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ORIGINAL ARTICLE

One-stage combined lumbo-sacral fusion, by anterior then posterior approach: clinical and radiological results

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Abstract
Introduction We intended to prospectively evaluate the clinical and radiological results of lumbo-sacral fusion achieved by a combined approach, anterior then posterior.
Material and methods 62 patients were consecutively treated at L5–S1, L4–L5 or L4–S1 for degenerative disc disease or low-grade isthmic spondylolisthesis by combined surgery.
Results Mean operative time and blood loss were 209 min and 308 ml, respectively, including the two approaches. VAS, ODI and Roland–Morris scores significantly improved postoperatively at 1 year ($p < 0.005$) and fusion was obtained in all cases on the CT scan at 1-year follow-up. Segmental lordosis significantly improved postoperatively ($p < 0.05$) with a mean gain of 10.2° at L5–S1 and 5.5° at L4–L5.
Conclusion The combined procedure meets the requested criteria for a lumbar fusion in terms of clinical results, functional outcomes, fusion rates while restoring segmental lordosis and disc height. It cumulates the advantages of the anterior and posterior approach performed alone, especially for L5–S1.

Keywords Spinal fusion · Combined approach · Lordosis · Fusion rates · Lumbar spine

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Introduction

One of the most common surgical procedures to treat degenerative diseases in the lumbar spine is represented by spinal fusion, defined as the bone fusion of the vertebrae achieved after surgery [1]. Different surgical approaches, methods of fusion, types of instrumentation and bone grafts have been developed in the past 20 years to improve the bone fusion success and clinical outcome [2–5]. Interbody fusion techniques have been developed to provide solid fixation of spinal segments while restoring a proper disc height and sagittal balance [6]. Although there is still controversy regarding the best technique, there seems to be a trend toward the use of the interbody technique, reported to achieve up to 95 to 100 % of fusion. The interbody lumbar fusions may be achieved by anterior lumbar interbody fusion (ALIF), transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF), extreme lateral approach (XLIF) or a combined approach. The purpose of this study was to prospectively evaluate a cohort of patients following a one-step ALIF surgery with PEEK cage combined with posterior pedicle-screw fixation. Our hypothesis was that combined lumbo-sacral fusion is a safe and efficient surgical technique to obtain a high-quality fusion, restore a proper disc height and appropriate segmental lordosis and provide good clinical and functional outcomes.

Materials and methods

Study design

This prospective study included all adult patients who underwent L5–S1, L4–L5 or L4–S1 spinal fusion by combined approach for degenerative disc disease or low-grade isthmic spondylolisthesis in our institution from December 2008 to June 2012.

Exclusion criteria were scoliosis, spondylolisthesis greater than Meyerding grade II or degenerative, infection, tumor, a prior fusion surgery or a fusion greater than two levels. The study was implemented respecting GCP and after ethics approval by an institutional board.

Population sample

Sixty-two patients (34 women and 28 men), mean age 46 ± 10 years, were operated by a single surgeon (CB) for a lumbar degenerative disc disease ($n = 46$, 74 %) or a low-grade isthmic spondylolisthesis ($n = 16$, 26 %).

Surgical technique

Lumbo-sacral fusion was achieved by combined approach, anterior then posterior, using anterior PEEK cage filled with BMP and posterior pedicle-screw stabilization (Fig. 1).

The morphology and location of pre-vertebral vascular structures in the lumbar spine were preoperatively analyzed by a 3D angio CT scan with a special interest on relationships between iliac veins and intervertebral discs [7].

Anterior approach

Patients were positioned supine, legs in abduction and the lumbar spine slightly hyperextended, on a standard operating table. A midline abdominal incision allowed for retroperitoneal exposure of the disc level(s). Following radiographic verification of the level to be treated, the intervertebral disc was removed. All cartilaginous material was removed from the endplates. In order to restore a normal disc height (comparing to adjacent levels), an appropriately sized lordotic PEEK cage was selected (Antelys™, Scient'x-Alphatec, Carlsbad, USA) and implanted after filling with recombinant human bone morphogenic protein (2rhBMP-2). Radiographic verification of correct positioning of the cage was finally obtained.

