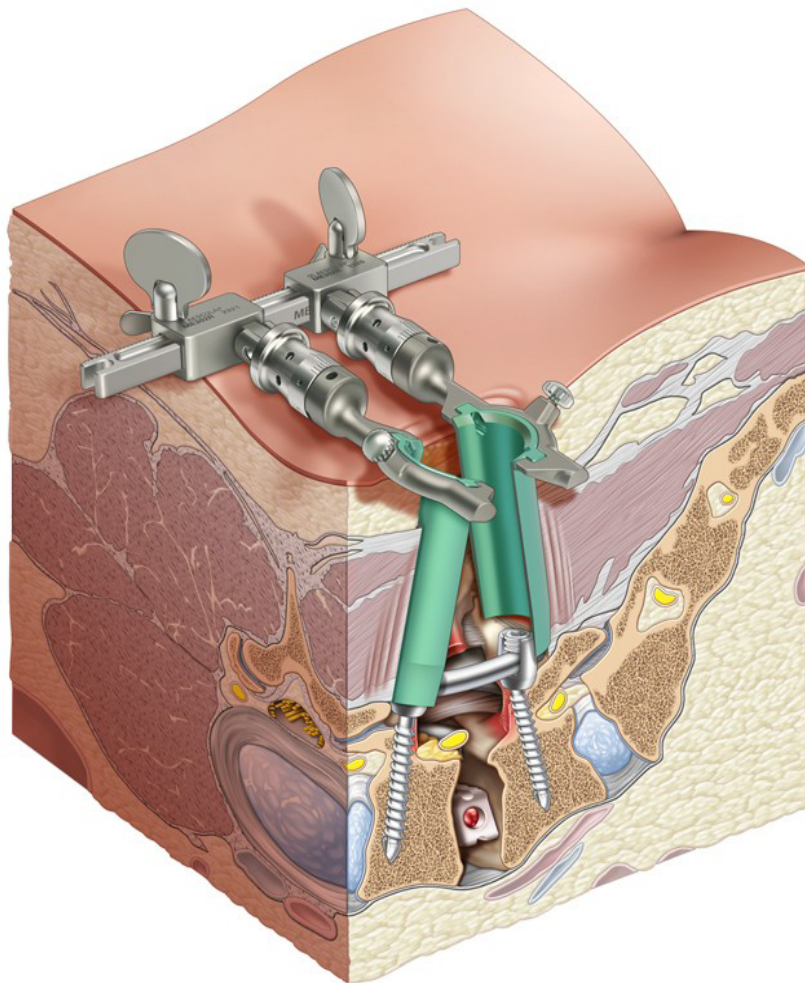


Mini Open

Transforaminal Lumbar Interbody Fusion (MOTLIF)

Surgical Technique, Pearls, and Pitfalls

Peyman Pakzaban, M.D.



Introduction

Mini open transforaminal lumbar interbody fusion (MOTLIF) is a powerful minimally invasive surgical (MIS) technique that achieves decompression, interbody fusion, posterolateral fusion, pedicle screw instrumentation and low-grade spondylolisthesis reduction (Table 1). As with other MIS techniques, incision size and muscle devitalization are minimized (1).

The MOTLIF technique and tools described here provide direct visualization of the relevant anatomical structures (pedicle entry points, exiting and traversing nerve roots, disc space, and transverse processes), thereby allowing the surgeon to use the familiar techniques of open fusion in this minimally invasive operation. Unlike previously-described mini open techniques (2,3), muscle creep into the field of view is minimized and visualization is improved.

MOTLIF is not only a comprehensive MIS technique in its own right, but also a “gateway technique,” facilitating a gradual and systematic transition from open surgery to percutaneous MIS operations.

MIS Fusion vs. Open Fusion

MIS approaches to lumbar fusion result in less intra-operative blood loss, faster patient mobilization, less postoperative pain, decreased length of hospitalization, and faster recovery when compared with open fusions (4,5,6,7). These benefits are in part mediated by preservation of paraspinal muscles (1,8,9). In addition, smaller incisions and less postoperative pain confer a psychological benefit to the patient recovering from surgery (10). These factors drive the demand for less invasive operations by an increasingly well-informed patient population.

MOTLIF vs. Other MIS Fusion Techniques

The capabilities of various MIS techniques available for lumbar fusion are described in Table 1. TLIF performed through non-expandable tubes, variably known as percutaneous TLIF (11) or MIS TLIF (12), is rarely performed as a standalone technique and is often combined with percutaneous pedicle screw (PPS) insertion. The limited visualization provided by percutaneous TLIF and PPS techniques and the inherent technical challenges associated with the use of non-expandable tubes, K-wires, towers attached onto cannulated screws, percutaneous rod insertion devices, and biplanar fluoroscopy amount to a steep learning curve for these techniques. Percutaneous TLIF and PPS also require greater use of intra-operative fluoroscopy than open fusion operations, resulting in increased radiation exposure (13). Surgeons cite technical difficulty, increased radiation exposure, and lack of training opportunities as their top reasons for avoiding MIS fusion (14).

The MOTLIF technique presented here overcomes these obstacles by providing an approach that closely resembles an open fusion operation, while adhering to the MIS principles of small incisions and muscle preservation (1). The incision size for a one- or two-level MOTLIF

operation is generally equal to the combined incision sizes for percutaneous TLIF and percutaneous pedicle screws.

Table 1. Comparison of MIS Techniques for Lumbar Fusion

| MIS Technique | Direct Decompression | Interbody Fusion | Screw Stabilization | Spondy Reduction (Low Grade) | Postero-Lateral Fusion |
|--------------------------|-----------------------------|-------------------------|----------------------------|-------------------------------------|-------------------------------|
| MOTLIF | ✓ | ✓ | ✓ | ✓ | ✓ |
| pTLIF* | ✓ | ✓ | | | |
| PPS** | | | ✓ | ✓ | |
| pTLIF + PPS | ✓ | ✓ | ✓ | ✓ | |
| XLIF | | ✓ | | | |
| XLIF + PPS | | ✓ | ✓ | ✓ | |
| Mini- ALIF | | ✓ | | | |
| Mini-ALIF + PPS or Plate | | ✓ | ✓ | ✓ | |

*pTLIF: percutaneous TLIF through non-expandable tubes; **PPS: percutaneous pedicle screws

Indications

MOTLIF is suitable for patients requiring one- or two-level circumferential lumbar fusions (6, 15). Such patients may have painful macro- or micro-instability associated with disc and facet degeneration and/or low-grade spondylolisthesis (7, 12). High-grade spondylolisthesis is best treated through an open posterior approach or combined anterior-posterior approaches. MOTLIF provides an excellent opportunity for lateral recess and foraminal decompression. With greater experience, central stenosis can also be addressed through the paramedian exposure offered by MOTLIF.

Equipment

The following items of equipment are needed for MOTLIF:

1. MOTLIF-specific retractor
2. TLIF implants and insertion tools
3. MOTLIF-optimized pedicle screws and insertion tools
4. Fluoroscopy unit
5. Operating microscope and/or headlight and loupes
6. High-speed drill and burrs
7. Microsurgical tools (bipolars, micro-scissors, etc.)
8. Standard instrument tray for open lumbar fusion
9. Bone graft substitute or osteo-biological (optional)
10. Intra-operative EMG monitoring

Aesculap's Spyder Retractor has been specifically designed and optimized for use in MOTLIF procedures. Detailed usage instructions for this retractor are available elsewhere (16). The retractor's tubular blades separate and tilt away from each other in cranio-caudal orientation, providing a conical field of view that is narrow at its apex (near skin surface) and wide at its base (near bone). A second retractor nests with the first to provide medial-lateral retraction (Fig. 1). The following characteristics distinguish Spyder from other mini-open retractors:

1. Narrower cranio-caudal and medial-lateral blades allow for smaller skin incisions. Wide array of the blade sizes and shapes also accommodate larger paramedian and midline exposures.
2. Each blade can be independently tilted, avoiding over- or under-retraction.
3. Cranio-caudal blades can be used without medial-lateral blades when appropriate.
4. Temporary speculum retractor facilitates muscle dissection before insertion of tubular blades.



