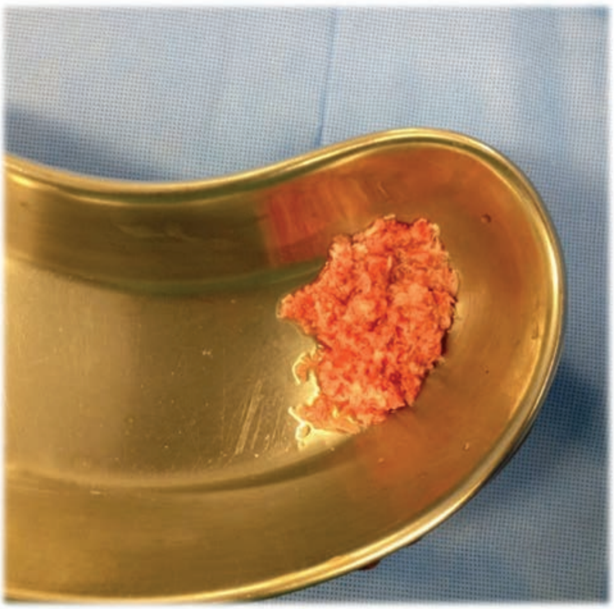


Figure 77 – One level disc volume

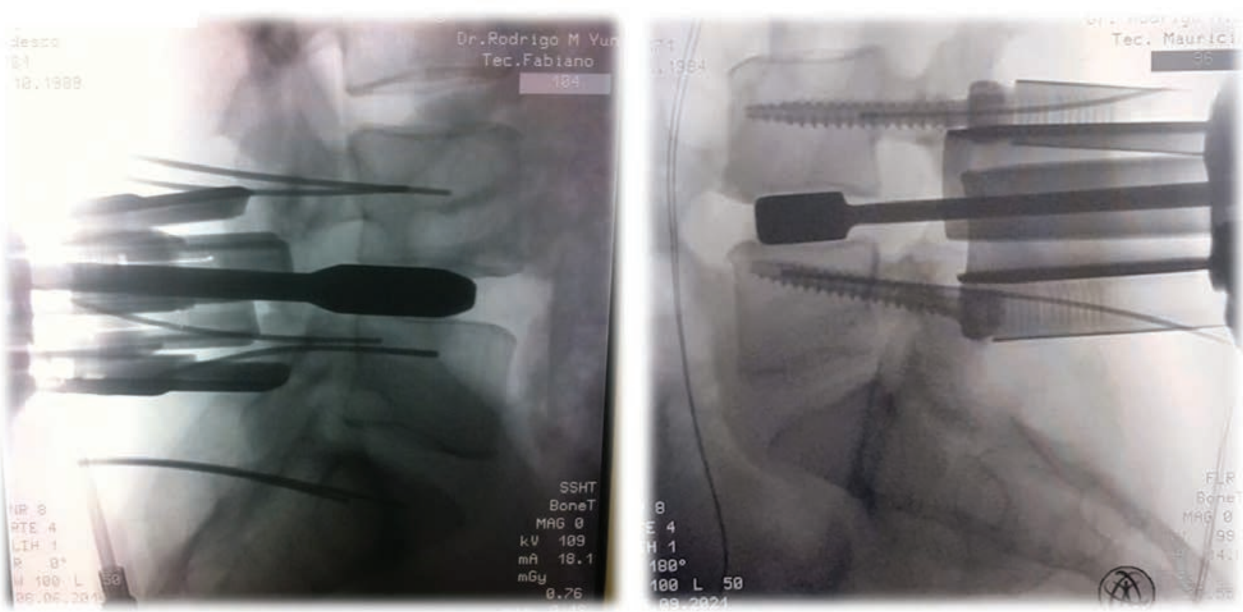


Figure 78 – Cage trial

predisposing for later migrations. Anterior vertebral disc space must be higher than the posterior, like a "fish mouth" (fig. 84). Motor evoked potential is rechecked, and, in general, there is a substantial gain after cage placement and intervertebral distraction.

Figure 79 – Cage preparation for placement

IPSILATERAL SCREWS PLACEMENT

The retractor is removed, and ipsilateral screws attached to the towers are placed through the guidewires (fig. 85 A to C). Appropriate-sized rods are measured with a caliper and inserted through connecting towers (figs. 86 and 87). The persuader helps attach the rod correctly into the screw´s head (fig. 88B). This step is performed under fluoroscopic aid for symmetrical positioning of the rods. The distal segment is locked to allow disc space

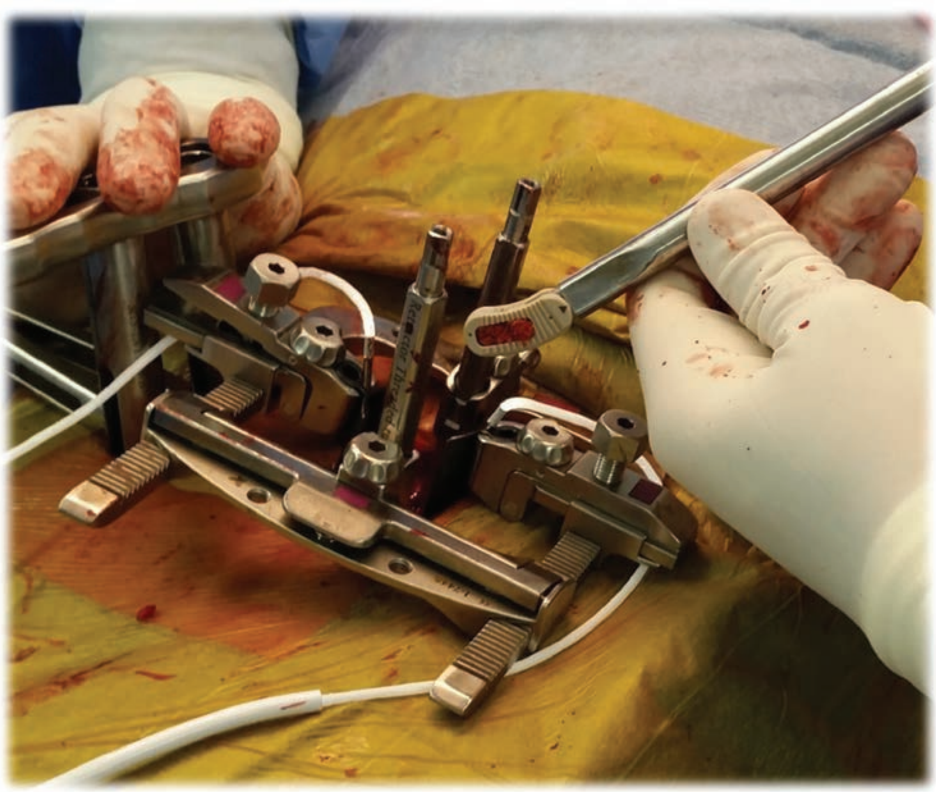


Figure 80 – Cage placement is always done under contralateral distraction

compression (fig. 87C). Cranial setscrews are locked under compression (fig. 88 D,E), and the connecting towers are removed (fig. 89). Final PA and lateral fluoroscopy are done for documentation purposes (fig. 83). Finally, the wound is closed (fig. 90A).

Hint:
- Remember to open the muscular fascia wide enough; otherwise, rod insertion will be difficult.

