Functional and radiological outcome of anterior retroperitoneal versus posterior transforaminal interbody fusion in the management of single-level lumbar degenerative disease

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OBJECTIVE In this study the authors compared the anterior lumbar interbody fusion (ALIF) and posterior transforaminal lumbar interbody fusion (TLIF) techniques in a homogeneous group of patients affected by single-level L5–S1 degenerative disc disease (DDD) and postdiscectomy syndrome (PDS). The purpose of the study was to analyze perioperative, functional, and radiological data between the two techniques.

METHODS A retrospective analysis of patient data was performed between 2015 and 2018. Patients were clustered into two homogeneous groups (group 1 = ALIF, group 2 = TLIF) according to surgical procedure. A statistical analysis of clinical perioperative and radiological findings was performed to compare the two groups. A senior musculoskeletal radiologist retrospectively revised all radiological images.

RESULTS Seventy-two patients were comparable in terms of demographic features and surgical diagnosis and included in the study, involving 32 (44.4%) male and 40 (55.6%) female patients with an average age of 47.7 years. The mean follow-up duration was 49.7 months. Thirty-six patients (50%) were clustered in group 1, including 31 (86%) with DDD and 5 (14%) with PDS. Thirty-six patients (50%) were clustered in group 2, including 28 (78%) with DDD and 8 (22%) with PDS. A significant reduction in surgical time (107.4 vs 181.1 minutes) and blood loss (188.9 vs 387.1 ml) in group 1 (p < 0.0001) was observed. No significant differences in complications and reoperation rates between the two groups (p = 0.561) was observed. A significant improvement in functional outcome was observed in both groups (p < 0.001), but no significant difference between the two groups was found at the last follow-up. In group 1, a faster median time of return to work (2.4 vs 3.2 months) was recorded. A significant improvement in L5–S1 postoperative lordosis restoration was registered in the ALIF group (9.0 vs 5.0, p = 0.023).

CONCLUSIONS According to these results, interbody fusion is effective in the surgical management of discogenic pain. Even if clinical benefits were achieved earlier in the ALIF group (better scores and faster return to work), both procedures improved functional outcomes at last follow-up. The ALIF group showed significant reduction of blood loss, shorter surgical time, and better segmental lordosis restoration when compared to the TLIF group. No significant differences in postoperative complications were observed between the groups. Based on these results, the ALIF technique enhances radiological outcome improvement in spinopelvic parameters when compared to TLIF in the management of adult patients with L5–S1 DDD.

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KEYWORDS anterior lumbar interbody fusion; transforaminal lumbar interbody fusion; degenerative disc disease; radiological outcome; functional outcome; lumbar lordosis

I N adult patients affected by degenerative disc disease (DDD) with chronic low-back pain, interbody fusion is performed to achieve pain relief with the aim of first obtaining a solid bone fusion, and second the restoration of the segmental lordosis, according to the pelvic incidence (PI). Different techniques—posterior, anterior, lateral, and combined—have been developed and advantages and drawbacks have been widely investigated.[1–8] The advantages of the anterior lumbar interbody fusion (ALIF) technique are the possibility to achieve a com-

plete anterior discectomy, under direct vision, after resection of the anterior longitudinal ligament (ALL) and the insertion of large and lordotic cages. This approach, using modern minimally invasive techniques, allows for an optimal local lordosis restoration and an indirect foraminal decompression with early perioperative pain reduction, preserving the integrity of the posterior tension band.[9] ALIF approach-related complication rates range between 8.4% and 31.1% in large patient series.[2,3] The most important complications are vascular injuries, especially venous, accounting for between 1.9% and 24%, mostly at the L4–5 space (iliolumbar vein).[4,5] Visceral injuries are uncommon. Neural structure injuries can include sympathetic dysfunction, and retrograde ejaculation in males (3%–5% of male cases).[5,6] Among posterior approaches, the advantages of transforaminal lumbar interbody fusion (TLIF) include unilateral access to the disc and eventual direct monolateral decompression reducing perineural scarring tissue, and the possibility to perform both interbody and posterolateral fusion. TLIF approach-related complications are dural tears and root injury, poor discectomy and endplate preparation, and screw and cage malpositioning or migration.[7,8] According to the literature, the perioperative TLIF complication rate accounts for between 14.2% and 25.4% in large series.[7,8] Rate of dural tears range between 0% and 20%, root injuries occur in 1%–3% of cases, symptomatic screw misplacement occurs in 4%–9% of cases, and cage migration is an uncommon but potentially serious complication.[8] Many comparative studies report the same fusion rate between these different techniques and better radiological results in terms of segmental lordosis for ALIF.[10] However, comparative data on surgical results and functional outcome of each procedure are unconvincing, probably because heterogeneous samples are analyzed, resulting in limited statistical power.[2,10] The purpose of this study was to compare retrospectively the two techniques (ALIF vs TLIF) in two homogeneous groups of patients in terms of sample size, sex, and age affected by single-level L5–S1 DDD and postdiscectomy syndrome (PDS). An analysis of perioperative, functional, and radiological data between the two techniques was performed.