Fig. 1. Spyder Retractor

The S4 pedicle screw system (Aesculap) has the following design features which make it uniquely suited to the MOTLIF technique:

1. One of the smallest available polyaxial screw head (OD = 10.5 mm) maximizes visualization of screw shaft during screw insertion through small incisions (Fig. 2).
2. The screwdriver engages only the center of the screw head, not its perimeter. This substantially reduces the screwdriver's footprint and improves visualization of the screw. The shorter shaft and delicate handles of the screwdriver, pedicle finder and tap facilitate their use under the microscope.

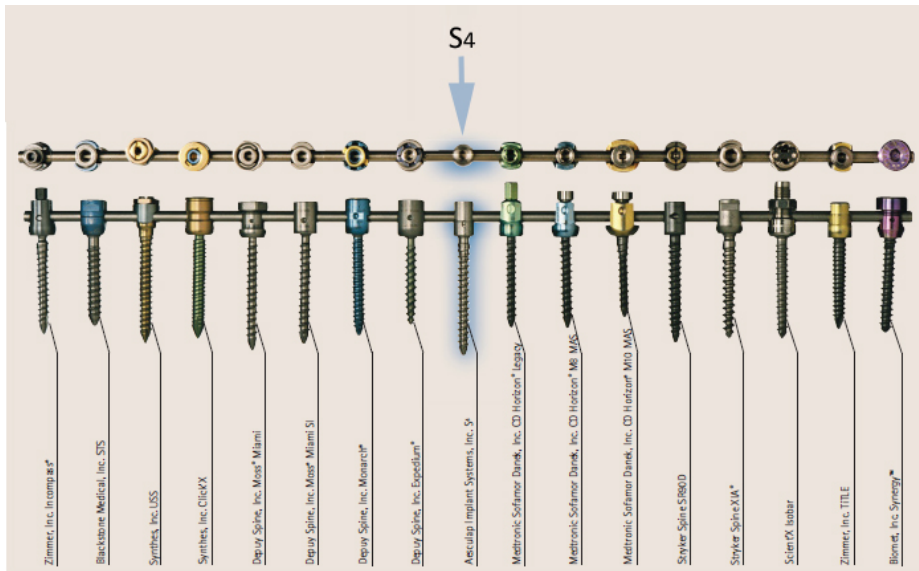


Fig. 2. Size comparison of S4 screw heads to other polyaxial screw heads

3. Extension tabs increase the effective polyaxiality of the screw head, facilitating rod capture in small exposures (Fig.3).

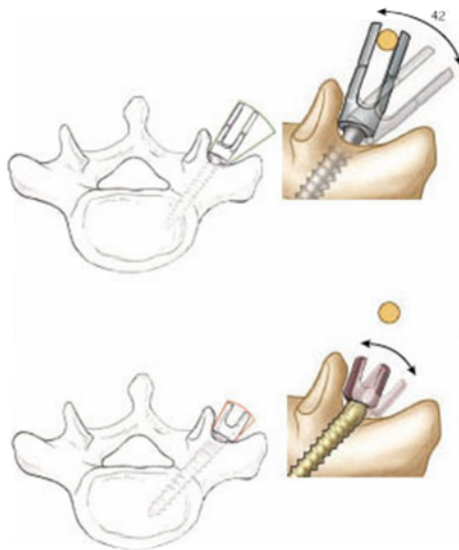


Fig. 3. Comparison of polyaxial range of screw heads with and without extension tabs

4. Threaded extension tabs prevent cross-threading of screw head when visualization of screw head is limited.
5. Threaded extension tabs act as built-in persuaders, facilitating final tightening of the set screw against the rod. They also provide for automatic reduction small degrees of spondylolisthesis (Fig. 4).

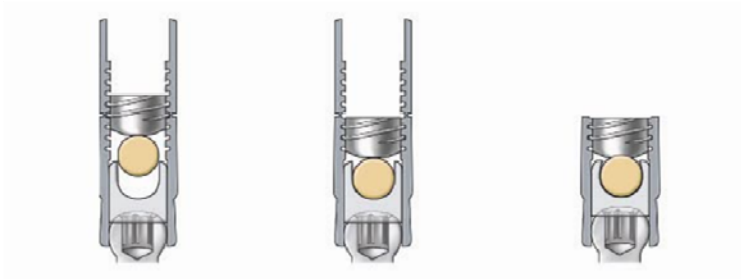


Fig. 4. Threaded extension tabs as built-in persuaders

6. Mini-open distractor-compressor tool fits through Spyder.
7. Available in cannulated and non-cannulated versions.

Unlike percutaneous techniques, only lateral fluoroscopy is used in MOTLIF. Illumination and magnification with loupes and headlights (or the operating microscope) are required, as are the usual instruments for open lumbar fusion and microsurgical discectomy, including bipolar electrocautery and a power drill. Thorough understanding of the anatomy and familiarity with the surgical technique of open fusion and pedicle screw fixation are prerequisites for successful and safe transition to MOTLIF. Intraoperative EMG monitoring further enhances the accuracy and safety of the operation (17).

Operating Room Set Up

The patient is positioned prone on a radiolucent frame or spine table. Electrodes for EMG monitoring are placed. After determining the incision site with AP and lateral fluoroscopy (see below), the C-arm can remain in lateral orientation for the remainder of the case. The author prefers to bring the C-arm under the table and completely drape it (Fig. 5), so that it can be easily operated by the surgeon and the assistant.



Fig. 5. The C-arm is brought under the table, placed in lateral orientation, and fully draped into the field.

The surgeon stands on the side ipsilateral to the planned TLIF. The assistant and scrub tech stand on the opposite side. If an operating microscope is used, its base is positioned contralateral to the base of the C-arm.

Surgical Technique

Incision

The precise location of the skin incision is of utmost importance. A paramedian incision made precisely in the sagittal plane that bisects the pedicles of interest allows vertical access to the facet joint, the lateral aspect of lamina, the transverse processes, and the pedicle entry points without the need to tilt the retractor complex medially or laterally. Before the surgical site is prepped and draped, lateral and AP fluoroscopy are used to mark the precise location of all pedicles of interest on the patient's skin (Fig. 6). For greater accuracy, the author uses a laser-guided localizer for this purpose (18,19).

Pearl: Make the skin incision in the parasagittal plane of the pedicles as determined by fluoroscopy.

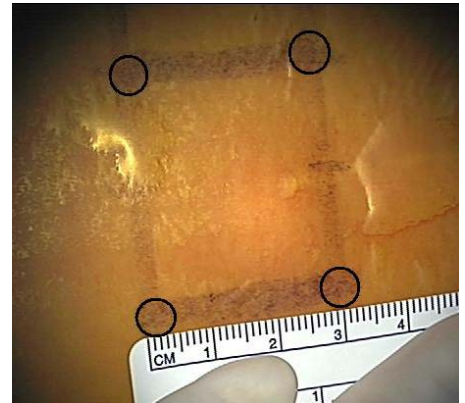


Fig. 6. The locations of the four pedicles of interest for an L4-5 MOTLIF have been marked on the patient's skin. The incision size is 3 cm.

For operations at or above L4-5, the incision extends from the center of one pedicle to another, generally measuring about 3 cm in length (for a one-level MOTLIF). For access to the L5-S1 segment, the incision extends from 1 cm above the S1 pedicle to 1 cm above the L5 pedicle to provide the optimal angle for TLIF and S1 screw insertion (Fig. 7).