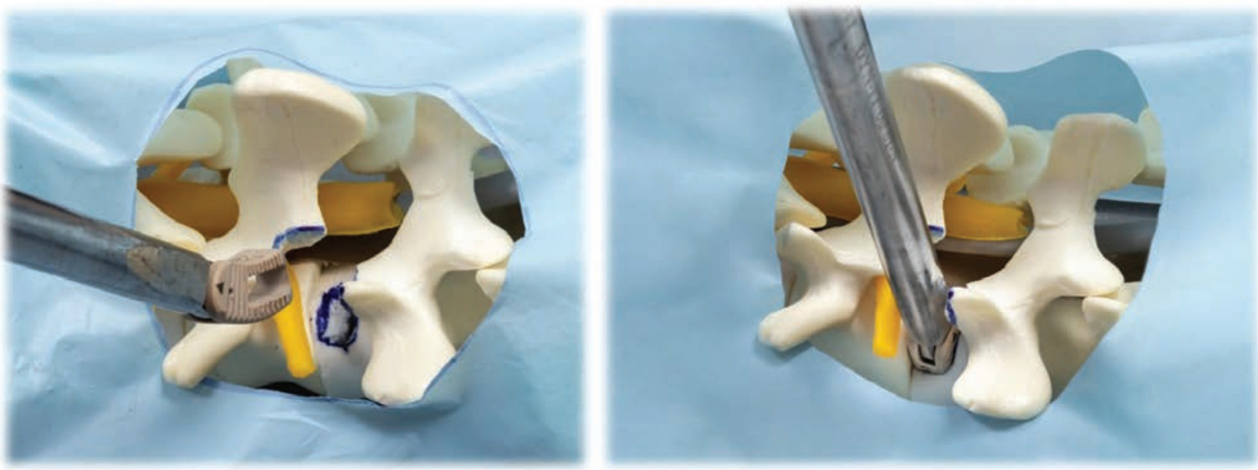


Figure 81 – During the cage placement, take care with the safe triangle nerve roots

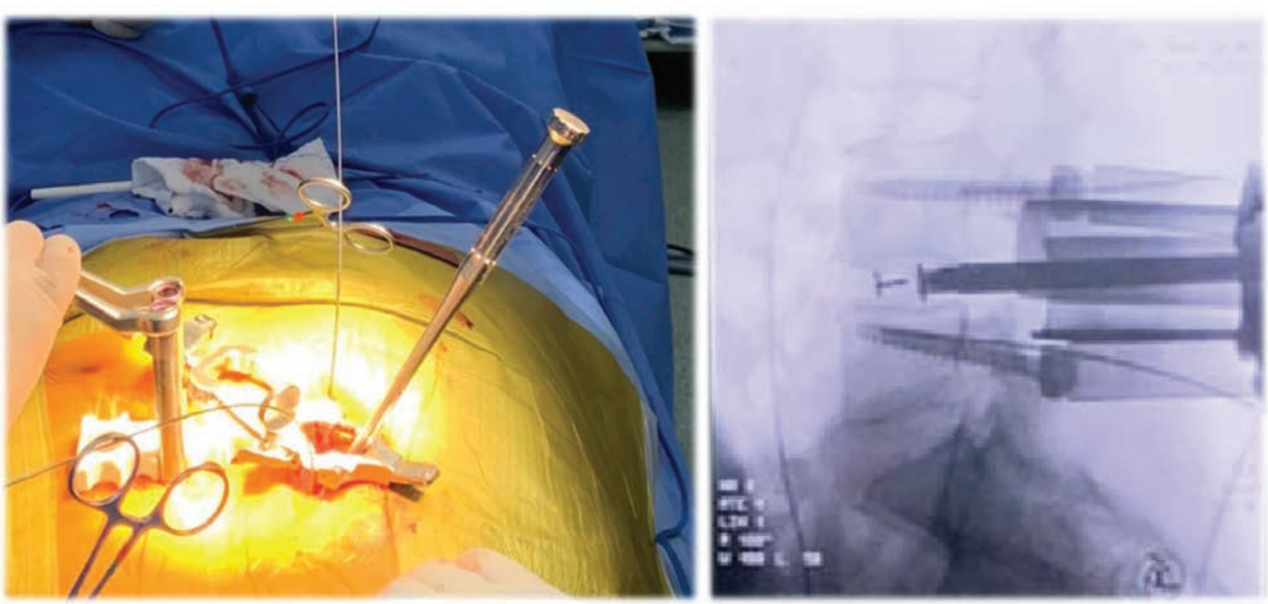


Figure 82 – Oppositely directed impacted cage guided by fluoroscopy under contralateral distraction

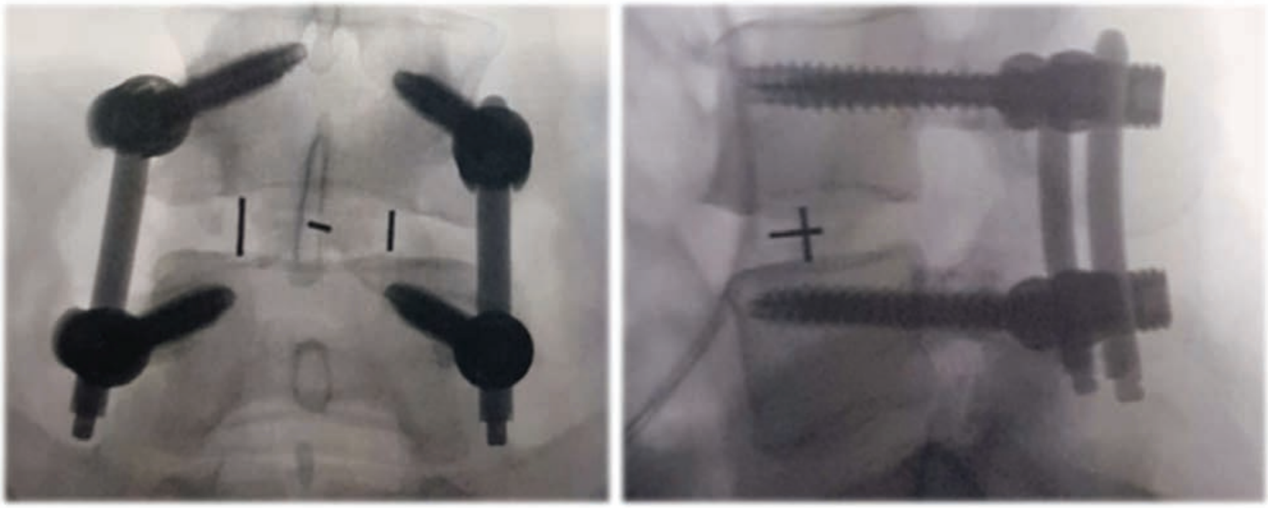


Figure 83 – The cage must be in the anterior vertebral half and rotated in the coranal plane