Methods

This is a retrospective analysis from the review of the Spine Surgery 2 Unit of the IRCCS Galeazzi Hospital database between 2015 and 2018, with a minimum 2-year follow-up (mean 49.7 months). Clinical and radiological deidentified registries were used to track patient care and outcome without direct patient involvement, even if informed consent was obtained. Patients ≥ 18 years old, with single-level L5–S1 interbody fusion performed by ALIF and TLIF techniques for DDD or PDS, were selected and included. The TLIF technique was performed in cases of DDD or PDS associated with bone stenosis. In pure DDD or PDS with or without association of soft stenosis, the ALIF procedure was performed (indirect decompression). Only patients with complete information in the database at the last follow-up were considered for the study. Patients with significant comorbidities (diabetes, inflammatory

diseases, BMI ≥ 30 kg/m^2), posttraumatic deformity, infections, spondylolisthesis, or previous fusion, were excluded. Surgery was performed to achieve pain improvement and to prevent neurological worsening. A single senior spinal surgeon trained in anterior approaches (R.B.) treated all included patients clustered into the anterior (group 1) and posterior (group 2) groups. Clinical, radiological, and surgical data of each patient were collected until final follow-up. Clinical and functional outcomes were assessed by visual analog scale (VAS) scores for back pain and leg pain and the Oswestry Disability Index (ODI) scoring systems. A spine registry (the IOG Spine-Reg) was used to track clinical follow-up. Radiological follow-up was obtained on the second postoperative day, after 3 months, and then every 12 months for 2 years. All radiological data were obtained by direct measurement of biplanar full-spine radiographs on EOS imaging platforms and collected in the institutional radiological registry. Each image was imported into Sectra Workstation IDS7 and the spinopelvic parameters were calculated using Ortho Toolbox (Fig. 1). Lateral and coronal images were reviewed, and pre- and postoperative spinopelvic parameters were assessed and compared. Fusion at the last follow-up was retrospectively assessed by a musculoskeletal radiologist with 15 years of experience in musculoskeletal imaging (L.M.S.) on both CT scans and radiographs, which, could be less subject to artifacts, particularly in the presence of tantalum cages. The Brantigan interbody fusion grading system was used to define radiological evidence of fusion on CT,[11] and grades 4 and 5 were considered as fusion. The presence of bone bridging in the disc space or in the anterior part of the disc space on radiographs was also used to confirm fusion.

Statistical Analysis

Statistical analyses were performed using GraphPad Prism (version 5.0, GraphPad Software Inc.). Data were expressed as median and interquartile range (IQR) or mean and standard deviation (SD) as specified in each case. Normal distribution of all variables was tested using the Shapiro-Wilk test. One-way ANOVA and the Kruskal-Wallis test with Dunn's posttest were applied to assess differences among different groups and time points in cases of normal and nonnormal data distribution, respectively. Similarly, the Student t-test or Mann-Whitney test were used for the comparisons between the two groups. A p value < 0.05 was considered statistically significant.