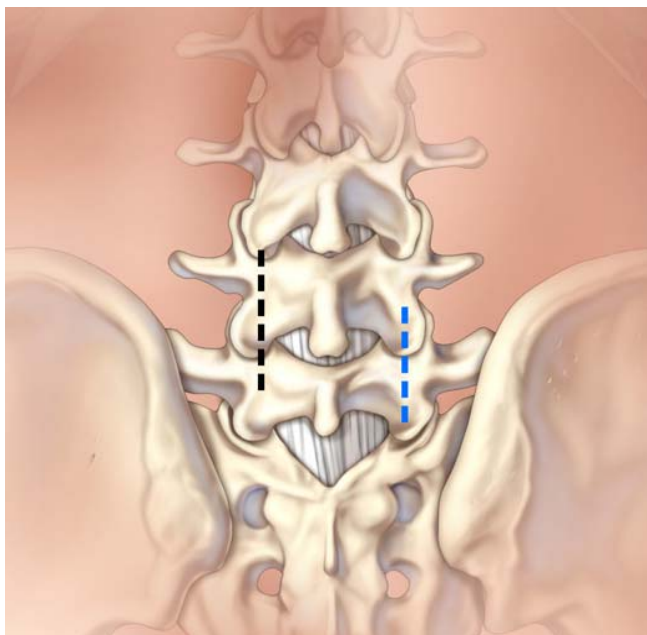


Fig. 7. Locations of paramedian skin incisions in the sagittal planes of the pedicles of interest for an L4-5 fusion (black) and an L5-S1 fusion (blue).

Exposure

Pharmacological muscle relaxation is induced and is designed to wear off by the time the surgeon is ready for pedicle screw insertion with EMG monitoring. After the skin and subcutaneous fat have been divided, the lumbar fascia is identified. A fascial incision is made in the sagittal plane of the skin incision (Fig. 8.) It is important to extend the fascial incision cranially and caudally beyond the limits of the skin incision in order to allow for the conical field of view that will be secured by the retractor (Fig. 9). A Gelpi retractor, initially used for skin retraction, is then deepened to retract the fascial edges.

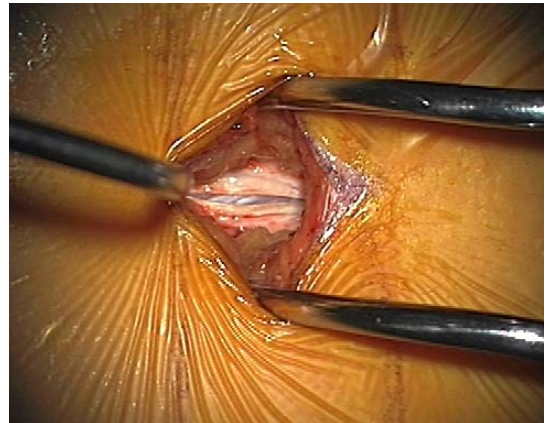


Fig. 8. The lumbar fascia is incised in the plane of the skin incision.

At this stage, based on a modification of the approach first described by Wiltse, some have advocated finding the cleavage plane between the multifidus and longissimus portions of the sacrospinalis muscle. However, when Wiltse described the “paraspinal sacrospinalis-splitting approach,” he intended it for a posterolateral

Pitfall: Do not attempt to find and follow the plane between multifidus and longissimus. This would direct the exposure too laterally.

fusion, not an instrumented interbody fusion (20,21). Later investigators have found this natural cleavage plane to occur about 4 cm off midline (22). Following this cleavage plane would lead one to the region just lateral to the facet

joint and would make it more difficult to achieve adequate medial visualization for decompression. We recommend splitting the muscle fibers in the sagittal plane of the skin and fascial incisions. This leads one directly to the center of the facet joint and substantially improves visualization throughout the remainder of the procedure.

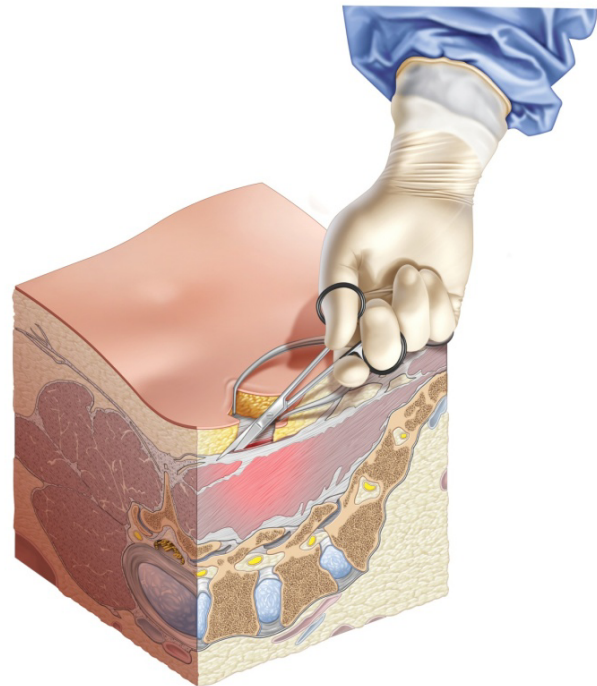


Fig. 9. The fascial incision is extended above and below the limits of the skin incision.

To accomplish this, an index finger is inserted into the muscle and is advanced along a plumb line until the most prominent portion of the facet joint is palpated (Fig. 10). The finger is then swept up and down in the sagittal plane, separating the longitudinally-oriented muscle fibers. One should perform enough finger dissection to be able to palpate the entire cranio-caudal extent of the facet joint of interest and the base of the facet joint at the level above. It is useful to think of the adjacent facet joints as two mountains separated by a valley – the latter corresponding to the *pars interarticularis*.

At this point, most other mini-open techniques recommend insertion of dilators and the retractor system. This misstep is the principle cause of the muscle creep problem that has plagued other mini-open techniques and impeded their widespread use. It is important to keep in mind that unlike percutaneous trans-tubular approaches, the mini-open approach requires a more extensive pedicle-to-pedicle exposure of the underlying bone. There are tough musculotendinous attachments to the facet capsule, lamina, *pars interarticularis* and transverse processes that cannot be detached by dilators or the opening force of retractor blades. Premature insertion of the retractor at this stage would only ensure a rush of muscle into the depth of the field, lifting the retractor away from the bone as the retractor blades are opened. It is critically important to divide these musculotendinous attachments to the underlying bone prior to insertion of the final retractor system.



Fig. 10. Finger dissection in the parasagittal plane separates the longitudinally-oriented muscle fibers. The rostro-caudal span of this blunt dissection extends from the base of the facet joint of interest (L4-5 in this case) to the base of the facet joint at the level above (L3-4).

Pearl: Cut the musculotendinous attachments to the underlying bone before inserting the mini-open retractor system.

Two different methods can be used to achieve this task. In the free-hand method, the surgeon uses bipolar electrocautery and Metzenbaum scissors, inserted along the plane previously developed by finger dissection, to sequentially coagulate and divide the muscle attachments to the bone (Fig. 11A). In the speculum method, a temporary speculum retractor provided in the Spyder retractor set can be used to simplify this task (Fig. 11B). The speculum is first inserted with its blades closed over a small dilator. The blades are then slightly

opened in the cranio-caudal orientation to expose a small portion of the underlying bone. After the muscle-bone attachments in this region are divided, the retractor is opened a little more and more dissection is carried out. This sequence is repeated until sufficient bony exposure is obtained, exposing the entire facet joint of interest, the *pars interarticularis* above that joint, and the base of the adjacent cranial facet joint.