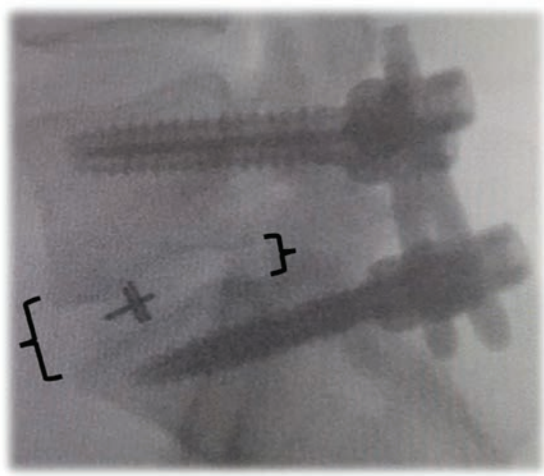


Figure 84 – The disc space “fish mouth” appearance

Rod inserter, setscrew, persuader, caliper, and setscrew holder

Distractor, compressor, counter-torque, and tightener

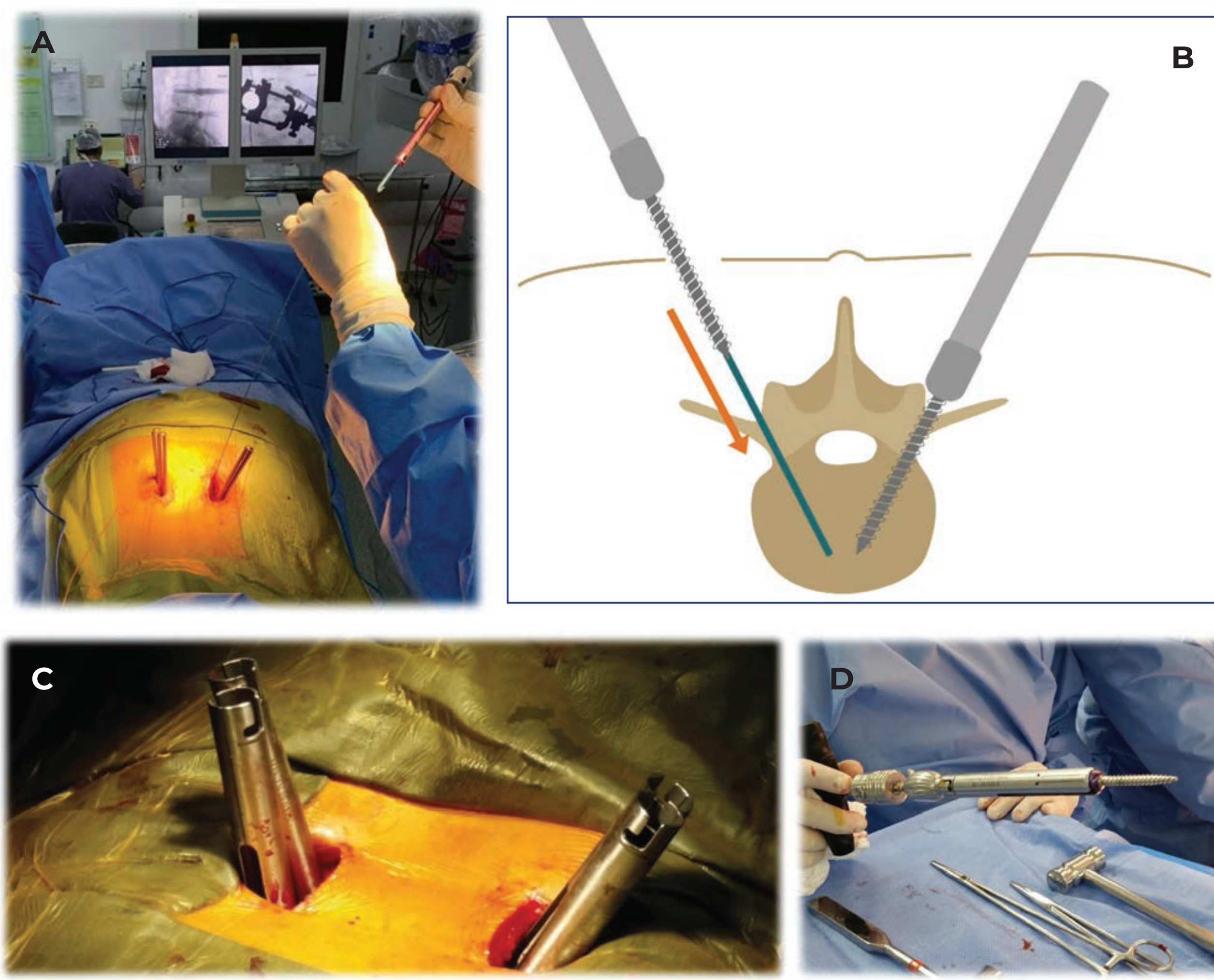


Figure 85 – **A/B**: Ipsilateral screw placement; **C**: Connecting tower attached to screw´s head; **D**: Cannulated screw attached to the connecting tower

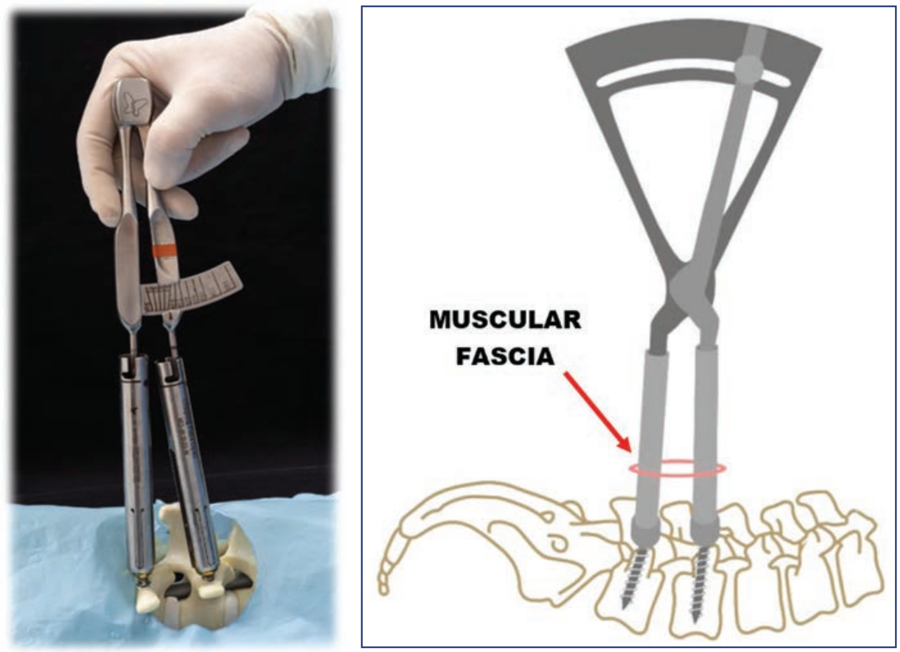


Figure 86 – Rod measurement

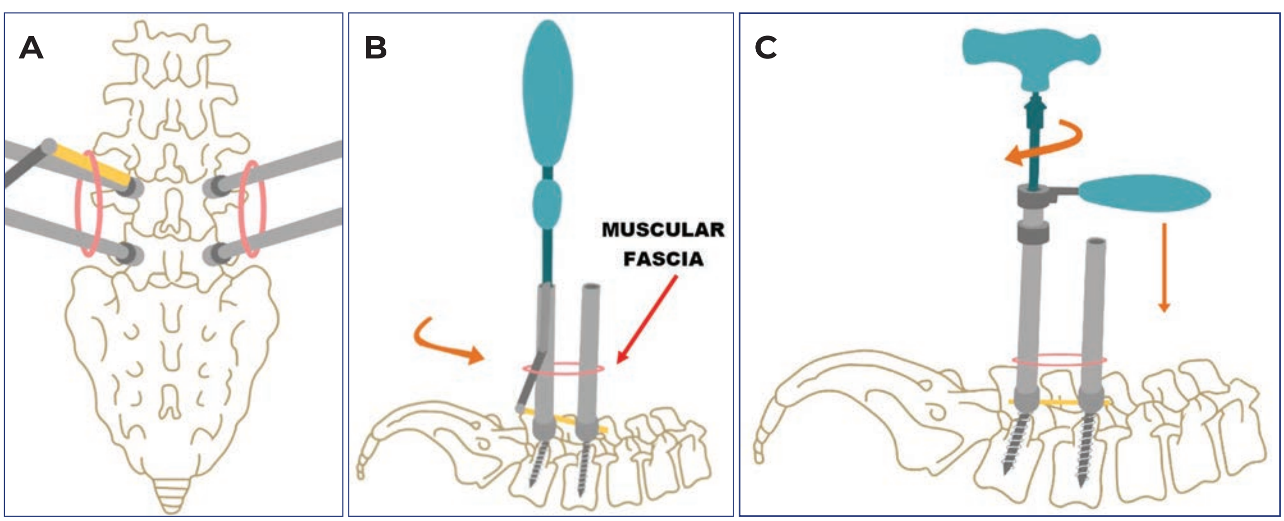


Figure 87 – **A/B**: Rod insertion through connecting towers; **C**: Distal segment setscrew locking

