Extreme Lateral Interbody Fusion (XLIF) with Lateral Modular Plate Fixation: Preliminary Report on Clinical and Radiological Outcomes

Daniele Armocida, Andrea Perna, Fabio Cofano, Marco Cimatti, Umberto Aldo Arcidiacono, Nicola Marengo, Marco Ajello, Diego Garbossa, Luca Proietti, Francesco Ciro Tamburrelli, Marco Maiotti, Antonio Santoro, and Alessandro Frati

Abbreviations

ALIF	Anterior lumbar interbody fusions
MISS	Minimally invasive spine surgery
PLF	Posterolateral lumbar fusion
PLIF	Posterior lumbar interbody fusion
TLIF	Transforaminal lumbar interbody fusion
XLIF	Extreme lateral interbody fusion

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1 Introduction

Minimally invasive spine surgery (MISS) is nowadays considered worldwide as an effective, low-risk, and safe treatment modality for degenerative spine disorders [1–3]. MISS has garnered interest as a feasible alternative to open surgery with some advantages, including reduced soft tissue manipulation, decreased blood loss, lower surgical site infection rates, improved cosmesis, and functional recovery [4].

The lateral approach to the lumbar spine has been growing in popularity because it has been adapted for a variety of indications, including neuroforaminal stenosis, spondylolisthesis, spinal stenosis with instability, and adult degenerative scoliosis [1, 4, 5].

Specifically, the lateral transpsoas approach, known as extreme lateral interbody fusion (XLIF), was devised to reduce the vascular injuries due to anterior lumbar interbody

D. Armocida (✉) · U. A. Arcidiacono · A. Santoro
Neurosurgery Division, Human Neurosciences Department, "Sapienza" University, Rome (RM), Italy

A. Perna
Division of Spinal Surgery, IRCCS Fondazione Policlinico Universitario Agostino Gemelli, Rome, Italy

F. Cofano
Spine Surgery Unit–Humanitas Gradenigo, Torino, Italy

Department of Neuroscience, "Rita Levi Montalcini," University of Torino, Torino, Italy

M. Cimatti
Unit of Neurosurgery, Sant'Andrea Hospital, Rome, Italy

N. Marengo · M. Ajello
Unit of Neurosurgery, AOU Città della Salute e della Scienza, Torino, Italy

D. Garbossa
Department of Neuroscience, "Rita Levi Montalcini," University of Torino, Torino, Italy

Unit of Neurosurgery, AOU Città della Salute e della Scienza, Torino, Italy

L. Proietti · F. C. Tamburrelli
Division of Spinal Surgery, IRCCS Fondazione Policlinico Universitario Agostino Gemelli, Rome, Italy

Institute of Orthopaedic, Università Cattolica del Sacro Cuore, Rome, Italy

M. Maiotti
Shoulder Unit Villa Stuart Clinic (Rome), Shoulder-Knee Unit PIO XI Clinic (Rome), Rome, Italy

A. Frati
Neurosurgery Division, Human Neurosciences Department, "Sapienza" University, Rome (RM), Italy

IRCCS "Neuromed", Pozzilli (IS), Italy

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fusions (ALIFs) and limit the muscular/soft tissue trauma due to transforaminal lumbar interbody fusions (TLIFs) and posterior lumbar interbody fusions (PLIFs).

The use of a lateral transpsoas approach allows surgeons to use nonlordotic and lordotic cage sizes to help restore intervertebral disk height, correct sagittal alignment, and improve fusion rates [1, 6].

The lateral access preserves the anterior and posterior stabilizing structures while affording liberal disk removal and the placement of a wide cage spanning the apophyseal ring. Given such inherent structural benefits, it has been proposed that extensive and/or invasive posterior fixation could be unnecessary with lateral approaches [7].

However, the use of standalone MISS devices has consistently raised doubts in the medical-scientific community because of the high risk of complications, including a reduced fusion rate and inadequate functional recovery that a circumferential arthrodesis can support.