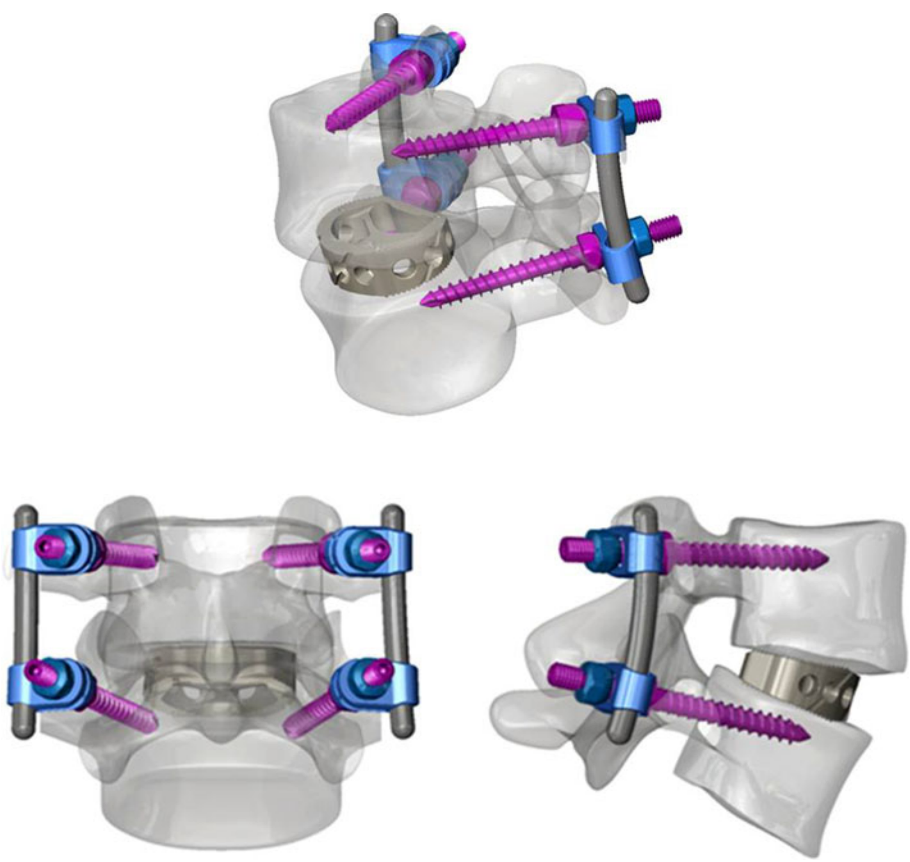

Fig. 1 Oblique, posterior and lateral views of the construct demonstrating anterior interbody PEEK cage associated with pedicle screw-based posterior stabilization

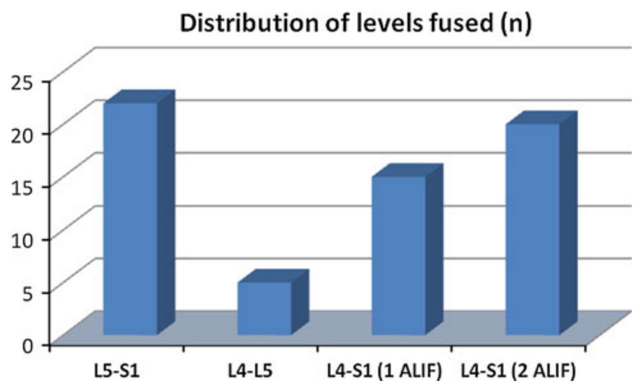

Fig. 2 Distribution of levels fused

Posterior approach

After this anterior approach, during the same surgical procedure and under continuous general anesthesia, patients were repositioned in ventral decubitus. They underwent single or double-level instrumented arthrodesis using mono- and poly-axial pedicle screws with pre-lordosed rods (Aladyn™, Scient'x-Alphatec, Carlsbad, USA). In cases of symptomatic lumbar stenosis with radicular pain, a recalibration of the lumbar canal was realized. Bone obtained from the spinous process and the arthrectomy was morselized and applied as graft material between lamina and facet joints.