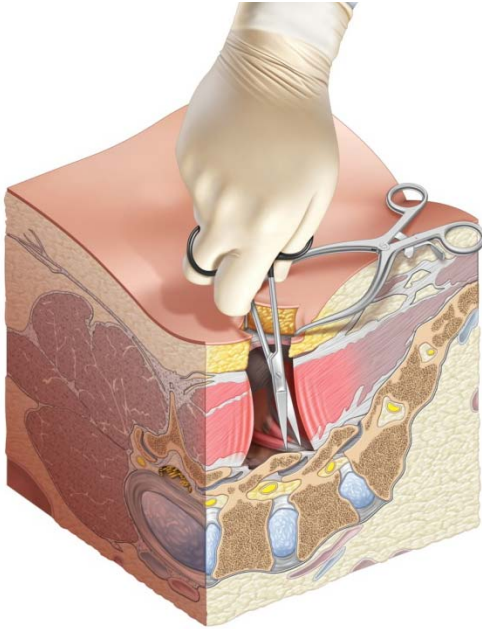


Fig. 11A. Free-hand detachment of muscle from bone

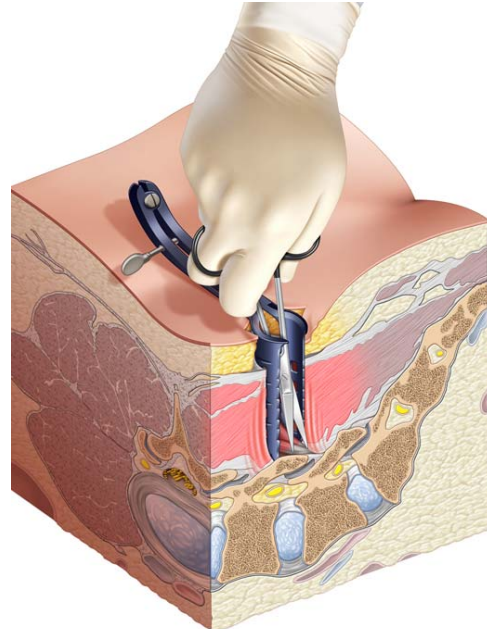


Fig 11B. Temporary speculum retractor used for muscle detachment

Spyder Retractor Insertion

The tubular blades of the Spyder retractor, designed for retraction in the cranio-caudal plane, come in three different diameters: 16.5 mm, 20 mm, and 24 mm (Fig. 12). The incremental dilator system contains corresponding dilators for each blade diameter. The smallest diameter tubular blades (16.5 mm) are generally appropriate for one-level exposures. The use of the small-diameter tubular blades reduces the required size of the incision, minimizes stretch trauma to the skin edges, and decreases the extent of muscle dissection required before insertion of the retractor. The larger diameter blades provide



Fig. 12. Spyder retractor tubular (cranio-caudal) blades and dilators.

more medial-lateral exposure at the cost of requiring greater muscle dissection before insertion.

The tubular blades are attached to the retractor and lowered over dilators into the wound (Fig. 13). At this stage, the dilators simply act as placeholders, since the muscle dissection has already been performed. The retractor handle can be positioned medially or laterally, depending on the surgeon's preference. Lateral fluoroscopy can be used to make sure the retractor is centered half-way between the pedicles. The dilators are removed.

Pearl: Use the smallest diameter tubular retractor blades required to provide the necessary exposure.

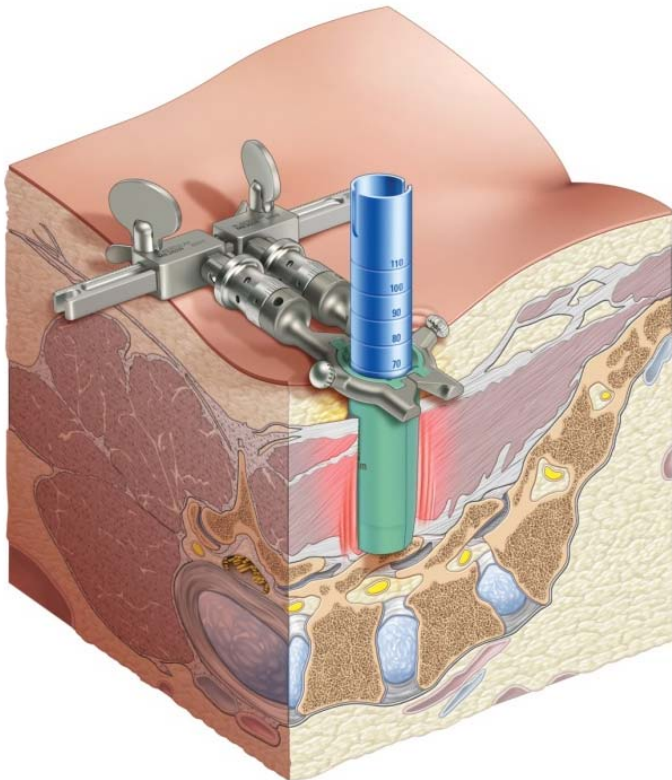


Fig. 13. Spyder retractor equipped with tubular blades is inserted over dilators. The blades are oriented in a cranio-caudal orientation.

The blades are opened slightly in the cranio-caudal orientation (Fig. 14). Avoid over-retraction at this stage. Next, the blades are tilted away from each other to provide the desired conical field of view (Fig. 15). The correct placement of the retractor blades in relation to bony landmarks is checked by direct visualization and lateral fluoroscopy. The pedicles of interest must be included within the span of the retractor blades on lateral fluoroscopy. One of the advantages of Spyder retractor is that the tilt on each blade can be adjusted independently to fine-tune the final placement of the retractor and to avoid under- and over-retraction. Occasionally, a large facet joint at the adjacent cranial level may force the cranial end of the retractor to sit proud of the skin surface. In this case, the cranial blade is replaced with a

shorter blade of the same diameter. Spyder's blade replacement tool allows the individual blades to be swapped *in situ* without removing the entire retractor.

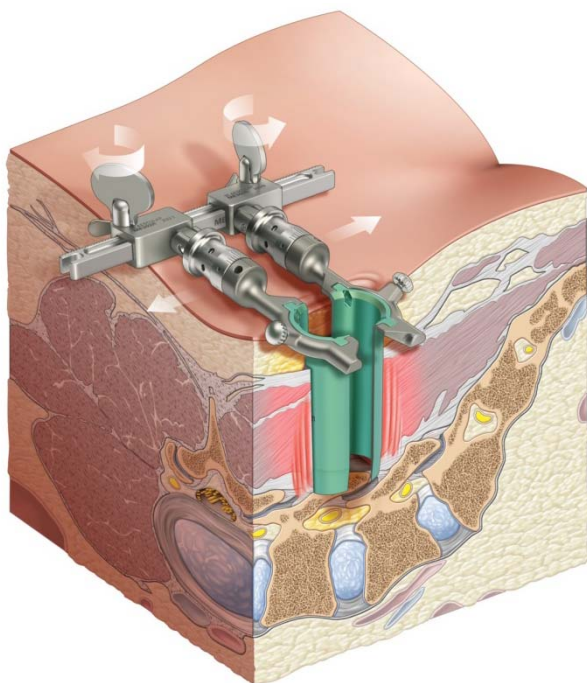


Fig. 14. Retractor blades are opened

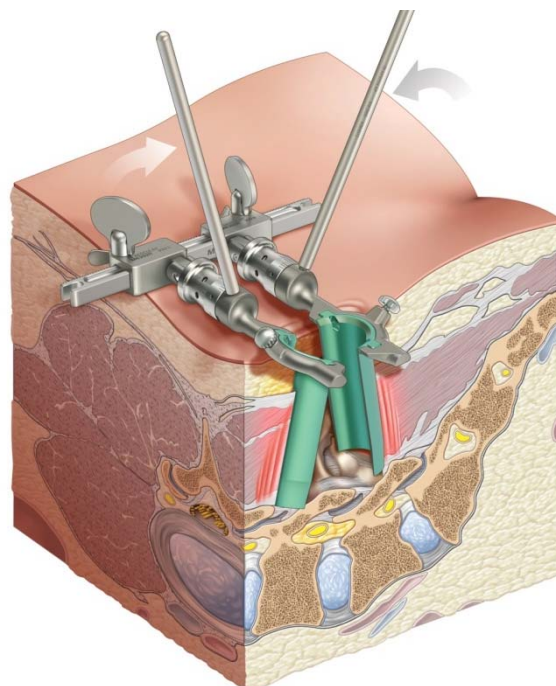


Fig. 15. Retractor blades are tilted. (Note inclusion of L4 and L5 pedicles in the conical field of view.)

In some cases, the cranio-caudal retractor provides sufficient exposure by itself. If additional medial-lateral retraction is needed, a second Spyder retractor equipped with flat blades is nested onto the first one at a 90 degree angle (Fig. 16). Tilting of the medial blade allows for exposure of the lateral aspect of the lamina for decompression of the lateral recess. Tilting of the lateral retractor blade exposes the transverse processes for posterolateral fusion.

If the incision has been placed accurately, the retractor complex remains in a “balanced” state; i.e., while the retractor is centered over the surgical target, the forces on the retractor blades are equal and opposite, eliminating the need for table arm stabilization and minimizing muscle creep into the field of view.