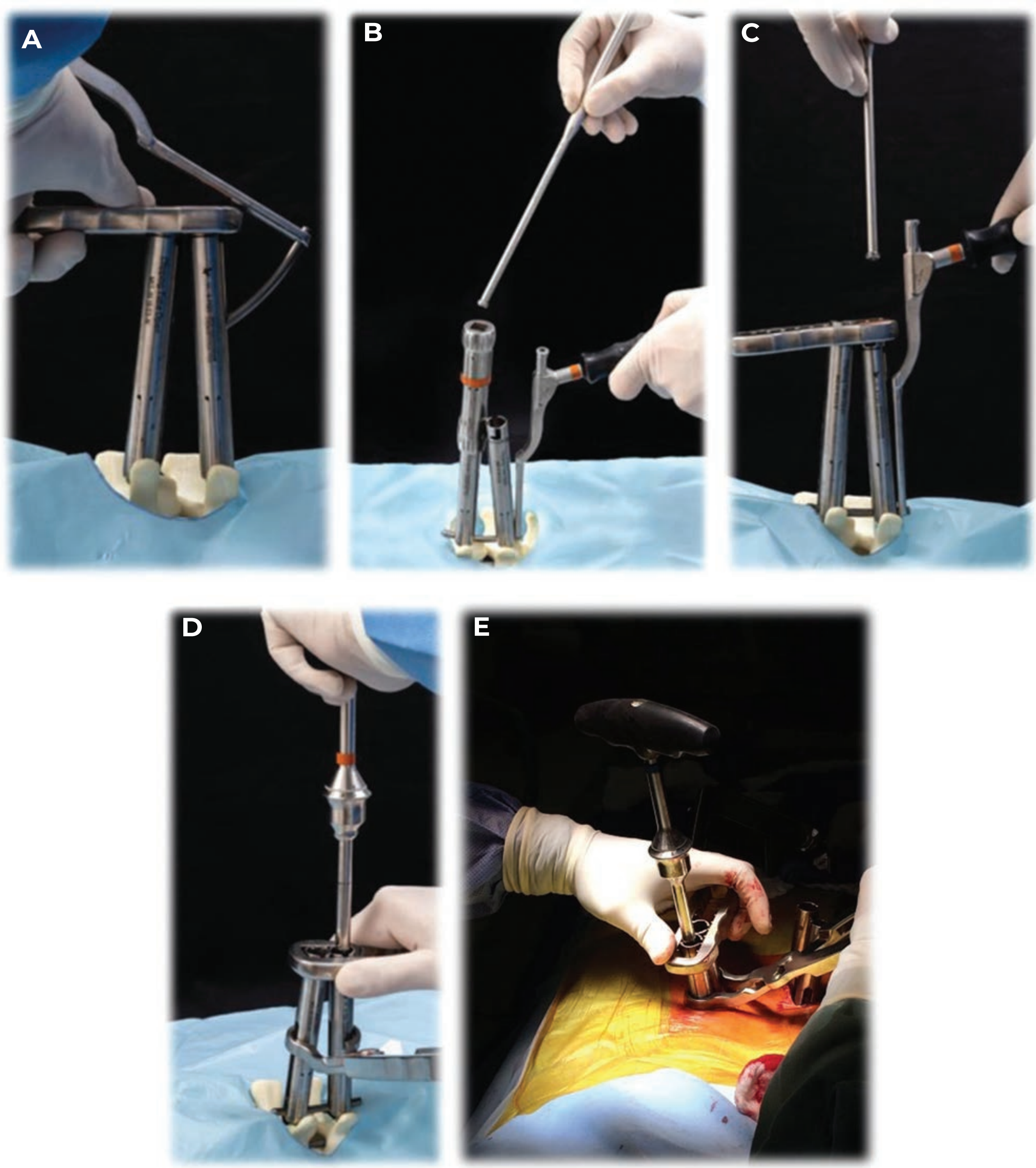


Figure 88 – **A**: Rod insertion; **B/C**: Setscrew placement; **D/E**: Final setscrew locking under segmental compression