In the end, a one-step 360° arthrodesis was obtained with optimal biomechanical stabilization of the spinal segment (Fig. 1).

The distribution of levels fused is presented in Fig. 2.

Collected data and evaluation methods

Clinical and radiological data were collected with a minimum 1-year clinical and radiographical follow-up for all the subjects. The average follow-up (FU) was 22 ± 8 months [12–26].

Clinical

Surgery related: operative and postoperative complications, estimated blood loss and surgical time. Surgical time for the anterior, posterior and total procedure was calculated from the initial skin incision to closure, the second skin incision to closure and the initial anterior incision to the posterior dressing, respectively.

Symptoms related (patient self-reported questionnaires): visual analog scores (VAS) for back and leg pain, Oswestry Disability Index (ODI) and Roland–Morris scores were prospectively collected preoperatively, at 1 year and at the last follow-up by an independent surgeon, not related to the surgery team.

Radiological

Each patient had preoperative and 1-year postoperative full-length standing radiographs with the EOS system (Biospace, Paris, France) [8]. Measured parameters were:

- Disc height (DH): as reported by Drain et al. [9], for the levels fused with cages.
- Pelvic incidence (PI): angle between the perpendicular to the sacral plate at its midpoint and the line connecting this point to the femoral heads axis.
- Pelvis tilt (PT): angle between the vertical line and the line through the midpoint of the sacral plate to femoral head axis.
- Lumbar lordosis (LL): angle between L1 superior endplate and S1 endplate.
- Segmental Lordosis (Lseg): angle between upper endplate of the vertebra above the instrumented disc and lower endplate of the vertebra below the instrumented disc (for L5–S1 disc, we considered S1

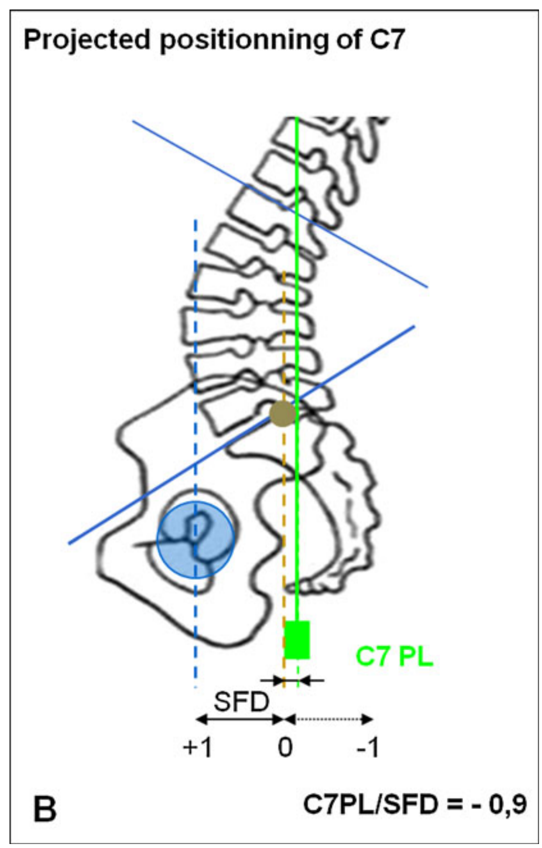

Fig. 3 C7 plumbline/sacro-femoral distance ratio defined as the ratio between the distance separating C7PL from the postero-superior corner of the sacrum and the sacro-femoral distance (i.e., SFD, the horizontal distance between the vertical bi-coxo-femoral axis and the vertical line passing through S1 endplate posterior corner). C7/SFD evaluates the global sagittal alignment of the spine above the pelvis (normal value −0.9 ± 1), [11]

endplate). Lseg was measured for the levels fused with cages only.