Results

Population

The analysis of our database showed 153 patients who underwent surgery for single-level L5–S1 degenerative disease treated with ALIF and TLIF techniques. Of these 153 patients, 56 (36.6%) were excluded due to exclusion criteria and 25 (16.3%) were excluded for incomplete data at the last follow-up. All of the 72 included patients were comparable in terms of demographic features and diagnoses (Table 1). Thirty-two patients were male and 40 female, the average age was 47.7 ± 11.5 years (range 28–83 years), and the median age was 46 years. The mean
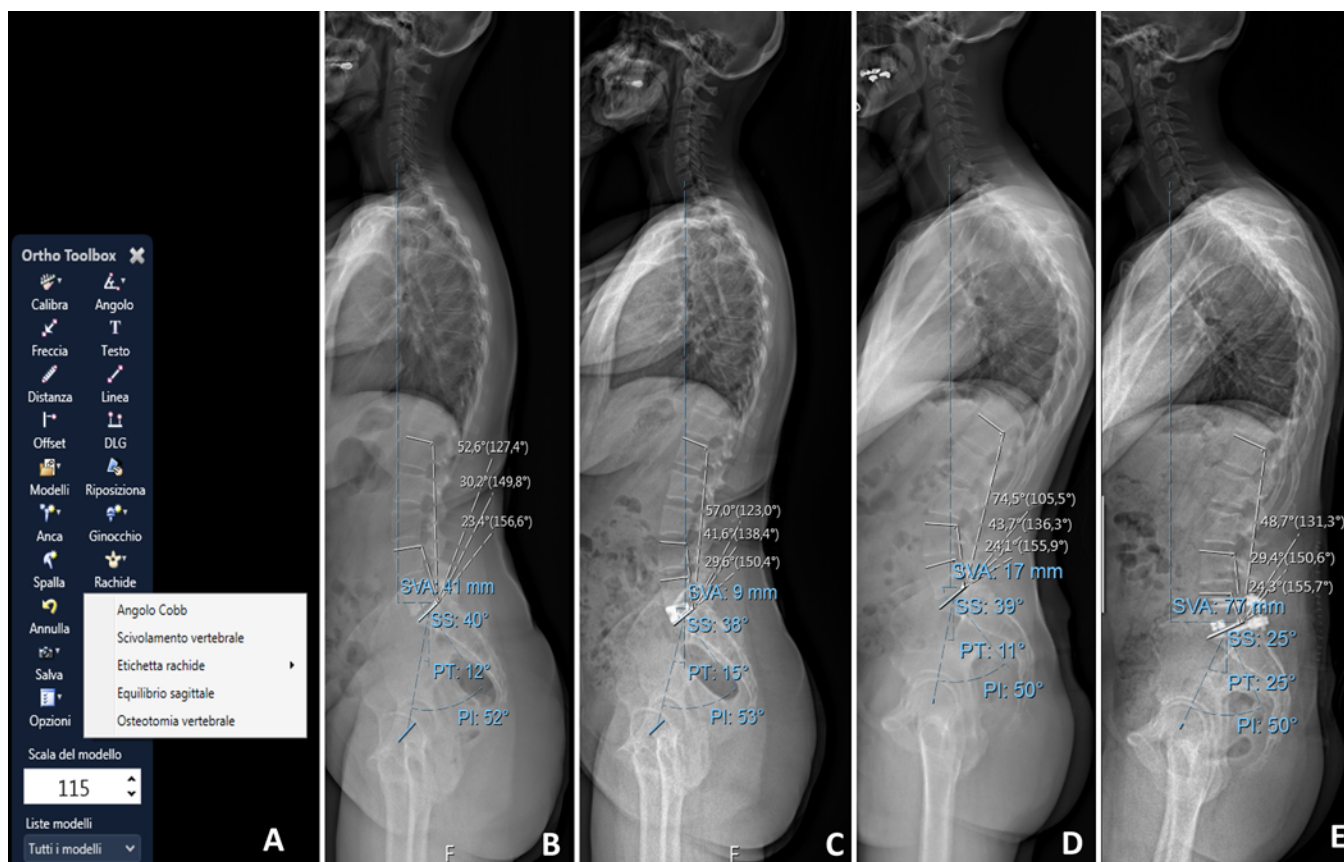
FIG. 1. Pre- and postoperative radiological measurement (**A**) of full-spine radiographs in the ALIF (**B and C**) and TLIF (**D and E**) groups. PI is measured by drawing an angle between a line perpendicular to the sacral plate at its midpoint and a line connecting the same point to the center of the bicoxofemoral axis. PT is measured by an angle between the center of the superior S1 endplate and a vertical line. SS is measured by an angle between the center of the superior endplate of S1 and the horizontal plane. LL is measured as the angle between the upper endplate of L1 and superior endplate of the sacrum, between the upper endplate of L4 and superior endplate of the sacrum, and between the upper endplate of L5 and superior endplate of the sacrum (L1–S1, L4–S1, and L5–S1).

follow-up duration was 49.7 ± 27.6 months (range 12–108 months). Thirty-six patients (50%) were clustered in group 1 (12 men, 24 women, average age 46.09 ± 9.15 years). Thirty-six patients (50%) were clustered in group 2 (20 men, 16 women, mean age 50.55 ± 13.41 years). There were 31 patients with DDD in group 1 (86%) and 28 patients with DDD in group 2 (78%). Five patients (14%) had PDS in group 1 and 8 (22%) had PDS in group 2.