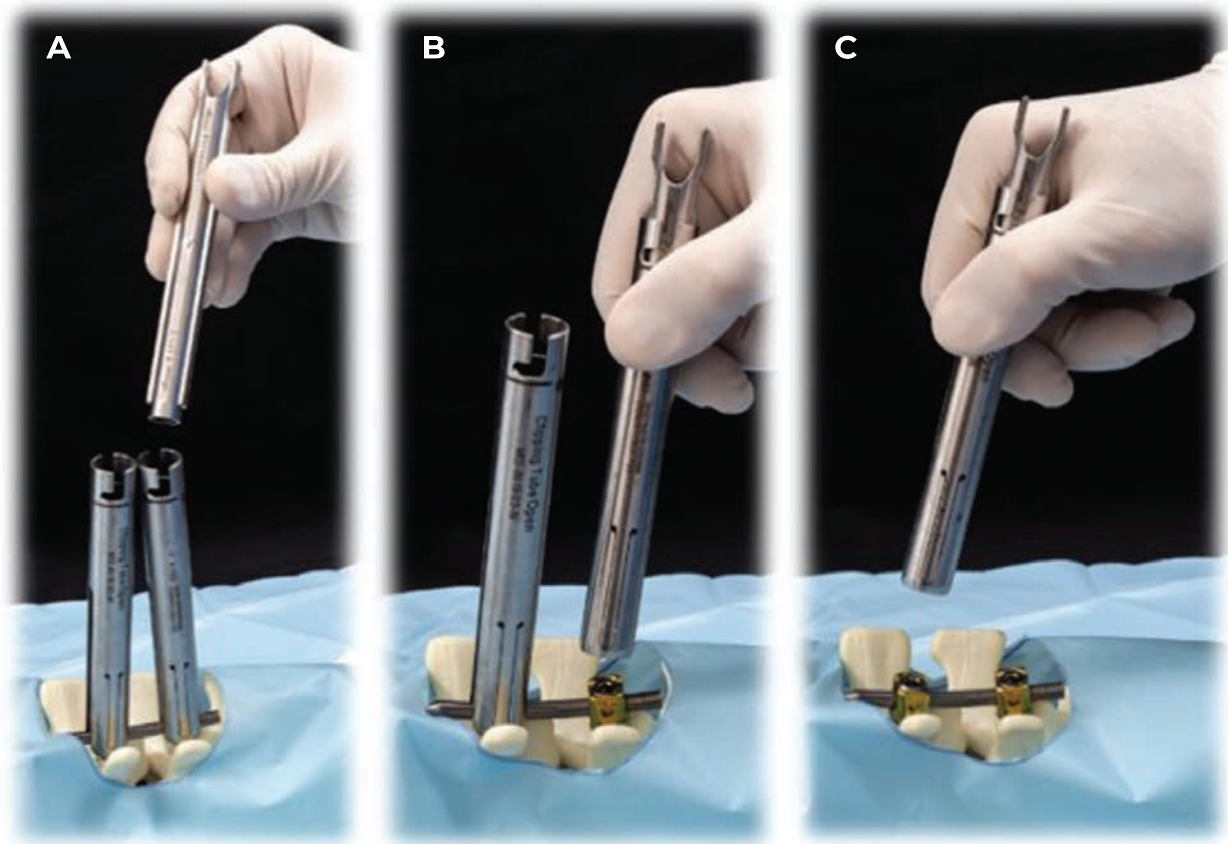


Figure 89 – Removing connecting towers

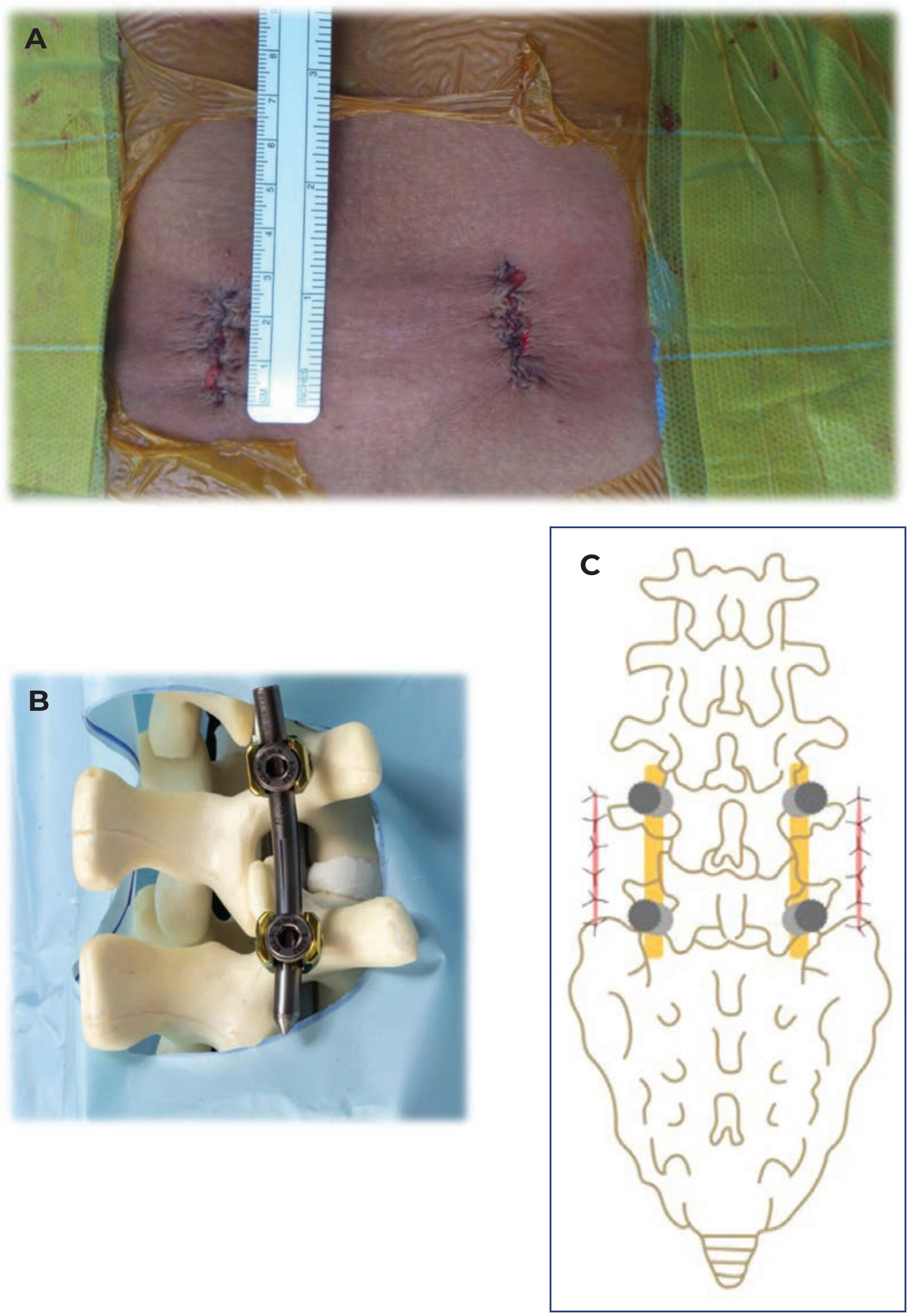


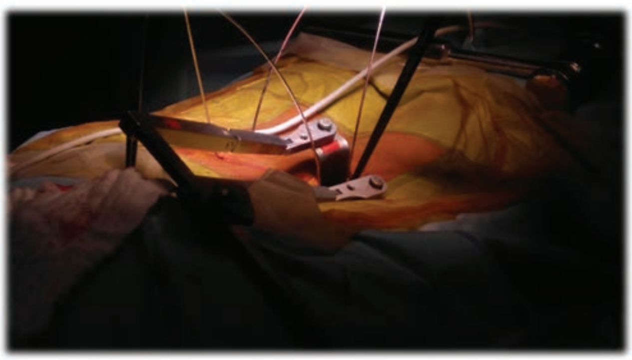
Figure 90 – Final result. **A**: One-level incision; **B/C**: Final construct

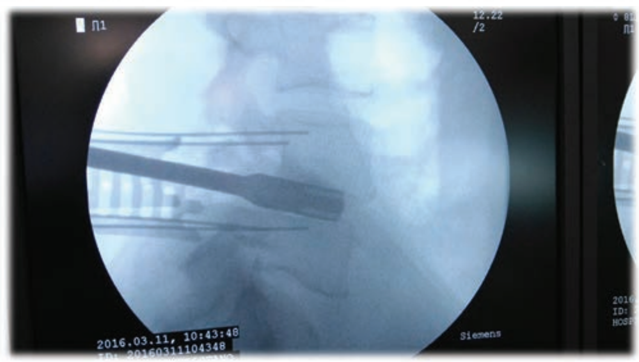
7 Case presentation

CASE 1

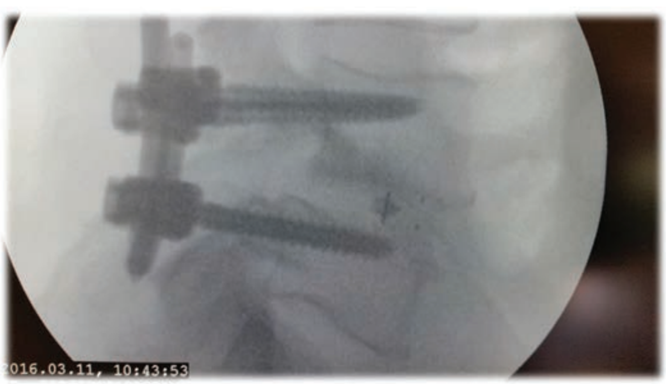
- 56 years old, male
- One year of bilateral radicular pain, L4 and L5 dermatomes
- Conservative treatment failure

- **Treatment option:**
  - ☐ Monosegmental fusion
  - ☐ Bilateral facetectomy due to disc space collapse
  - ☐ Intersomatic distraction with disc shaver aid
  - ☐ Contralateral TLIF
  - ☐ No central spinal canal decompression





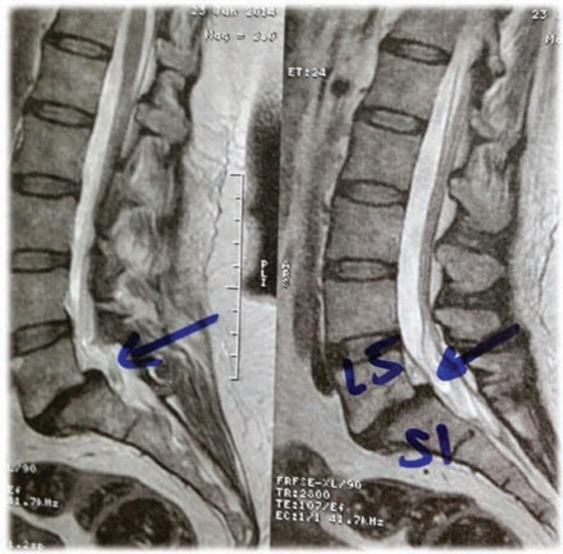
- ☐ 1st post-op day discharge
- ☐ NRS score 3
- ☐ No root pain