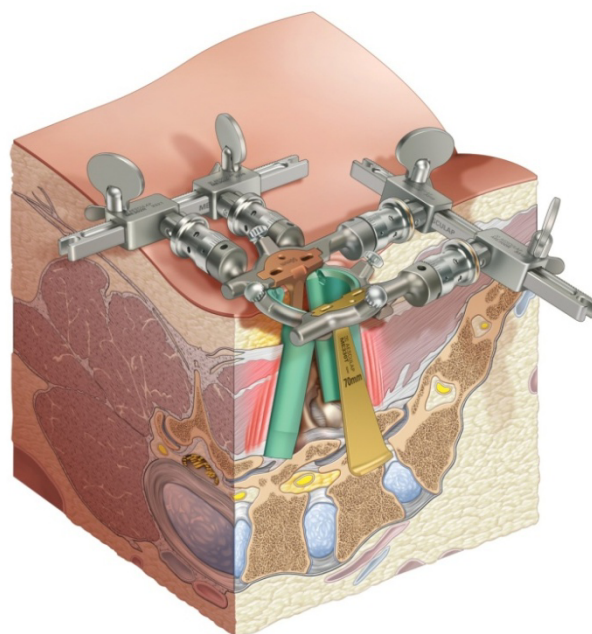


Fig. 16. Nesting Spyder retractors provide cranio-caudal and medial-lateral exposure.

The unique array of blades offered by Spyder allows a fully nested retractor system to be inserted through a very small incision (Fig. 17).

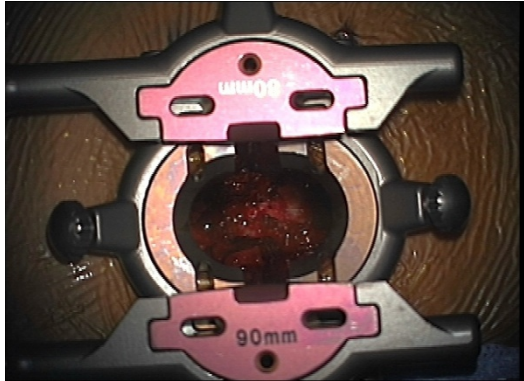


Fig. 17. Nesting retractors equipped with 16.5 mm cranio-caudal tubular blades and thin medial-lateral retractors provide exposure for a one-level MOTLIF through a 3 cm incision.

Decompression

It is important to perform a **complete** facetectomy in order to achieve the following goals:

- Thorough decompression of exiting and traversing nerve roots.
- Safe insertion of TLIF implant without undue pressure on the nerve roots.
- Identification of pedicles for pedicle screw insertion under direct vision.
- Facilitation of spondylolisthesis reduction.

This step should be performed with illumination and magnification provided by loupes and a headlight or the operating microscope. The facet capsule is coagulated with a Bovie and resected. A high speed drill is used for bone removal (Fig. 18). If a facet is hypertrophic, a cutting burr may be used for rapid debulking; however, it is best to switch to a diamond burr as one gets close to the nerve roots. The key to a systematic facetectomy is early identification

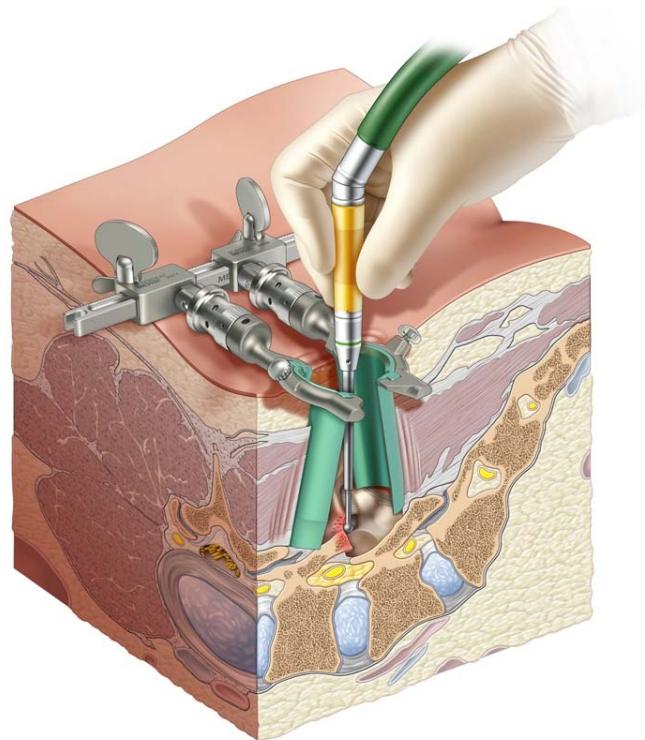


Fig. 18. A high-speed drill is used for facetectomy.

Pearl: Identify the *pars interarticularis* before starting the facetectomy.

of the *pars interarticularis*. This structure is found in the “valley” between two adjacent facet joints and is definitively identified by visualizing the characteristic concavity along its lateral aspect. When in doubt, lateral fluoroscopy can help locate the *pars* just under the pedicle. A transverse cut across the *pars* joined with a vertical cut along the lateral aspect of the lamina completely mobilizes the inferior articulating process and allows it to be removed *en masse* (Fig. 19). This maneuver unroofs the neural foramen and exposes the inferior surface of the more cranial pedicle.

Pitfall: Exercise care when drilling the *pars*, as it overlies the exiting nerve root.

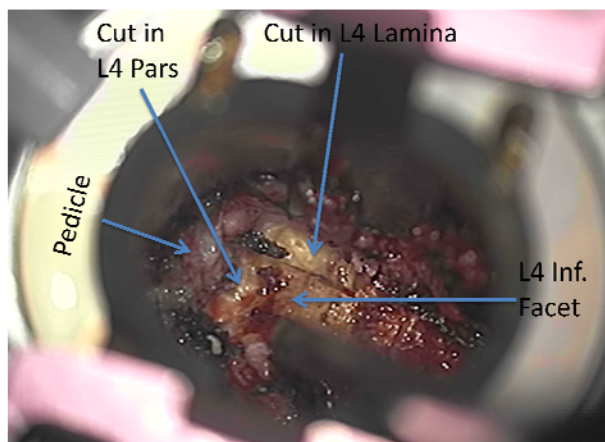


Fig. 19. A transverse cut across the *pars interarticularis* of L4 and a vertical cut along the lateral aspect of the lamina of L4 mobilize the inferior articulating process. Notice the position of L4 pedicle above the *pars*.

Next, the superior articulating process (of the caudal vertebra) is drilled away to expose the disc space and the superior surface of the caudal pedicle. The lateral extension of *ligamentum flavum* is resected and the epidural veins in the neural foramen are carefully bipolar

Pitfall: Exercise care when resecting the lateral edge of the lamina from a lateral approach.

coagulated and divided with micro-scissors to fully expose the disc space and the exiting nerve roots. Care is exercised as the traversing nerve root is exposed and decompressed along the medial aspect of the exposure. In this lateral-to-medial dissection,

passing a Kerrison rongeur under the lateral edge of the lamina may result in grasping the lateral edge of the traversing root and causing a cerebrospinal fluid leak or nerve root injury. It is best to drill the lamina over the traversing root and then carefully resect the *ligamentum flavum* in the lateral recess. A pedicle-to-pedicle exposure is thus obtained (Fig. 20).

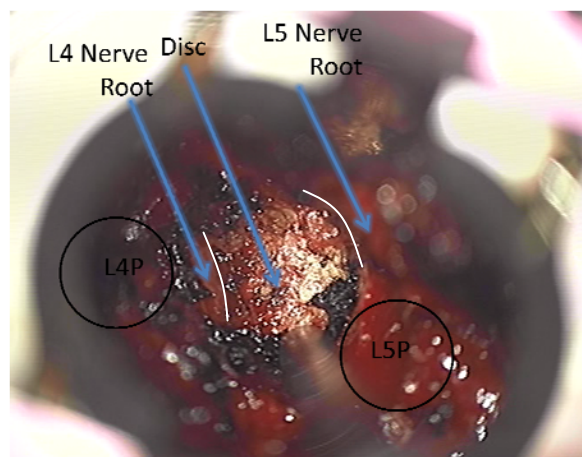


Fig. 20. A pedicle-to-pedicle exposure is obtained, exposing the traversing and exiting nerve roots and the disc space.