- L4–S1 Lordosis (LL4–S1): angle between L4 superior endplate and S1 endplate.
- Sagittal vertical axis (SVA): distance between C7 plumbline and S1 top margin posterior corner [10].
- C7 plumbline/sacro-femoral distance ratio (C7/SFD): ratio between the C7 plumbline (i.e., distance between C7PL from the postero-superior corner of the sacrum) and the sacro-femoral distance (i.e., the horizontal distance between the vertical bi-coxo-femoral axis and the vertical line passing through S1 endplate posterior corner) (Fig. 3). C7/SFD evaluates the global sagittal alignment of the spine above the pelvis (normal value −0.9 ± 1) [11].

Fusion: two independent observers assessed the quality of the fusion at the 1-year CT scan, following the Spine Interbody Research Group criteria [12].

Statistics

Statistical analyses were conducted using SPSS version 12.0 (SPSS Inc, Chicago, IL, USA). Paired-samples *t* tests were used to compare the preoperative and postoperative radiological parameters. A *p* value inferior to 0.05 was considered as significant.

Results

Surgery data

Mean surgery times for anterior, posterior and global procedure were respectively 91 ± 26, 98 ± 24 and 209 ± 40 min. The corresponding average blood loss was 72 ± 100, 260 ± 160 ml and 308 ± 179 ml (Table 1).

Complications

There were no dural tears, no postoperative infection and no neurologic deficit observed postoperatively. During an anterior approach, one vascular wound (1.6 %) of the right external iliac artery occurred, needing the intervention of a vascular surgeon with no secondary side effects. There was no revision surgery. No instrumentation breakage, cage migration/subsidence or implant failure was observed.

Table 1 Operative data

($n = 62$)	Operative time (min)	Blood loss (ml)
Anterior step	91 ± 26	72 ± 100
Posterior step	98 ± 24	260 ± 160
Total surgery	209 ± 40	308 ± 179

Table 2 Postoperative evolution (1 year) for clinical and functional scores

	Preoperative	Postoperative (1 year)	*p*
VAS	7.4 ± 3	3.2 ± 3	<0.001
ODI(/100)	48 ± 22	24 ± 18	<0.001
Roland–Morris (/24)	18 ± 6	8.2 ± 8	<0.001

Table 3 Postoperative evolution of radiological parameters

	Preoperative	Postoperative	*p*
DHL5–S1	0.26 ± 0.5	0.37 ± 0.9	<0.01
DHL4–L5	0.26 ± 0.5	0.35 ± 0.7	<0.01
PI	56 ± 10	56 ± 10	NS
PT	16 ± 6	15 ± 6	NS
LL	52 ± 12	54 ± 12	NS
LsegL5–S1	13 ± 6	24 ± 6	0.01
LsegL4–L5	7 ± 5	12 ± 6	0.05
C7/SFD	0.35 ± 0.5	0.2 ± 0.5	NS

Clinical outcome

Preoperative and postoperative scores are reported in Table 2. VAS, ODI and Roland–Morris/24 significantly decreased postoperatively at 1 year, $p < 0.001$, highlighting a significant and stable symptoms relief.

Radiological outcome

Preoperative and postoperative values of spinal and pelvic parameters are reported in Table 3. Disc height DH, and segmental lordosis LsegL5–S1, LsegL4–L5 and LsegL4–S1 significantly increased postoperatively (Fig. 4). Mean correction was 10.2° for LsegL5–S1, 5.5° for LsegL4–L5, 0.11 for DHL5–S1 and 0.09 for DHL4–L5.

All levels instrumented with cages were fused at the last-time follow-up CT scan (Fig. 5).

The sagittal balance global analysis (PT, SVA, C7/SFD, LL) showed no significant modifications between preoperative and postoperative measurements.