The recent introduction of a novel XLIF cage possessing integrated lateral modular plate fixation (XLPF) may further enhance the structural rigidity. XLPF, which consolidates the cage and the plate into a single modular entity, creating a continuous rigid body at an index level capable of promoting an effective and durable arthrodesis of the segment without needing posterior instrumented surgery. However, the extent to which this device facilitates segmental rigidity is not yet understood, according to the literature [8], and its effectiveness is limited to a few cadaveric studies and case reports.

This study illustrates our multicenter experience in the use of XLPF in XLIF using standalone devices for selected cases of lumbar spine pathologies.

2 Material and Methods

2.1 Patient Selection and Demographics.

Between January 2020 and February 2021, nine patients underwent a procedure of 1-level extreme lateral interbody fusion using an XLIF cage with lateral modular plate fixation in the neurosurgical centers of the Sapienza University of Rome (Hospital Sant'Andrea and Policlinico Umberto I, Rome, Italy), the Cattolica University of Rome (Hospital Gemelli, Rome, Italy), and the University of Turin (Molinette Hospital, Turin, Italy).

The diagnosis prompting fusion was junctional stenosis following previous multilevel posterior stabilization with disk collapse and with up-down foraminal stenosis in six patients and was adult degenerative scoliosis with sagittal imbalance and adjacent-level (juxtafusion) degeneration in three patients. The cohort included six women and three men, with an average age of 60.1 years (range: 47–73.8 years; the assumed data appear in Table 1). Exclusion criteria for the procedure were primarily multisegment limited pathology and the presence of osteoporosis or the oncologic pathology of the bone.

Clinical information was obtained for all patients from office charts, operative notes, and radiographic images. The information obtained from medical records included patient demographics, medical comorbidities, preoperative and postoperative clinical assessments, intraoperative findings, operative times, implant information, and postoperative complications. Visual analog scale (VAS) scores for pain were obtained before surgery and at each postoperative office visit

Table 1 Patients' demographics

No	Patients	Age	Surgical center	Date of intervention	Diagnosis	Pre-operative VAS	Level	Procedure time (min)	Outcome	Post-operative VAS
1	QM	47	Sapienza, Rome	14/12/2020	Junctional Stenosis	8	L2-L3	54	Good	2
2	BP	54	Sapienza, Rome	07/01/2021	Junctional Stenosis	9	L2-L3	45	Good	2
3	ME	54	Sapienza, Rome	19/02/2021	Junctional Stenosis	9	L3-L4	45	Good	2
4	MS	66	Sapienza, Rome	21/02/2021	Junctional Stenosis	8	L3-L4	65	Good	2
5	FA	67	Cattolica, Rome	13/01/2021	Adult Scoliosis with sagittal imbalance	8	L3-L4	34	Good	3
6	RJ	59	Cattolica, Rome	08/06/2016	Adult Scoliosis with sagittal imbalance	9	L3-L4	27	Good	4
7	PV	73	Cattolica, Rome	16/03/2016	Adult Scoliosis with sagittal imbalance	8	L3-L4	24	Good	3
8	GG	\	Università degli studi di Torino	16/03/2021	Junctional Stenosis	8	L2-L3	62	Good	2
9	TR	\	Università degli studi di Torino	07/02/2020	Junctional Stenosis	9	L3-L4	68	Good	3

(6 weeks, 3 months, 6 months, 1 year). Standing preoperative, immediate postoperative, and most-recent radiographs at a minimum of 1 year after surgery were measured for end plate angulation in the operated discal space in both the coronal (scoliotic angle) and sagittal (lordotic angle) planes. The interbody cage position was measured in the coronal and sagittal planes with reference to adjacent vertebral borders on immediate postoperative and final follow-up radiographs. Fusion was routinely assessed at 1 year after surgery by using computed tomography (CT) scans. CT images were also used to measure the amount of subsidence in the interbody cage that is imparted into the superior and inferior end plates (Fig. 1).