Next, a thorough discectomy is performed (Fig. 21). The annulotomy should be as large as possible, limited by the edges of the exiting and traversing nerve roots, in order to allow for insertion of the TLIF implant. Any overhang of the posterior endplate over the disc space is resected to provide unimpeded access to the disc space. It is important to reach toward to the contralateral side with angled curettes and up-biting pituitary rongeurs in order to make room for optimal placement of the TLIF implant. The cartilaginous endplates are removed with large curettes or bone rasps provided in the TLIF implant set. Thorough preparation of the endplates optimizes the success of fusion. As with all discectomy, uncontrolled deep penetration with any instrument is avoided in order to prevent vascular injury.

TLIF

The author prefers banana-shaped PEEK cages for use as TLIF implants (Fig. 22). The implant has a bullet nose to facilitate insertion, serrated edges that engage the endplates, a large bone chamber for fusion, radio-opaque markers that help with orientation, and insertion tools with small footprints that allow visualization of the implant during insertion.

A trial device is first inserted into the disc space to measure its height (Fig. 23). One generally starts with a small trial and moves up to successively larger trials until the trial fits snugly within the disc space. Trials are available in curved and straight varieties – the author prefers the straight variety. A banana-shaped implant of appropriate size is then selected, packed with bone or a bone substitute, and mounted on the insertion tool.

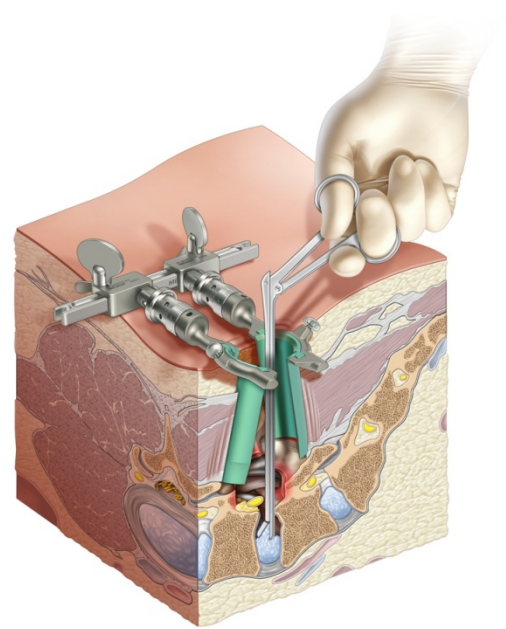


Fig. 21. A thorough discectomy is performed to optimize placement of the TLIF implant and maximize fusion success.



Fig. 22. Banana-shaped PEEK TLIF implant



Fig. 23. Trials are metal tools with dimensions similar to the TLIF implant. They are used to measure the disc space height in order to select the appropriate implant size.

The implant is then inserted into the disc space under direct vision, initially in a vertical orientation (Fig. 24). Gentle back and forth twisting of the wrist is often sufficient to “walk” the implant into the disc space. If necessary, the insertion tool can be gently struck with a mallet. While the nose of the implant is entering the opening in the annulus, the handle of the insertion tool is held medially. As the implant descends into the disc space, the handle moves more laterally, allowing the implant to follow its curvature and become obliquely positioned within the disc space.

It is critical to visualize the traversing and exiting nerve roots throughout this process (Fig. 25). The author does not use a nerve root retractor as it occupies additional room in this limited space and increases compression of the nerve roots.

Once the trailing end of the implant is flush with the posterior endplates, the insertion tool is disengaged and removed. A tamp is then placed over the back end of the implant (Fig. 25) and the implant is tamped under lateral fluoroscopy. Care is taken so that the tamp does not slip off the implant and compress the nerve roots. As the implant is tamped, it assumes a transverse orientation within the disc space. Lateral fluoroscopy demonstrates that the radio-opaque markers get closer to each other and nearly overlap as the implant turns to its final position (Fig. 27).

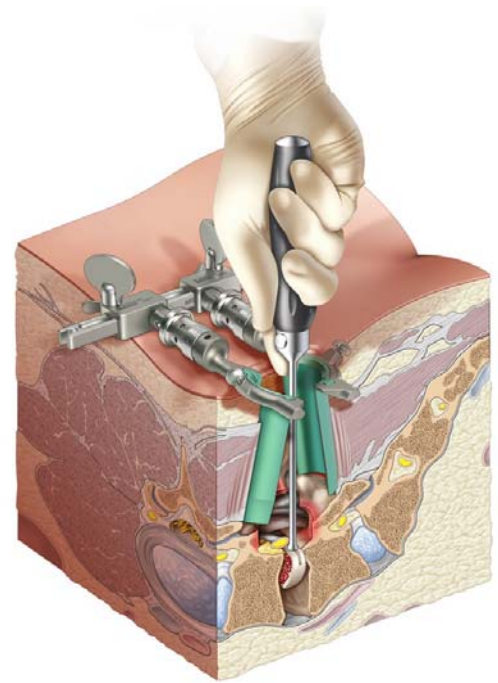


Fig. 24. TLIF implant is inserted into the disc space.

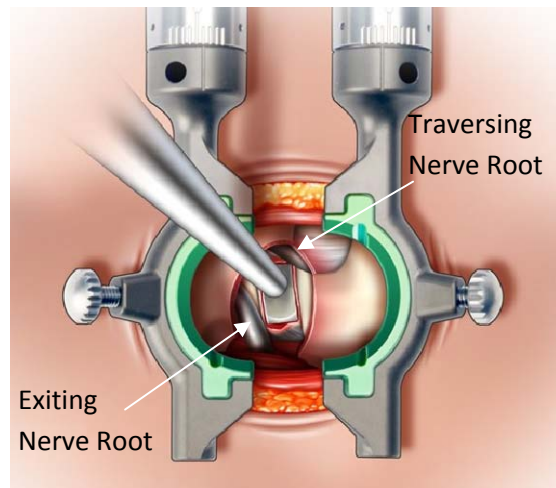
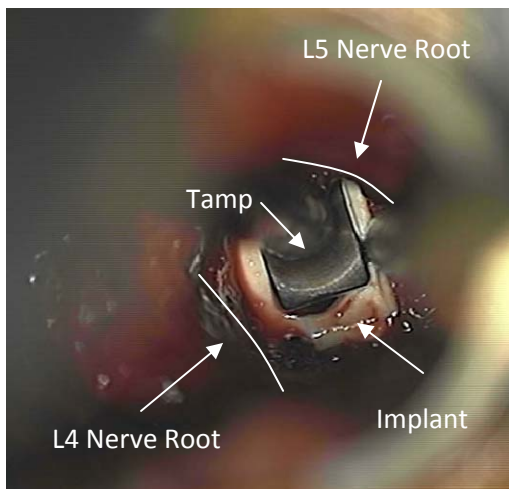


Fig. 25. The nerve roots are visualized during implant insertion.

Pearl: For narrow disc spaces and cases of spondylolisthesis, consider first inserting pedicle screws on the contralateral side and distracting them before inserting the TLIF implant.

The anterior margin of the disc space is carefully observed on lateral fluoroscopy throughout

the implant insertion process to make sure that the implant does not enter the retroperitoneal space. Once the implant is in place, the disc space posterior to the implant is packed with bone or a bone substitute.

Pedicle Screw and Rod Insertion

Non-cannulated pedicle screws are inserted under direct vision, using the same steps and instruments used in an open fusion. The use of Aesculap's low profile S4 screws and insertion tools allows the entire insertion process to be visualized in this mini-open exposure. The inferior margin of the cranial pedicle and the superior margin of the caudal pedicle have been previously exposed by virtue of a complete facetectomy. The medial edge of each pedicle can be palpated. The transverse processes are visualized. The medial inclination of each pedicle can be estimated on the basis of pre-operative imaging studies.