Discussion

Lumbo-sacral arthrodesis is one of the most common surgical procedures for the management of lumbar degenerative disease. Its objectives are decompression of the

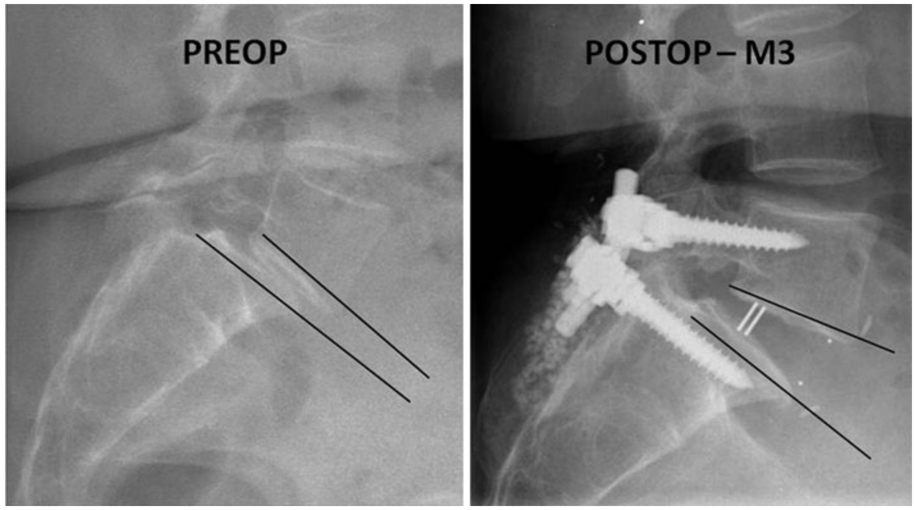

Fig. 4 Grade II isthmic spondylolisthesis treated by combined approach, anterior then posterior. Segmental lordosis significantly increased postoperatively at the index level while nearly complete reduction of slipping was obtained

Fig. 5 Low-grade L5–S1 isthmic spondylolisthesis. Combined approach allows obtaining a 360° intervertebral fusion with a large interbody and postero-median (i.e., interlaminar and interfacet) bone mass fusion

neurological structures when required, spinal segment stabilization, to restore lordosis and to obtain intervertebral fusion. We assessed a specific approach for lumbar fusion consisting, in one-step, ALIF surgery using rhBMP-2 and PEEK cage combined with posterior pedicle-screw fixation (during same surgical procedure).

While combined anterior/posterior arthrodesis procedures are already documented in the literature data, most authors focused on fusion success, without relating it to the sequence and details of anterior and posterior procedures. El Masry et al. [13] reported an overall fusion success of 97 % in 47 patients treated by ALIF, using autogenous iliac crest bone combined with posterior pedicle fixation. Anterior arthrodesis and posterior instrumentation succeeded in 95 % of 58 patients from a study by Moore et al. [14]. Finally, a radiographic fusion rate of 100 and 93 % for single- and two-level procedures was reported in 43 patients who underwent ALIF followed by a posterior instrumented fusion [15]. The present study observed 100 % of fusion at 1 year FU; this high rate is probably due to the following facts: (i) the ALIF procedure allowing for

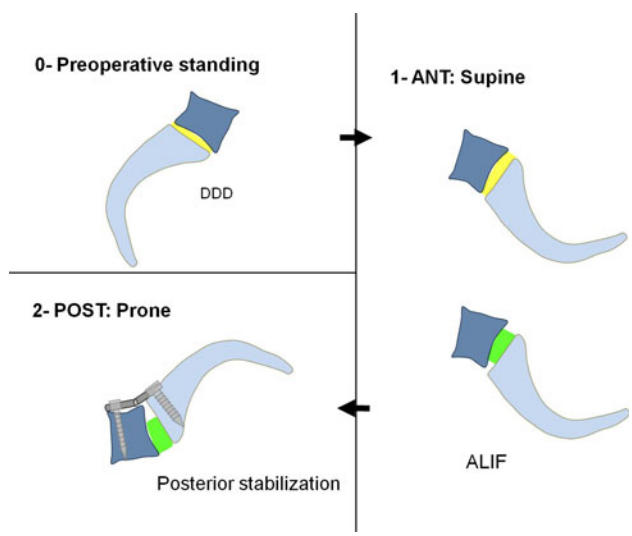

Fig. 6 Advantages of the AP sequence are: realignment of the spine and restoration of disc height during the anterior step (ANT) facilitated by the patient placed in supine position and the lumbar spine slightly in extension, and then, optimal stabilization during the posterior stage (POST), with the patient in prone position, by pedicle screw-based fixation

thorough discectomy, appropriate cleaning of endplates and large bone grafts (ii) the use of osteoinductive agent rhBMP-2 [16, 17], (iii) the posterior approach providing an adequate rigid stabilization [18] and performing a 360° graft [19, 20].