CASE 2

- 52 years old female
- Two years of low back pain associated with right side radiculopathy, L5 dermatome
- Conservative treatment failure

- ☐ RX - Spondylolisthesis grade 2
- ☐ MRI – bilateral foraminal stenosis with central canal widening

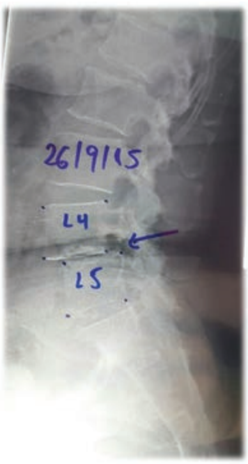


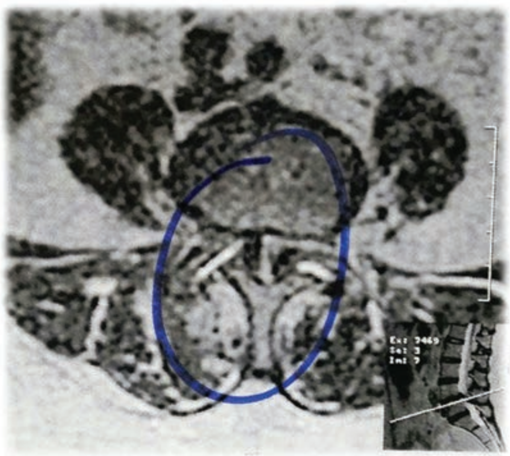
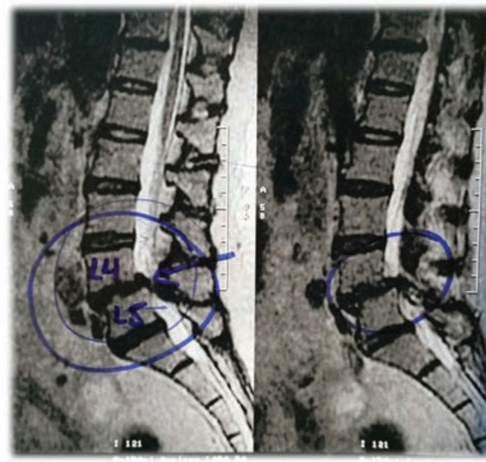
- **Surgical treatment:**
  - ☐ Monosegmental spinal fusion
  - ☐ Bilateral facetectomy due to disc space collapse
  - ☐ Intersomatic distraction with disc shaver aid
  - ☐ Contralateral TLIF
  - ☐ No spinal canal decompression (foraminal decompression and indirect central canal opening)
  - ☐ 1st-day post-op discharge
  - ☐ No radicular pain
  - ☐ NRS < 5

CASE 3

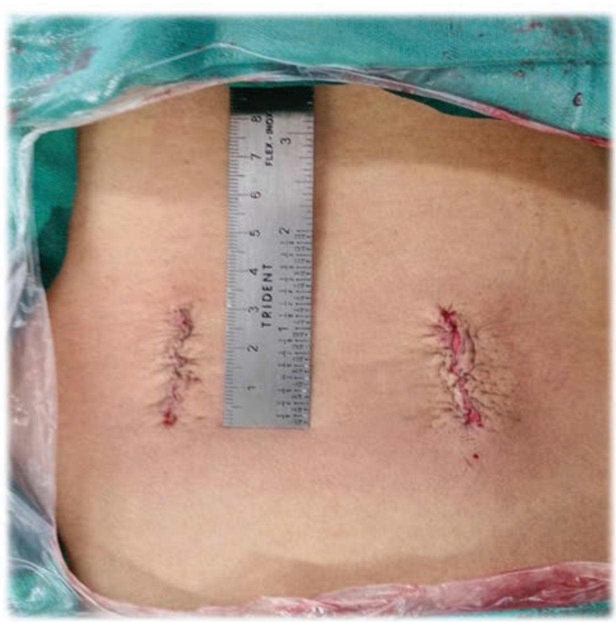
- 72 years old, female
- Normal bone density
- 1.5 year of low back pain with left radiculopathy, L4 and L5 dermatomes
- Conservative treatment failure

- ❑ RX - Spondylolisthesis grade 2
- ❑ MRI – central and foraminal spinal canal stenosis



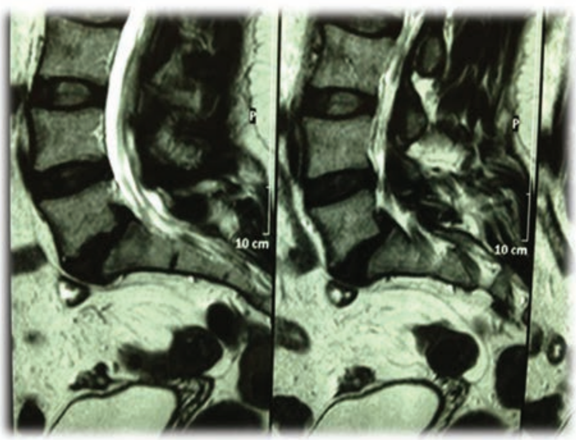



- **Surgical treatment:**
  - ❑ Monosegmental arthrodesis
  - ❑ Bilateral facetectomy due to disc space collapse
  - ❑ Intersomatic distraction with the aid of the intersomatic distractor
  - ❑ Contralateral TLIF
  - ❑ No laminectomy (direct decompression of the foramina and indirect decompression of the canal through the segmental distraction and olisthesis correction)
  - ❑ Discharge on the 1st postoperative day

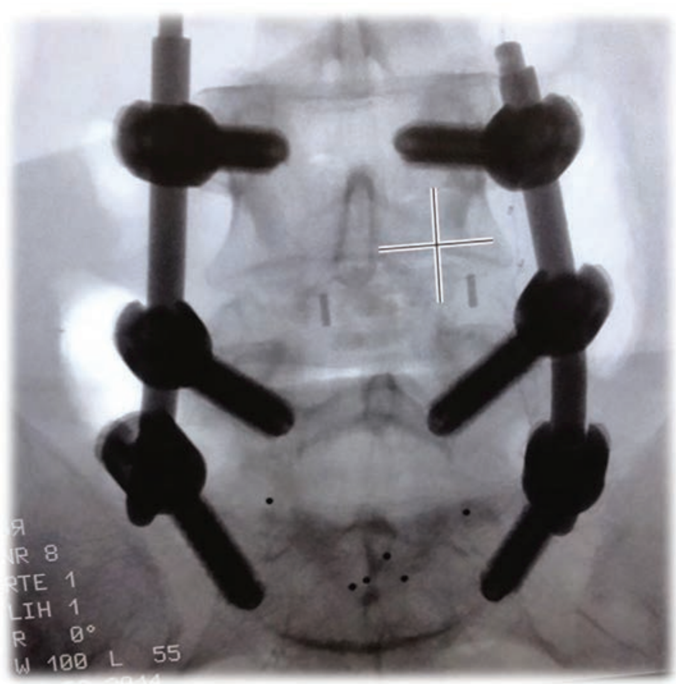



CASE 4

- 58 years old female
- Two years of bilateral low back and radicular pain
- Due to bilateral radicular symptoms, I considered L4 disc disease symptomatic. Confirmed by epidural blocks and patient complaints