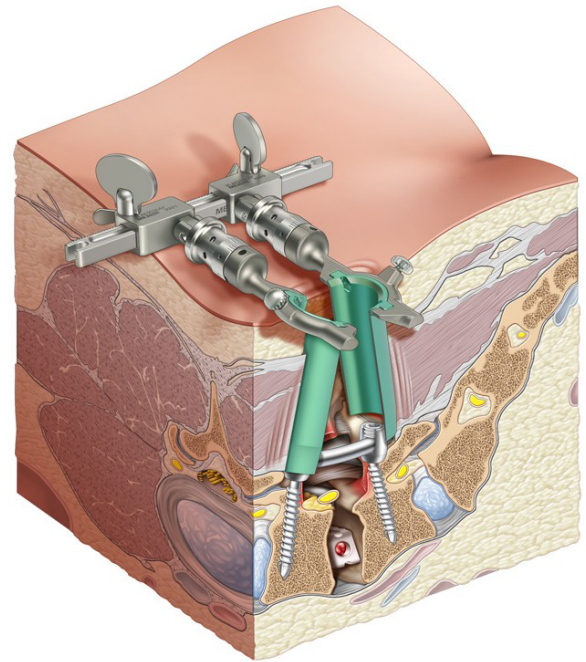


Fig. 26. Pedicle screws are inserted under direct vision.

The entire sequence of pedicle screw insertion is monitored with lateral fluoroscopy and direct visualization. The cortical bone over the pedicle insertion site is perforated with a drill or an awl (Fig. 27A). The pedicle is probed with a pedicle finder (Fig. 27B). The pedicle finder is electrically stimulated and EMG is monitored in the lower extremities. The pedicle is tapped (Fig. 27C). The core of the pedicle is palpated with a ball probe to ensure that the pedicle wall is not breached. A pedicle screw is then inserted (Fig. 27D).

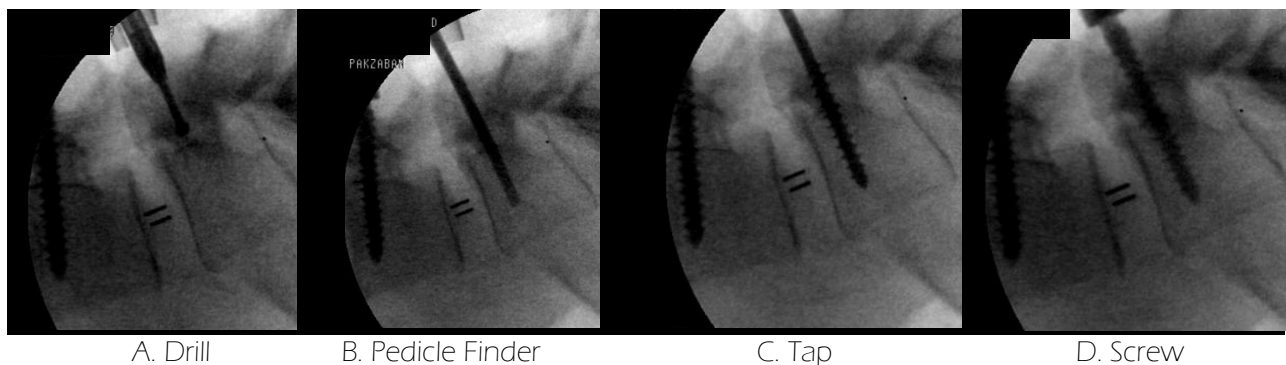


Fig. 27. Pedicle screw insertion sequence is monitored by lateral fluoroscopy.

Once all of the screws have been installed (Fig. 28A), a rod is simply dropped onto the screw heads (Fig. 28B). There is no need for specialized rod insertion tools, since all screw heads are located within the same exposure. The extension tabs on the S4 screw heads increase the polyaxiality of the screw heads and facilitate rod capture and positioning.



Fig. 28A. Two pedicle screws have been inserted.



Fig. 28B. A rod is dropped onto the screw heads under direct vision.

Spondylolisthesis Reduction

Low grade spondylolisthesis (grades 1 and 2) may be reduced via a mini-open approach. Each of the following steps during the operation contributes in part to the overall reduction:

- A complete facetectomy is performed. Although minimal spondylolisthesis can be reduced with a unilateral facetectomy, reduction of grade 2 spondylolisthesis requires bilateral facetectomy for full release.
- After a complete discectomy, the TLIF trials are used to distract the disc space.
- Additional distraction is achieved by applying a distractor to screws contralateral to the side of TLIF. The distractor-compressor tool provided in the Spyder set significantly simplifies distraction through a mini-open exposure (Fig. 29).
- If the spondylolisthesis is sufficiently reduced by distraction, the TLIF implant is inserted to maintain the distraction and the screws heads are locked.

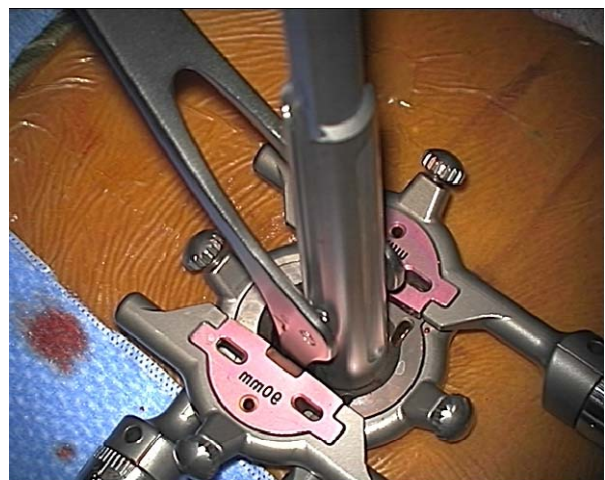


Fig. 29. Spyder distractor-compressor tool allows tightening of the set screw through the tool's central tube.

- If not, the built-in reduction mechanism in the threaded extension tabs is used to reduce the remaining spondylolisthesis, as described below.

To achieve the final stage of spondylolisthesis reduction, the set screw on the caudal screw head is first tightened such that the other end of the rod sits proud of the cranial screw head but within the boundaries of the extension tabs. As distraction is applied, the set screw on the cranial screw head is tightened through the distractor tool. The threaded extension tabs on the cranial screw persuade the screw back toward the fixed rod (Fig. 4). If needed, the same procedure is repeated on the contralateral side. After final tightening of all set screws with a torque wrench, the extension tabs are fractured and removed (Fig. 30).



Fig. 30. The set screws are tightened and the extension tabs are removed.

Posterolateral Fusion

One of the advantages of MOTLIF over percutaneous (trans-tubular) TLIF is that the interbody fusion can be supplemented with a posterolateral fusion with relatively little effort. To accomplish this, the lateral blade of the retractor is tilted away to expose the transverse processes. Alternatively, the retractor complex can be removed and a large triangular Spyder blade attached to a handle can be used as a hand-held retractor to expose the transverse processes. The transverse processes are decorticated with a high speed drill and covered with bone graft or bone substitute.

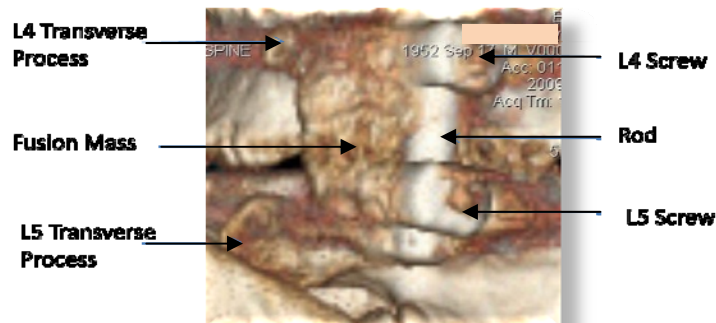


Fig. 31. Three-dimensional CT reconstruction of a posterolateral fusion mass with beta-tricalcium phosphate 3 months after MOTLIF.