The ALIF procedure allows the placement of the cage without opening the vertebral canal, which probably explains that mean blood loss of 308 ± 180 ml was lower than those usually described in open PLIF, TLIF and circumferential procedures [21, 22]. In order to compare surgery data with existing studies, a literature search was performed, with a special focus on blood loss and surgery duration in interbody and circumferential procedures on lumbar spine [23–26]. In the light of literature data, surgery length and blood loss are comparable to those observed in single PLIF, TLIF or ALIF procedures and inferior to those observed in circumferential fusion or ALIF with percutaneous posterior stabilization. Limiting the blood loss is an important point since it increases hospital stay, postoperative complication rates and early recovery.

In the present series, only one case (1.6 %) of vascular injury during ALIF step was observed; this situation compared favorably to the 6 cases (8.2 %) of mini-ALIF complications and 6 (8.2 %) of percutaneous PF complications described by Kim et al. [26] in combined procedure of ALIF and percutaneous posterior stabilization. The absence of postoperative infections, dural tears or radicular deficit may be explained by the surgery sequencing: ALIF procedure to place the cage without the need for nerve roots manipulation and shorter posterior surgery time with no opening of the canal. The interest of this combined approach also lies in the need of a unique anesthesia allowing a shorter hospital stay, possibly relating to a lower postoperative infection rate.

Surgery sequencing of this combined approach has also an impact on sagittal alignment and balance. Thus, it allows for: (i) realigning the spine during the anterior step by the patient position: supine and slightly extension of lumbar spine and (ii) stabilization during the posterior step, as explained in Fig. 6.

As reported for the TLIF procedure, no significant changes in global balance analysis were observed in our study, which can partly be explained by the proper preoperative balance of most patients. As complete correction