Spinopelvic Parameters

In group 1, the mean preoperative PI was 49.4° ± 11° (median 46°), the mean pelvic tilt (PT) was 16.8° ± 7.3° (median 17°), and mean sacral slope (SS) was 31.1° ± 8.3° (median 33°; Table 2). The mean lumbar lordosis (LL) at L1–S1 was 48.7° ± 7.3° (median 49°). Lower LL (LLL) at L4–S1 was 31.5° ± 7.5° (median 31.7°) and L5–S1 LL was 17° ± 6.2° (median 16.5°).

In group 2, the mean preoperative PI was 50.9° ± 9.7° (median 49°), the mean PT was 17.2° ± 10° (median 16°), and mean SS was 33.5° ± 6° (median 32°). The mean LL at L1–S1 was 47.9° ± 12.8° (median 45°). LLL at L4–S1 was 32.8° ± 7.6° (median 33°) and L5–S1 LL was 19.8° ± 12.3° (median 18°).

Preoperative Clinical Data

All included patients reported low-back pain. Leg pain was recorded in 42 patients (58.3%). No motor weakness (0%) was observed, while sensitive dysfunction was recorded in 12 patients (16.7%). The median preoperative ODI score was 70.2% ± 1.6% (range 55%–97%), the median preoperative VAS score was 7.5 ± 1.3 (range 5–10). In group 1, the mean preoperative ODI score was 65% ± 15%, and the median ODI was 65. The mean preoperative VAS score was 8.02 ± 1.2 (median 8). In group 2, the mean preoperative ODI score was 77.8% ± 8.7 (median 75.3), and the mean preoperative VAS score was 6.9 ± 1.2 (median 7).

Intraoperative and Perioperative Data
Group 1

In group 1, a video-assisted mini-open anterior retroperitoneal approach with the patient supine was per-
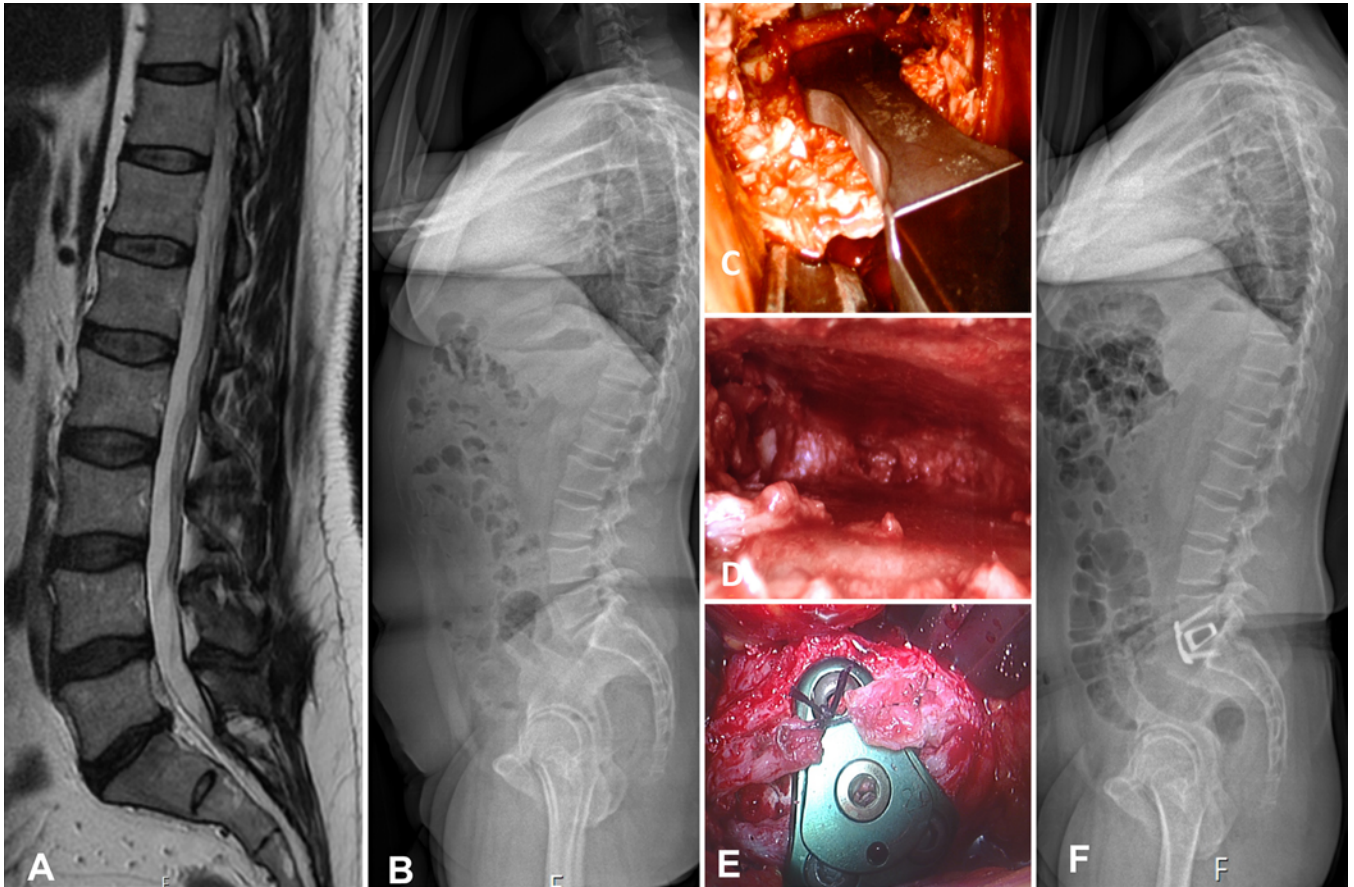
FIG. 2. Case example of 52-year-old man who suffered from low-back pain and left-side sciatica with sensory impairment at L5 on the left, was resistant to conservative treatment, and underwent ALIF. **A:** Sagittal T2-weighted MR image showing L5–S1 Pfirrmann grade IV degeneration (inhomogeneous disc with a hypointense dark gray signal intensity and decreased disc height). **B:** Preoperative whole standing-spine radiograph showing normal sagittal and coronal balance. **C–E:** Intraoperative endoscopic view and magnification showing mobilization of the two vertebral bodies with a spreader, the posterior wall of the disc space, and the two preserved anterior ligament flaps sutured together once a 3-screw fixed plate stabilized the cage. **F:** Postoperative whole standing-spine radiograph showing L5–S1, the correct positioning of the cage, and L5–S1 lordosis.