Bone Graft vs. Bone Substitute

While autologous bone graft harvested from the iliac crest has been the gold standard for lumbar fusion, increasingly surgeons tend to use alternative materials in minimally invasive operations in order to obviate the morbidity associated with the former. Alternatives include

(but are not limited to) autologous bone obtained from the facetectomy, bone morphogenic protein, demineralized bone matrix, beta-tricalcium phosphate, and hydroxyapatite.

The Contralateral Side

Several options are available for management of the side contralateral to the side of TLIF. If contralateral decompression or significant spondylolisthesis reduction is required, the contralateral side is handled in exactly the same way as the ipsilateral side, minus the TLIF step. Otherwise, a mini-open exposure can be obtained, as described, and the pedicle screws can be inserted on the basis of anatomical landmarks (at the intersection of transverse process and superior articulating process), guided by fluoroscopy and EMG monitoring. Alternatively, the contralateral pedicle screws can be inserted percutaneously, using K-wires, cannulated screws and biplanar fluoroscopy.

Pearl: Determine the medial angulation of the pedicle in relation to the planned entry point on the pre-operative imaging studies, especially if you plan to insert a pedicle screw without direct visualization of the pedicle.

MOTLIF as a Gateway Technique

Surgeons who are adept at lumbar fusion through an open approach often encounter substantial training obstacles when attempting to convert to percutaneous MIS approaches (14). In addition to being a “destination technique,” MOTLIF can serve as a transitional technique for surgeons wishing to become trained in percutaneous approaches (Fig. 32).

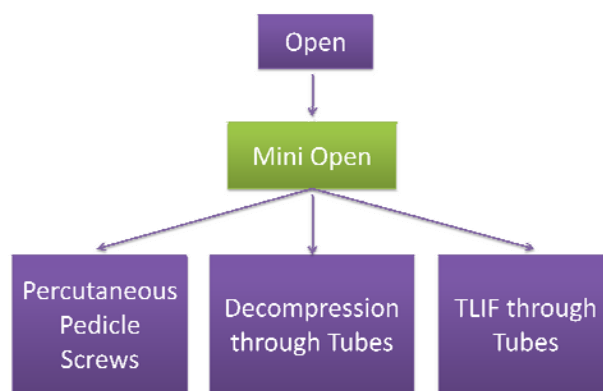


Fig. 32. Mini Open TLIF can help surgeons transition from open surgery to percutaneous techniques.

To transition to percutaneous pedicle screw insertion, one would first perform a MOTLIF exposure and facetectomy, exposing the pedicles and nerve roots. Then one would use the techniques particular to percutaneous pedicle screw insertion (not described here) to insert cannulated screws over K-wires. The advantage of such a transitional approach is that the surgeon can visually guide the placement of K-wires and screws and double-check the radiographic landmarks before taking the final leap to blind fluoroscopically-guided screw placement.

Pitfall: If a K-wire is to be used after a facetectomy, keep in mind that the nerve roots are exposed and vulnerable. Initial placement of the K-wire should be visually guided.

Similarly, when transitioning to percutaneous decompression and TLIF through tubes, one would first proceed with a MOTLIF exposure. Then one would insert the Spyder retractor attached to a table arm with its tubular

blades in closed position. The Spyder tube can be manipulated, tilted, and repositioned as a closed tube, while the surgeon uses bayoneted instruments to achieve decompression and TLIF. The retractor blades can be intermittently opened to provide greater exposure until the surgeon gains confidence with a tubular exposure.

Complication Avoidance

Complications associated with MOTLIF are similar in type and frequency to those occurring with open lumbar fusion operations (23). It is important to identify the procedural steps that are vulnerable to specific complications, so that one can not only avoid complications, but also manage them if they occur.

Cerebrospinal fluid leakage can be avoided by paying close attention to the step in which the lateral recess is decompressed. In a midline exposure, Kerrison rongeurs are passed in a medial-to-lateral orientation into the lateral recess. Unless the lateral recess is particularly tight, the heel of the instrument usually displaces the traversing nerve root as *ligamentum flavum* and bone are resected. In MOTLIF, a facetectomy is performed first; therefore, the sequence of decompression is from lateral to medial. Passing a Kerrison rongeur into the lateral recess from a lateral orientation exposes the nerve root sleeve to the mouth of the instrument and produces a risk of CSF leakage and nerve root injury. It is best to drill the lateral aspect of the lamina first and then dissect the *ligamentum flavum* away from the nerve root before resecting it.

Dural lacerations are difficult to repair in mini-open exposures. Fortunately, the small dead space created by MOTLIF reduces the risk of pseudomeningocele formation and percutaneous CSF leakage. If a CSF leak occurs early in the operation, one should first plug the dural opening with a piece of Gelfoam or muscle and then decide whether to forego insertion of an interbody implant in order to avoid enlargement of the dural tear. A “soft TLIF” (insertion of interbody bone without an implant) or a posterolateral fusion can be considered instead. At the end of the procedure, the facetectomy defect is filled with a fat graft and a biocompatible adhesive. A lumbar drain may be placed at the surgeon’s discretion.

Nerve root injury is avoided by exercising care during the following steps. Drilling of the *pars interarticularis* should be performed with care using a diamond burr, as the exiting nerve root lies underneath. Decompression of the lateral recess has been discussed above with regard to the risk of injury to the traversing nerve root. Bipolar coagulation should be used judiciously in the neural foramen. During insertion and tamping of the TLIF implant, the exiting and traversing nerve roots must be visualized and avoided. During pedicle screw insertion, the pedicle margins are visualized or palpated, fluoroscopy is used, lower extremity EMG is monitored, and the pedicle core is probed before insertion of the screw. Thorough nerve root decompression and judicious use of distraction are important for safe reduction of spondylolisthesis.

Blood loss in miniopen exposures is less than that in open fusion operations. However, even clinically insignificant bleeding during the operation can obscure the limited field of view offered by the small exposure and render the operation more difficult. Careful attention to hemostasis throughout the operation facilitates the entire procedure. Bipolar electrocautery is an indispensable tool in this regard.

The main source of arterial bleeding in this operation is the facet artery, generally encountered at the superior-lateral aspect of the facet joint. Compared to a midline exposure, the paramedian exposure offers a better opportunity for direct visualization and coagulation of this artery. If a bleeding facet artery is hidden behind a hypertrophic facet joint, expeditious resection of the lateral aspect of the facet allows visualization and control of the artery. Venous bleeding is often encountered in the neural foramen. Tamponade with Gelfoam and a cottonoid is often sufficient to reduce venous bleeding and visualize the nerve roots. The veins are then isolated between the tips of the bipolar forceps away from the nerve roots and coagulated.

Malpositioning of the TLIF Implant would occur if the implant does not turn to a transverse orientation within the disc space, or worse, if it protrudes through the anterior annulus into the retroperitoneum. To facilitate the rotation of the implant within the disc space, it is important to thoroughly evacuate the contralateral side of the disc space and to use an implant that is not excessively large for the disc space. If the disc space is narrow, distraction of pedicle screws on the side contralateral to TLIF facilitates insertion and rotation of the implant. If the implant does not turn, and if its leading edge appears to be heading close to the anterior annulus, one must decide whether to leave the implant in its current state (if snug and away from the nerve roots) or to remove and replace the implant. Alternatively a straight PLIF-type implant can be positioned obliquely across the disc space through a transforaminal approach.

Malpositioning of pedicle screws in the sagittal plane is avoided by use of lateral fluoroscopy. Medial malpositioning was discussed under the topic of nerve root injury. Lateral malpositioning can often be detected if a ball probe passed through the pedicle core encounters soft tissue. A review of radiographic studies with regard to the medial angulation of the pedicle and appropriate adjustments in the screw trajectory can address this problem.

Disclaimer

Surgery cannot be learned by reading a manuscript. This surgical technique manual is intended for surgeons who are proficient in open lumbar fusion and who believe that the techniques described herein are well within their technical capabilities. Cadaver work and expert-supervised surgery are recommended before proceeding with independent surgery. This manual should not be relied upon by surgeons or staff as adequate training for performing the techniques and surgeries illustrated. Neither the author nor Aesculap Implant

Systems and its affiliates take responsibility for poor surgical judgment and skill that would result in misapplication of the surgical techniques described here.

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