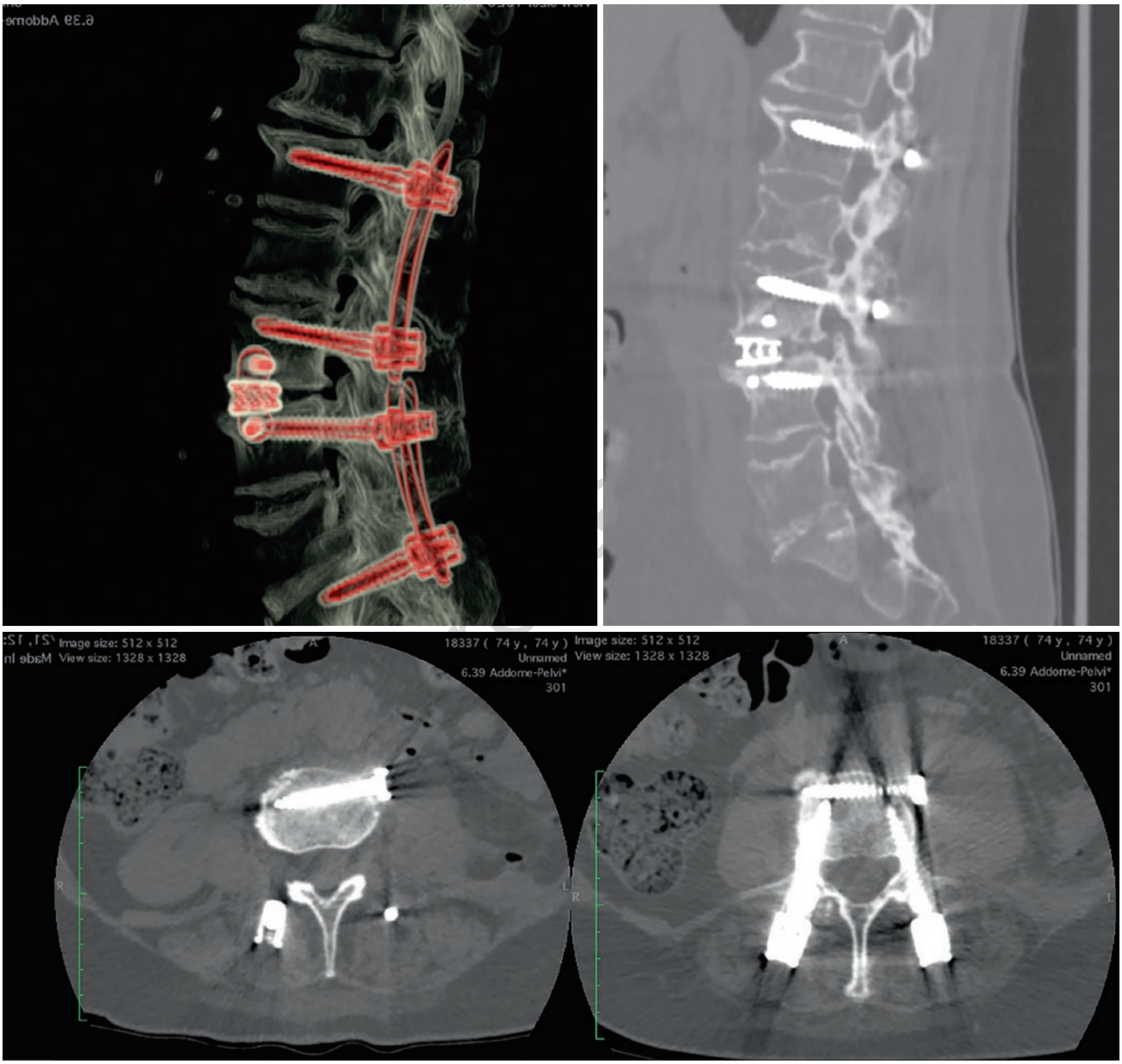

Fig. 1 A 66-year-old woman presenting with bilateral leg pain, neurogenic claudication, and lower-back pain for whom medical treatment failed; preoperative radiographs and magnetic resonance imaging demonstrating a previous stabilization on L1-S1 for lumbar stenosis and a debut of the severe monosegmental stenosis of the L2-L3 segment within the context of junctional syndrome

2.2 Operations and Technical Note

Lateral interbody fusion was performed by using the technique described by Ozgur et al. [9].