formed in all cases with a standard transverse modified Pfannenstiel incision of 5 cm.[12,14] The anterior sheath of the left rectus abdominis muscle was dissected longitudinally from the left side, approximately 2 mm lateral to the linea alba and the muscle retracted upward and laterally with careful blunt finger dissection. A short incision in the far lateral tract of the arcuate line allowed visualization of the retroperitoneal space. Under direct visual and endoscopic assistance (30°, 10-mm cold light endoscope coupled to a high-definition screen) the preparation of the anterior surface of the intervertebral disc was performed, paying special attention to the inferior hypogastric plexus between the iliac vessels after coagulation of the middle sacral vein and artery. Therefore, an autostable retractor with blades was put in place. After complete resection of the ALL, the vertebral bodies were then mobilized with a spreader, providing posterior indirect decompression in each case (Fig. 2). Thirty-four (94.4%) 20° lordotic-shaped titanium cages and 2 (5.5%) 13° lordotic-shaped tantalum cages filled with bone graft or bone substitute (tricalcium phosphate) were implanted (Fig. 3). A plate fixed with 3

screws secured each cage. The mean duration of surgery was 107.4 ± 29.2 minutes (median 102.5 minutes, range 90–120 minutes). The mean intraoperative blood loss was 188.9 ± 52.2 ml (median 200 ml, range 150–200 ml). Intraoperative surgical complications were recorded in 2 patients (5.5%): 1 case (2.8%) of a small peritoneal tear repaired directly, and 1 case (2.8%) of common iliac vein bleeding treated by surgical compression and hemostatic agents. The mean hospitalization duration was 6.4 ± 1.1 days (median 6 days, range 6–7 days). A total of 2 blood transfusions (5.5%) were performed on 36 patients. Early postoperative complications were recorded in 2 cases: 1 superficial hematoma treated conservatively, and 1 postoperative new-onset radiculopathy subsequently treated with a posterior decompression (Table 1).