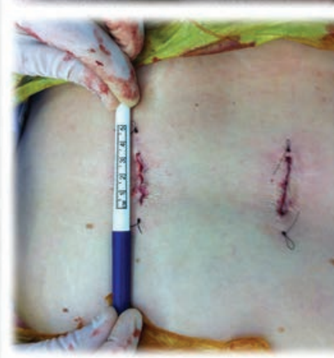
- ❏ RX – L5 grade 1spondylolytic spondylolisthesis
- ❏ MRI – L4 disc disease
- ❏ Bilateral foraminal stenosis
- ❏ Two-segment spinal fusion, bilateral facetectomy L5, and unilateral L4 facetectomy
- ❏ No center canal decompression
- ❏ No spinal canal exposure
- ❏ 2nd-day post-op discharge



CASE 5

- 32 years old female
- Bilateral low back and radicular pain
- Conservative treatment failure

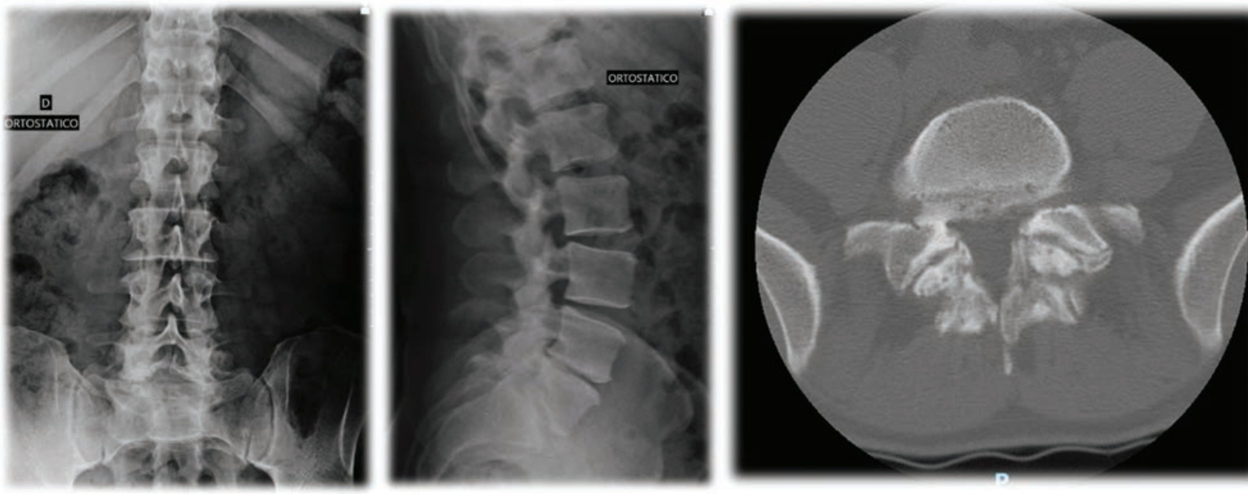
- ☐ RX - Spondylolisthesis grade 2
- ☐ MRI – bilateral foraminal stenosis, spinal canal widening
- ☐ Bilateral facetectomy
- ☐ Disc space distraction using disc shaver
- ☐ Discharge on the 2nd postoperative day
- ☐ Follow-up 5 years
- ☐ No symptoms



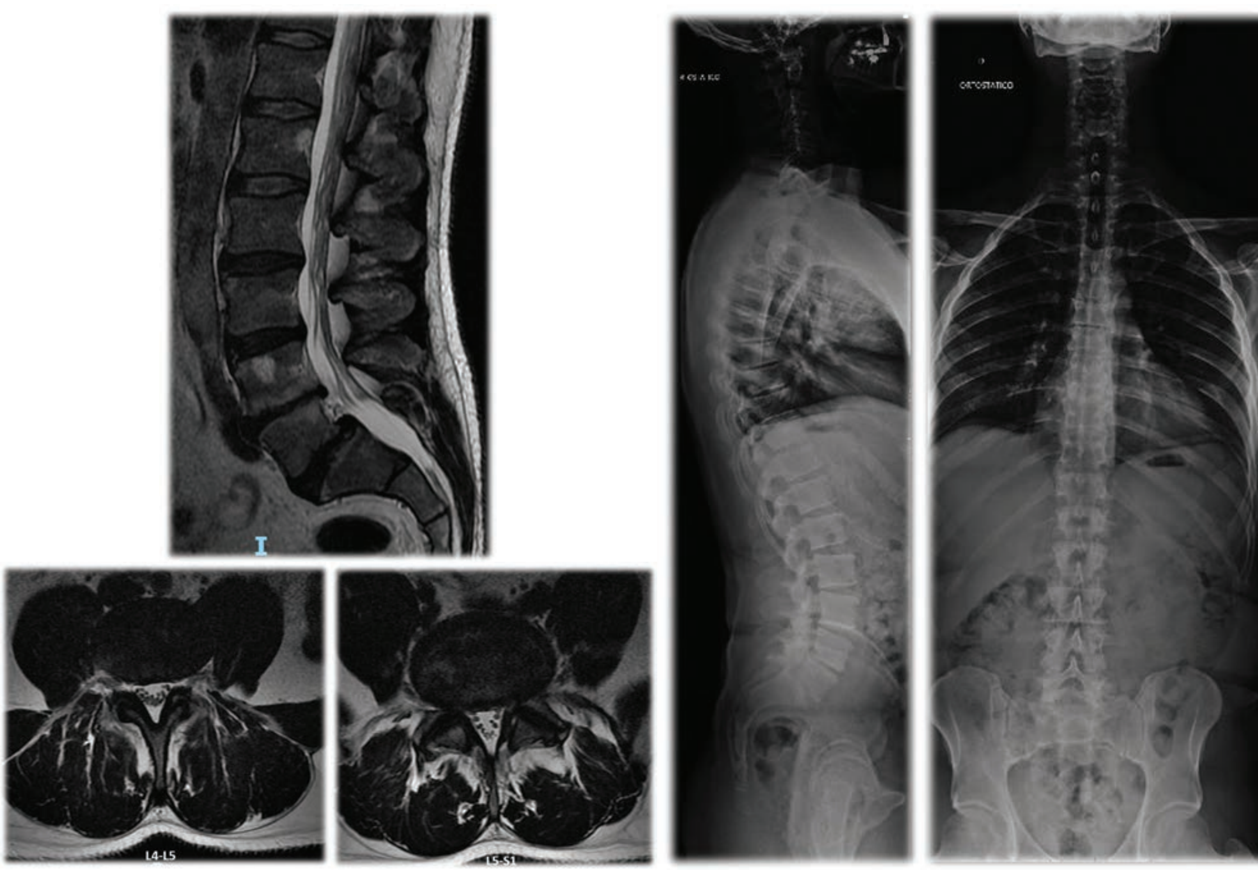
5y follow-up

CASE 6

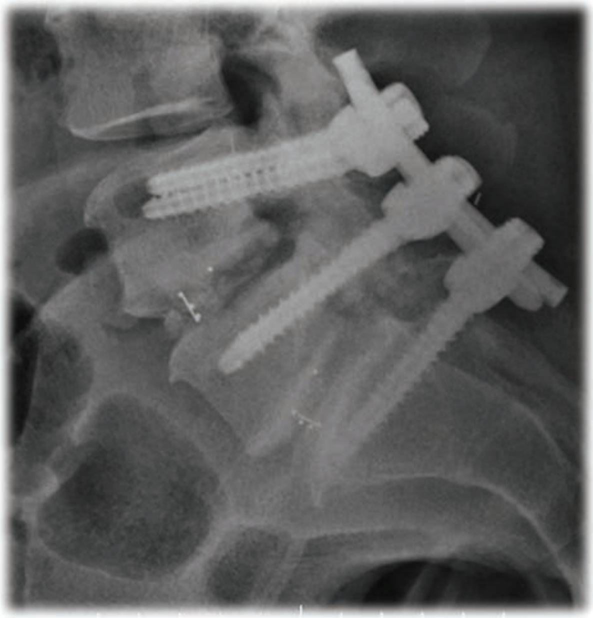
- 50 y old male
- 5 years low lumbar pain and bilateral sciatica
- Grade II displastic L5-S1 spond
- Pfirrmann 4 L4 DDD
- Normal sagital balance