The side for the procedure was chosen on the basis of which side of the column had the greater concavity, the presence of large vessels, and the level of any osteophytes in the affected soma. Each procedure was performed with the aid of the level of neurophysiological monitoring necessary to detect any stretch damage caused to the adjacent nerve plexus. XLIF cages were filled with Grafton demineralized bone matrix.

In cases of reported degenerative scoliosis, the anterior longitudinal ligament section was performed to allow the insertion of a 30° lordotic cage; in all other cases, the cage had a 15° lordosis.

After the interbody cage was placed, anterior instrumentation (Nuvasive XLP plate) was placed via the same incision. The XLPF system uses a 5.5 mm fixed-angle screw placed into the vertebral bodies above and below the cage. Before cage insertion, any possible reduction in the number of somatic lateral osteophytes was performed to allow the placement of the plate adjacent to the somatic bodies.

3 Results

The mean operative time was 47.11 min, starting from the time when the positioning of the patient in the lateral decubitus position began until the posterior wound was closed. The estimated blood loss averaged 125 mL. No patient received a transfusion during the procedure or the postoperative period. The average length of postoperative hospital stay was 3.6 days.

VAS scores improved from a preoperative average of 8.4 to a postoperative average of 2.5, a statistically significant improvement of 5.9 points ($p < 0.001$).

3.1 Radiographic Findings

The mean radiographic follow-up time was 13 months. Four patients had sufficient clinical follow-ups to be included in the study but were excluded from the radiographic portion of the study because their available radiographic follow-up times were <1 year. It was radiographically demonstrated that there was no cage migration in either the coronal plate or the sagittal plane at the final follow-up. There were no end plate fractures or signs of subsidence on either immediately postoperative radiographs or final follow-up radiographs.

4 Discussion

Since its introduction, the XLIF technique has undergone constant technical evolution, in which a powerful light system, new retractors, and electromyography combined in a minimally invasive procedure have allowed for the insertion of a large interbody implant through the lateral aspect of the intervertebral discal space. Thus, these techniques may minimize interbody cage subsidence and preserve intervertebral disk height and alignment correction depending on appropriate cage size selection [5].

The interbody cages developed for XLIF are biomechanically distinct from cages used for anterior or posterior lumbar interbody fusion. The cage used with XLIF, placed from the lateral aspect of the vertebral body, is wide enough to span the entire width of the vertebra so that it rests on apophyseal bone on either side. This could provide a biomechanical advantage in that the peripheral apophyseal bone is significantly stronger than the central cancellous bone, which is used to provide support for interbody fusion devices used in posterior approaches [10].

In general, the benefits of this lateral approach include the preservation of back muscle and of bony and ligamentous structures, and it also allows for the placement of an intervertebral cage. In addition, the current procedure results in the correction of spondylolisthesis and rotatory deformity and in indirect nerve decompression thanks to ligamentotaxis force. These advantages may result in less surgical pain and quicker recovery than those achieved in traditional approaches.

Because of the XLIF implant's inherent stability, many surgeons use the cage with alternative forms of fixation, including anterior plate fixation or unilateral posterior pedicle screw fixation, or they use it as a standalone implant. Although the effectiveness of minimally invasive lumbar interbody fusions with percutaneous pedicle screws has been described and well noted, a comparatively high complication rate of standalone XLIF, including postoperative thigh symptoms, not has been reported [11]. In contrast, relatively few biomechanical studies have evaluated the stability of an interbody fusion construct with and without additional anterior or posterior instrumentation inserted while using this approach [8, 12].

The XLPF plate (NuVasive, Inc., San Diego, CA, USA) is an anterolateral instrumentation system developed for use with the XLIF system for lateral approaches. The XLPF lateral plate is made of titanium and is fixed to the lateral vertebral bodies by using two screws that lock into the plate, creating a fixed-angle construct. Biomechanical data demonstrate that the XLPF plate increases construct stiffness when used in conjunction with the XLIF interbody cage compared