Group 2

In group 2, surgery was performed in all cases with a standard open posterior midline approach. Bilateral subperiosteal paraspinal muscle dissection, monolateral laminectomy, and medial bilateral artrectomy were per-
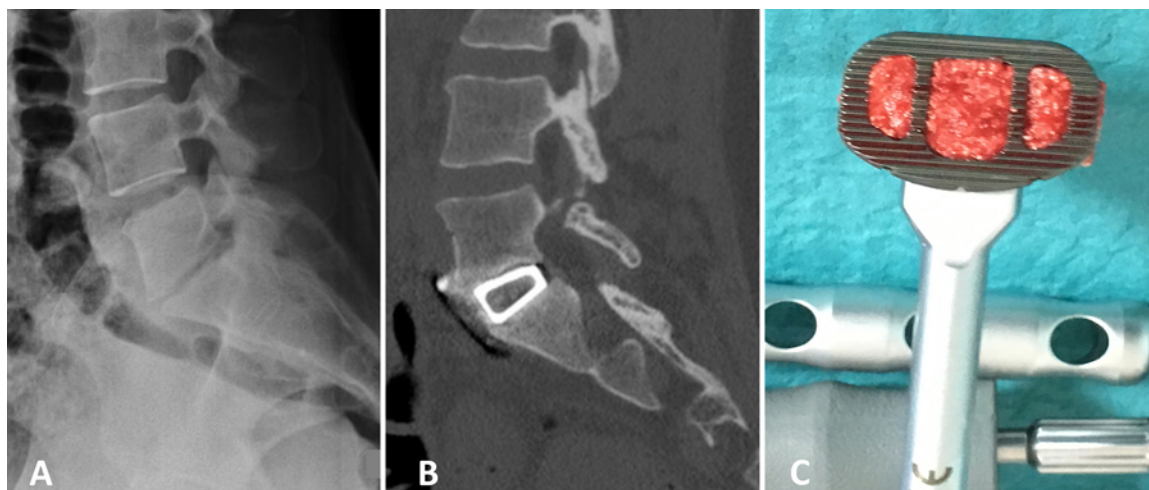
FIG. 3. Radiological evidence of collapsed disc height and segmental lordosis restoration after an anterior cage implant. **A:** Preoperative lumbar radiograph showing L5–S1 severe discopathy. **B:** Postoperative sagittal CT scan showing the lordotic-shaped cage. **C:** Intraoperative view of the cage filled by heterologous bone substitute.

formed in all cases. Transpedicular screw positioning was performed freehand with final fluoroscopic control. Once ipsilateral neural elements were decompressed if needed, discectomy was performed and parallel "banana"-shaped titanium cages (filled with bone autograft) or tantalum cages were implanted in the most anterior part of the interbody space to create a pivot for posterior compression, in order to restore segmental lordosis. Posterior autologous bone grafting was placed in all cases. The mean duration of surgery was 181.1 ± 21.9 minutes (median 180 minutes, range 135–210 minutes). Mean intraoperative blood loss was 387.1 ± 145.5 ml (median 350 ml, range 300–450 ml). One intraoperative surgical complication

(a dural tear repaired directly) was recorded (2.8%). The mean hospitalization length of stay was 6.7 ± 0.9 days (median 7 days, range 6–7 days). Blood transfusions were necessary in 4 patients (11.1%). An early postoperative complication was recorded in 1 patient with residual postoperative sciatica (2.8%), which was managed conservatively (Fig. 1D and E). Intra- and perioperative data are summarized in Table 1.

Postoperative Spinopelvic Parameters

In group 1, the mean postoperative PI was 50° ± 9° (median 46.5°), the mean PT was 17.2° ± 15.7° (median 16.5°), and the mean SS was 32.9° ± 7.7° (median 32°; Table 2). The mean LL at L1–S1 was 46.5° ± 11° (median 45.5°), LLL at L4–S1 was 35.2° ± 6° (median 35°), and mean L5–S1 LL was 26.3° ± 5.6° (median 25°).

In group 2, the mean postoperative PI was 50.6° ± 7.5° (median 50°), the mean PT value was 18.6° ± 6.7° (median 19.5°), and the mean SS was 31.5° ± 5.5° (median 33°). The mean LL at L1–S1 was 47.8° ± 9.8° (median 45.5°), the LLL at L4–S1 was 34° ± 17.2° (median 32.5°), and the mean LL at L5–S1 was 22.9° ± 5.7° (median 23.5°; Table 2).

TABLE 1. Intra- and perioperative data

Variable	ALIF (n = 36)	TLIF (n = 36)	p Value
Males/females	12/24	20/16	NA
Mean age (SD), yrs	46.09 (9.15)	50.55 (13.41)	NA
Diagnosis			NA
DDD	31 (86%)	28 (78%)	
PDS	5 (14%)	8 (22%)	
Mean surgical time (SD), mins	107.4 (29.2)	181.1 (21.9)	<0.0001
Intraop blood loss, ml			<0.0001
Median (IQR)	200 (150–200)	350 (300–450)	
Mean (SD)	188.9 (52.2)	387.1 (145.5)	
Intraop complications	5.55%, n = 2	2.7%, n = 1	0.561
Hospitalization length of stay, days			0.1303
Median (IQR)	6 (6–7)	7 (6–7)	
Mean (SD)	6.4 (1.1)	6.7 (0.9)	
Blood transfusion	5.55%, n = 2	11.1%, n = 4	0.4095
Early postop complications	5.55%, n = 2	2.7%, n = 1	0.561

NA = not available.