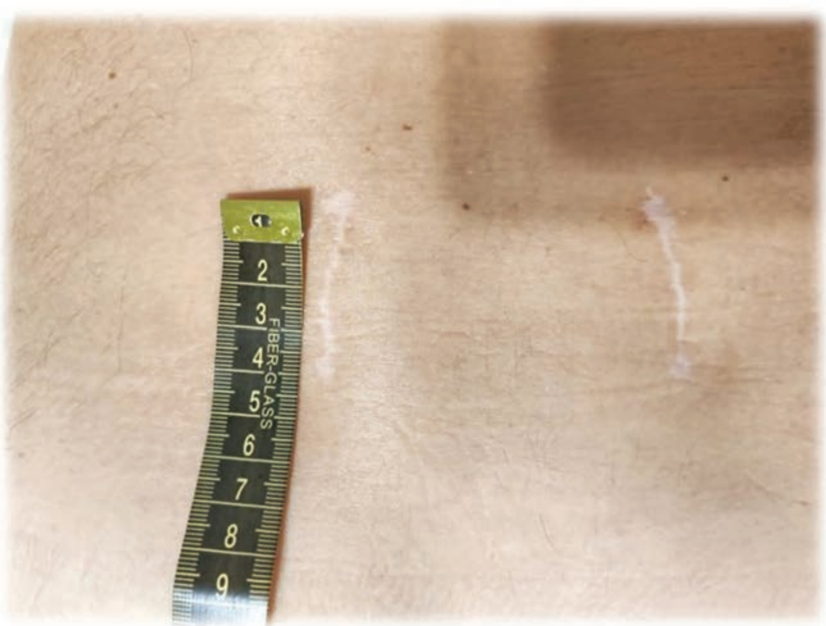


- ☐ L5 *spina bifida oculta*
- ☐ Hypoplastic L5 facet joints



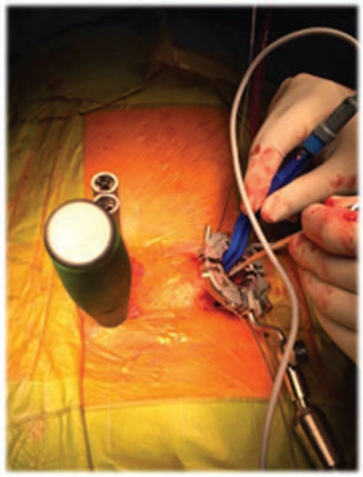
- ❑ MIS TLIF L4 and L5
- ❑ Bilateral L4 and L5 facetectomy
- ❑ 1 day post-op discharge
- ❑ 1 year follow-up: no complaints
- ❑ Return to regular activities



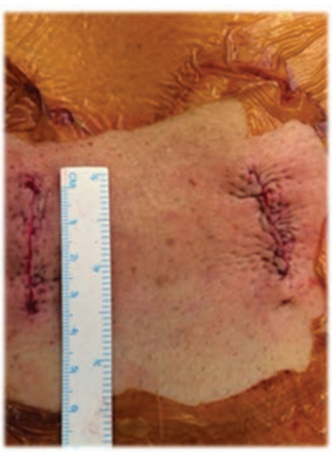


CASE 7

- 38 years old male
- Acute bilateral sciatic pain
- MRI: Bulky central L4-L5 disc extrusion



- ☐ Monosegmental spinal fusion
- ☐ L4 TLIF through the most symptomatic side



CASE 8

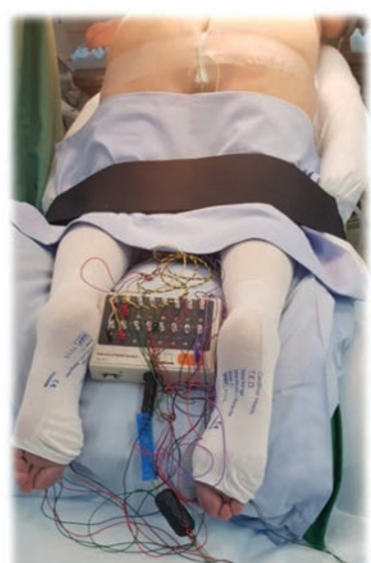
- 70y old female
- 2 years low lumbar pain and left ciatica
- RX – L4-L5 grade I spond with instability
- L4-L5 disc collapsed
- MRI: L4-L5 spinal stenosis

Neutral

Flexion

Extension

- ☐ Treatment option: MIS TLIF L4-L5 and unilateral left facetectomy
- ☐ Spond reduction and disc space opening with neuromonitoring



Neuromonitoring

Contralateral disc space distraction

Intersomatic disc space distraction

Cage placement and spond reduction

CASE 9 – VIDEO PRESENTATION

- Follow the link to watch the MIS TLIF video demonstration. Remember not to fast forward it; otherwise, you will lose the audio description.

8 About the author

Rodrigo Miziara Yunes was born in 1976 and lives in São Paulo/Brazil. His father is a retired general surgeon and was his inspiration for Medicine, as he is passionate about Human Anatomy and an excellent surgeon.

In 1995 he initiated Medical School at the Faculty of Medicine of the Federal University of São Paulo (UNIFESP). During his medical school years, Dr. Rodrigo fell in love with Human Anatomy, creating solid bases he uses to this day. As a great mentor, he had the famous Anatomist Prof. José Carlos Prates, a source of knowledge and inspiration through his scientific lectures with deep philosophical content, lacking today in Medical Schools.

During an introductory internship to the hospital in the first medical school year, Dr. Rodrigo attended his first neurosurgery. He felt great emotion, which motivated him to choose neurosurgery as a medical specialty.

Since then, he graduated in 2000 and has been practicing Neurosurgery and spinal surgery with much love and dedication. He attended medical residency in Neurosurgery between the years 2002 to 2006 at Hospital São Paulo, linked to UNIFESP, where he had the opportunity to train all the neurosurgery specialties, from brain surgery, spine and peripheral nerves surgery, having acquired extensive knowledge of the neurological surgery.

He earned the Brazilian Neurosurgery Society Board in 2006. During the first years of neurosurgery residency, he honed his knowledge in the spine surgery area, which was just being born within Medicine, especially in Neurosurgery, as the techniques were simple. However, there weren't many instruments that allowed excellent instrumentation, and, therefore, the eldest surgeons showed no interest in this area, which motivated him to work through this field.

At that time, the concepts for treating lumbar pain due to discopathies were still primary, limited to medication and physical therapy. Spine surgery was not yet entirely believed as a treatment option for low back pain. With the advent of modern implants and new techniques, Dr. Rodrigo could use his solid Human Anatomy knowledge and apply it in his surgeries.

Dr. Yunes treats degenerative disc diseases, adults and children spinal deformities, vertebral and spinal cord tumors, spinal fractures, and minimally invasive surgical procedures, such as spinal endoscopy, epidural nerve blocks, and MIS TLIF.

Like any good doctor, he conveys his knowledge to the younger ones and is the author of other literary works in the scientific area. However, scientific knowledge is dynamic and does not stop in time, and Dr. Rodrigo continues studying and acquiring new knowledge to improve his operative techniques.

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