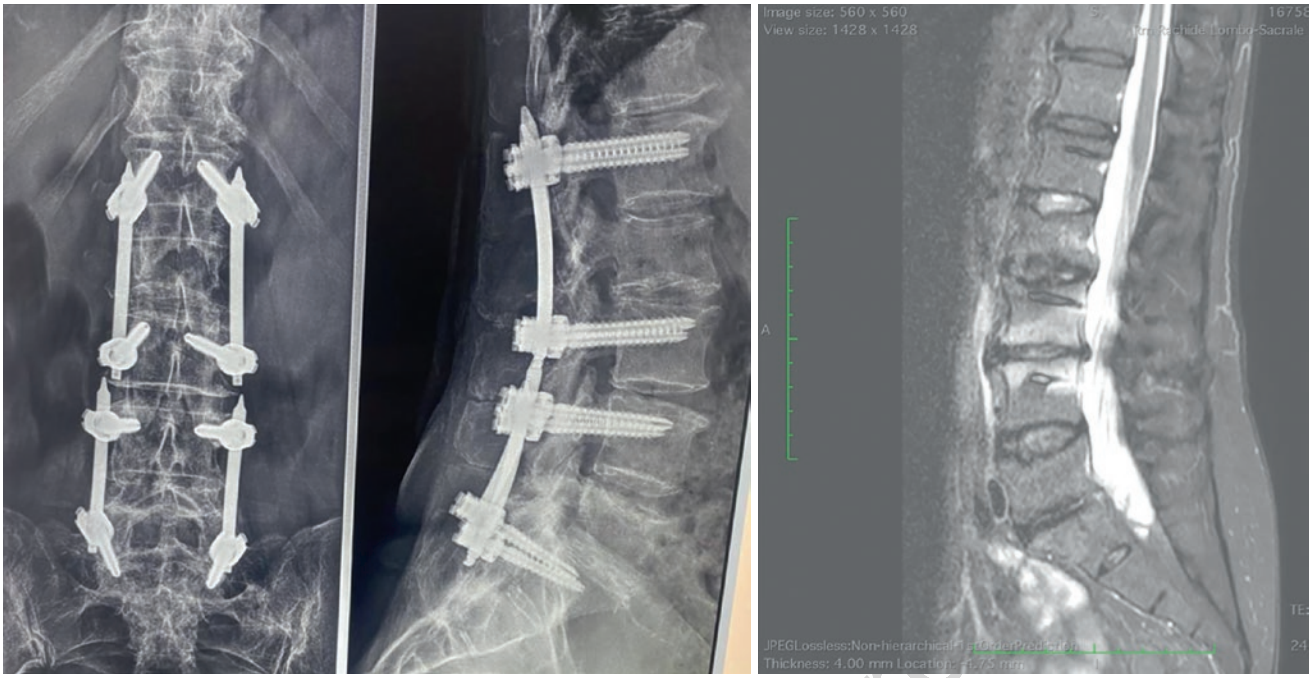

Fig. 2 Postoperative CT scan and radiograph: The patient was submitted to L2-L3 XLIF with anterolateral instrumentation and with lateral plating and minimally invasive decompression; her initial postoperative course was unremarkable, and she mobilized well with resolution of leg pain and mild lower-back pain; the patient showed improvement in lower-back and pelvic pain and mobilized gradually; at her 3-month follow-up, her lower-back pain and pelvic pain were mild; at her 1-year follow-up, her leg pain has resolved without lower-back pain; the patient recently underwent a CT scan, which demonstrated the solid fusion of the system

with a standalone interbody cage [5]. Other studies have produced data on the efficacy and complications associated with anterolateral lumbar instrumentation [6, 7, 11, 13, 14], but the clinical performance of plating systems used in association with LTIF has not been reported, because of the recency of its introduction (Fig. 2).

By providing comparable rigidity in patients who have previously undergone an arthrodesis procedure or in patients with extensive degeneration of the spine, the XLPF iterations could significantly diminished the need for posterior fixation in those respective planes. Whether assembled before insertion or in situ, the integrated design of the XLPF construct may also support the intraoperative ease of plate placement and plate alignment optimization not achieved with traditional independent plates [13, 14]. DenHaese et al. [8] reported the operative time, fluoroscopy time, and blood loss data from XLPF, and they did not differ from the data on those variables from placing a traditional cage alone [15].