TABLE 2. Radiological data

Radiological Outcome	Group 1 Mean (SD)		Group 2 Mean (SD)		p Value
	Preop	Postop	Preop	Postop	
PI (°)	49.4 (11)	50 (9)	50.9 (9.7)	50.6 (7.5)	NA
PT (°)	16.8 (7.3)	17.2 (15.7)	17.2 (10)	18.6 (6.7)	NA
SS (°)	31.1 (8.3)	32.9 (7.7)	33.5 (6)	31.5 (5.5)	NA
L1–S1 LL (°)	48.7 (7.3)	46.5 (11)	47.9 (12.8)	47.8 (9.8)	NA
L4–S1 LLL (°)	31.5 (7.5)	35.2 (6)	32.8 (7.6)	34 (17.2)	NA
L5–S1 LL (°)	17 (6.2)	26.3 (5.6)	19.8 (12.3)	22.9 (5.7)	<0.001

TABLE 3. Functional data

Functional Outcome	Mean Preop (SD)	Mean Postop (SD)	Mean Last Follow-Up (SD)	Unchanged (%)	Improved (%)
ODI score					
Group 1	65 (15)	25 (12)	15 (7.1)	1 (2.8)	35 (97.2)
Group 2	77.8 (8.7)	35 (9.3)	21 (9.9)	3 (8)	33 (92)
VAS score					
Group 1	8.02 (1.2)	3.3 (2)	1.8 (1.2)	NA	NA
Group 2	6.9 (1.2)	3.4 (1.2)	2.5 (1.3)	NA	NA
Total	NA	NA	NA	4 (5.5)	68 (94.5)*

Neither of the groups experienced worsened outcomes.

* $p < 0.001$.

FIG. 4. Radiological evidence (*left*, CT image; *right*, radiograph) of interbody fusion in ALIF (**left**) and TLIF (**right**) at the last follow-up (Brantigan grade 5).

Follow-Up Data

In group 1, the mean postoperative ODI score at 12 months follow-up was 15% ± 7.1% (median 13%). The mean postoperative VAS score at 12 months follow-up was 1.8 ± 1.2 (median 1). The median time until return to work was 2.4 months. At last follow-up, functional improvement (ODI/VAS) was recorded in 35 patients (97.2%) and in 1 patient remained stable. In group 2, the mean postoperative ODI score at 12 months follow-up was 21% ± 9.9% (median 20%). The mean postoperative VAS score at 12 months follow-up was 2.5 ± 1.3 (median 3). The median time until return to work was 3.2 months. At last follow-up, functional improvement (ODI/VAS) was recorded in 33 patients (92%), and in 3 patients (8%) remained stable (Table 3). Brantigan grade 4 or 5 was observed in all patients at the last follow-up. The presence of bone bridging in the anterior part of or into the cage was observed in all patients in both groups at final follow-up (Fig. 4). A delayed second surgery was necessary in 1 patient (2.8%) in group 2 for adjacent disc disease (ADD). Preoperative sensory disturbance was persistent in 2 patients (1 in group 1 and 1 in group 2) at 24 months follow-up (5.5%). Preoperative radicular pain improved in 40 patients (96%) and remained unchanged in 2 patients (4%) among the 42 patients with preoperative neurological symptoms.

Surgical Considerations

A shorter surgical time was recorded in group 1 (107.4 minutes) compared to group 2 (181.1 minutes) with a statistically significant difference ($p < 0.0001$) between groups, as well as significantly reduced blood loss in group 1 (188.9 vs 387.1 ml, $p < 0.0001$). No other variables between the two groups were significant, including hospitalization length of stay ($p = 0.1303$), number of postoperative blood transfusions ($p = 0.4095$), and perioperative complications ($p = 0.561$; Table 1).

Radiological Evaluation

Postoperative spinopelvic parameters were compared between the two groups. An ANOVA was performed on pre- and postoperative spinopelvic parameters. L5–S1 segmental 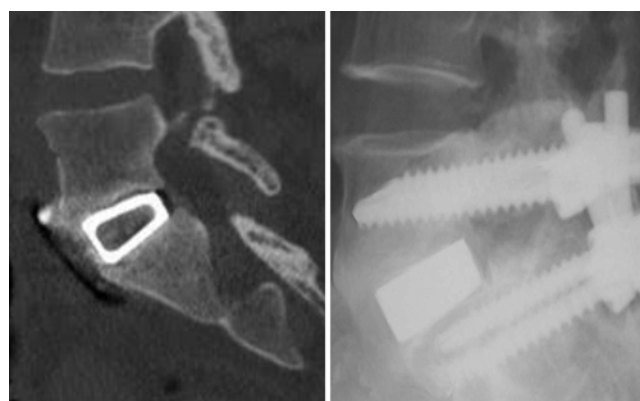increase of LL emerged between pre- and post-operative values in groups 1 ($p < 0.001$) and 2 ($p < 0.05$), and was particularly greater in group 1. The mean value of increase was 9° (range 4.5°–13.7°) in group 1 and 5° (range 0°–10.5°) in group 2 ($p = 0.023$; Table 2).