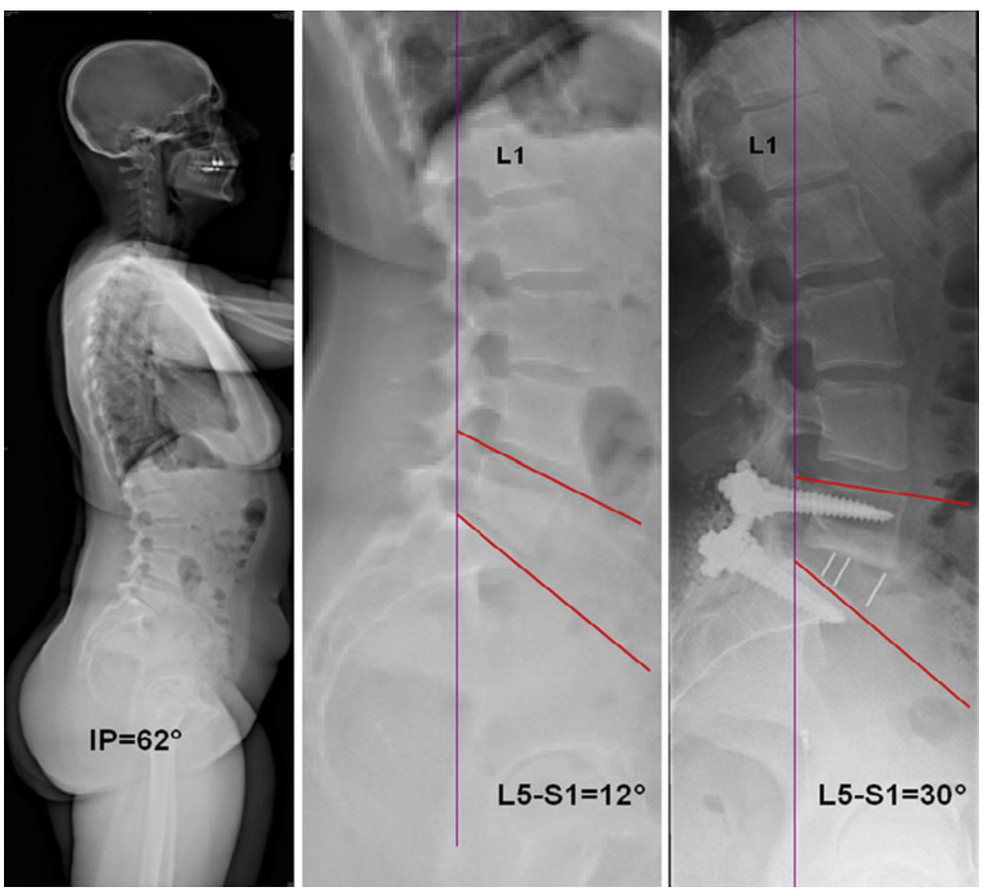

Fig. 7 The amount of lordosis restored was adapted to the spinopelvic parameters. This is the case of a woman with a high PI (more than 60°), theoretical lumbar lordosis was estimated to 70° meaning that L5–S1 segment required between 25° and 30° of lordosis (corresponding to 40 % of the global lordosis). The need to restore 25-30° at L5-S1 could be achieved using the combined approach

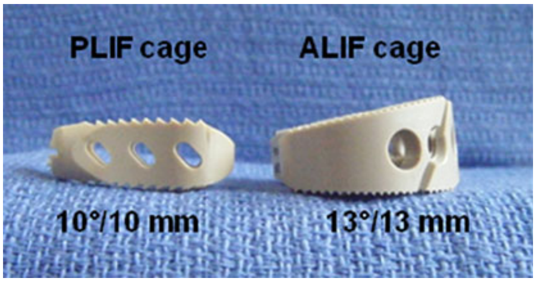

Fig. 8 Comparison of interbody cages usually implanted during posterior technique (PLIF, 10° of lordosis and 10 mm of height) versus anterior approach (ALIF, 13°/13 mm). This underlies the advantages of the combined approach in terms of lordosis and disc height restoration and bone graft volume

of sagittal imbalances requires more invasive surgical procedures, such as multi-level fusion or osteotomies [9], the proper sagittal alignment and balance observed avoid potential long-term complications. Furthermore, proper disc height and segmental lordosis restoration allowed by single or two-level fusion remain of great importance (see Fig. 7) as they seem to improve short- and long-term outcomes. The high lordotic cage (average 13 mm) used in this ALIF procedure yielded a more correction of narrowed L5–S1 and L4–L5 discs than those observed in published PLIF or TLIF procedure, and therefore, seemed more adequate to restore local balance (see Fig. 8), with a 10° mean gain of lordosis for L5–S1.

Further comparative studies will be necessary to evaluate this procedure and longer term to assess final outcomes, with the mention that controlled trial studies seemed to demonstrate already the benefits of a combined approach compared to posterior or anterior approach alone [20].

Conclusions

Our results suggest that one-step combined approach is a safe and efficient technique to achieve lumbo-sacral fusion while restoring an appropriate disc height and a correct sagittal balance, especially for L5–S1. Lumbo-sacral fusion achieved by a combined approach offers the benefits of the both ALIF and posterior procedures, with a more thorough discectomy (removing source of pain), optimal clearing of endplates (promoting fusion), anterior insertion of a large and lordotic cage with a great surface of contact between the bone graft and the endplates, a larger bone graft, no vertebral canal opening limiting dural tears, nerve roots manipulation and blood loss, and more rigid pedicle screw-based stabilization. Without significantly increasing the global operative time and blood loss, this procedure leaded to satisfactory clinical and radiological outcomes with a low complications rate. Although further comparative studies will be necessary to validate the final outcomes, surgeons might consider this combined approach technique before performing a routine lumbar fusion.

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Conflict of interest None.

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