Lateral plating does not extend the intraoperative footprint, because the plate is placed through the same surgical corridor as that for the interbody cage, and it provides immediate rigidity to the anterior column in the axial and coronal planes [8] without any additional surgical risk. In our cases, the standalone XLIF cage implantation procedure may require more time than the simple procedure does, mainly because the lateral osteophytes need to be osteo-reduced to allow the correct application of the cage. It is further important to not violate the end plates with the plates and to exercise extreme caution when reducing the lateral osteophytosis necessary for proper plate placement, avoiding the possibility of impairing the cortical of the vertebral soma or impairing the oversized interbody implants with XLPF because it may exacerbate any stress-rising effects. This step is to be considered the most delicate for this procedure because the reduction must be performed without encouraging the excessive demolition of compact bone. The selection of the cage must also be carefully evaluated, favoring in some cases a slightly narrower size, always to avoid the imperfect lateral alignment of the plate. It is important to sequentially unbreak the table before tightening the XLPF bolts until the plate is locked into a physiological position. The position of the iliac crest in the extreme lateral interbody fusion approach can prohibit a true lateral trajectory to the spine at L4-L5, thus making plates difficult if not impossible to place in an orientation orthogonal to the long axis of the spine [16]. Finally, in cases of advanced osteoporosis, bilateral posterior supplementation may be appropriate and standalone plating should be avoided in osteoporotic patients because of the risk of vertebral body fracture [17].

Most studies on standalone XLIF using lateral plates have evaluated the outcome measure only indirectly, through cadaveric studies. In fact, most studies have positively evaluated range of motion (ROM) as a variable affecting the safety and efficacy of a treatment. Biomechanically, the XLIF construct significantly reduced ROM in all directions of loading compared with an intact spine, indicating an inherent measure of stability in the standalone approach.

The addition of an XLPF did not increase the stability of the LLIF construct during flexion or extension [10, 18]. In addition, posterior screws are harder to place on the plated side because of the potential for interference with the screws and the screw trajectory of the lateral plate fixation. When using XLPF, the screws are placed in proximity directly above and below the cage. This places a stress riser in an area of stress concentration, possibly resulting in fracture. Some authors advocate for the use of additional unilateral posterior fixation in single-level lumbar fusion. Unilateral posterior fixation could be used in patients undergoing a single-level lumbar fusion, which was amenable to LTIF, depending on the level (above L5-S1) and in the absence of spondylolisthesis. It was used on the nonplated side to provide additional contralateral stabilization [15].

XLIF constructs with posterior bilateral pedicle screw fixation or facet screw fixation, or combined anterior-posterior lateral-spinous process plate fixation, provided the most stability in the three principal planes of motion, and in our opinion, it is still fundamental in the treatment of some degenerative forms of spondylolisthesis with isthmic lysis and in the treatment of advanced forms of degenerative scoliosis.

5 Limitations and Further Studies

The main limitation of this preliminary report is the limited number of cases examined and the retrospective nature of the study. In addition to increasing the series, it is necessary to evaluate sagittal and coronal imbalance changes by comparing them with the more traditional XLIF technique. Clinical studies are essential to support the validity of this instrumented surgical strategy in order to evaluate its complications, clinical stability, risk of subsidence, quality-of-life outcomes, and fusion rates and to compare them with those of traditional implantation with posterior stabilization.

6 Conclusion

A large number of clinical studies involving XLIF have been reported in the medical literature, with good outcomes and low complication rates. Although it has been shown that the use of interbody fusion cages with supplemental posterior fixation improves stabilization in all directions, the technique of standalone lateral cages may also have a place in spine surgery because the stability may be sufficient in selected cases, such as in junctional syndrome in patients who have already undergone posterior arthrodesis surgery and in some forms of degenerative scoliosis instead of traditional osteotomies. The use of the standalone XLIF approach with the use of XLPF is a valid and effective technique, but at the moment, it can be implemented only in a few selected cases and is not applicable to the whole range of degenerative pathologies of the lumbar spine for which the technique with posterior screw fixation remains more indicated.

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Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study. The patients consented to the submission of this review chapter.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing, we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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