Clinical Evaluation

The difference in the ODI values between preoperatively, 3 months, and 12 months follow-up was significant in both groups ($p < 0.001$). In group 2 we observed a further significant improvement between 3 and 12 months ($p < 0.05$), while in group 1 we found an early improvement of all the scores at 3 months follow-up. No significant differences emerged between the two groups at last follow-up because of persistent improvement in both groups (Table 3).

Discussion

Single-level L5–S1 interbody fusion is achieved through posterior or anterior techniques. The main advantages of posterior approaches are direct neural element decompression and posterolateral grafting for fusion. The drawbacks to this approach may be injury of neural structures and denervation of paraspinal muscles weakening the posterior tension band.[1,7,8] The anterior approach can achieve an optimal restoration of segmental lordosis, especially in collapsed discs.[1–6] It is possible an indirect decompression leads to faster recovery despite possible injuries to surrounding structures or vascular complications, without a significant difference in terms of fusion rate (88.6% vs 91.9%, $p = 0.23$) compared to TLIF.[1–6,15] We found a significant increase in segmental lordosis with ALIF compared with TLIF procedures.[1,10,12,13] Over the last decade, the development of mini-open approaches has increased the efficiency and safety of anterior surgery.[9,14,16,17]

Intraoperative and Perioperative Data

The analysis of our data showed a significant reduction of surgical duration and intraoperative blood loss in ALIF ($p < 0.0001$) when compared to TLIF. According to the literature, hospitalization length of stay is similar in the two groups (6 days for ALIF and 7 days for TLIF).[18]

Minor intraoperative surgical complications (1 small peritoneal tear and 1 minor bleeding from the common iliac vein) were recorded in 2 patients (5.5%) for group 1 and directly repaired without any consequences. One intraoperative complication (2.8%) was recorded in group 2. Early postoperative complications were recorded in 3 patients (4.1%): 2 patients in group 1 (5.5%), and 1 patient in group 2 (2.8%). We observed 1 postoperative superficial hematoma (2.8%) in the ALIF group that did not required revision and 1 case of early sciatica for each group. Despite the fact that we did not find a significant difference between the two groups, our results are comparable to findings reported in the literature (4.4% for the anterior approach and 5.9% for the posterior approach).[15] In our series, 2 patients needed a second unexpected surgery: 1 patient in group 1 for acute postoperative radiculopathy due to a small disc fragment compressing the nerve root, and 1 patient in group 2 for delayed ADD at 1-year follow-up. Recent studies comparing approach-related complications between anterior and posterior procedures found different and conflicting results in terms of morbidity rate. Some authors have described a worse outcome in the posterior group and others concluded that anterior approaches might be associated with higher postoperative morbidity and reoperation rates than posterior approaches.[17–19] Although we found a significant increase of blood loss in the TLIF group, we did not find a significant difference in complication and reoperation rates between the two approaches (p = 0.561). In our series, to reduce bias, we included only patients with 1 level of DDD treated by a single senior surgeon trained in anterior approaches, to limit the impact of the access-related complications in both groups. All ALIF procedures were performed by video-assisted mini-open exposure which, as reported in large series, is associated with lower intra- and perioperative complications[20–24] (Table 1).

Radiological Outcomes

Significant differences regarding improvement in L5–S1 segmental lordosis (p < 0.0001) favoring the ALIF group were observed. The ALIF procedure allows powerful space distraction by ALL resection and the insertion of large lordotic cages (Fig. 5). We recorded a greater median value of final L5–S1 lordosis (25°) probably because the cage acted as a pivot. In large series reported in the literature, radiographic outcome showed a significant greater disc height, segmental lordosis, and an increase of whole LL in ALIF versus TLIF groups.[25–29] Compared to the TLIF technique, the ALIF procedure is associated with a better postoperative segmental lordosis restoration and may be a reasonable option in the presence of severe DDD, when an optimal sagittal alignment should be obtained and when direct spinal canal decompression is not needed[28,30] (Table 2). Even if it was not the main goal of this study, at the last 2-year follow-up evaluation we observed radiological evidence of fusion on radiography or CT (Fig. 4) in all patients. This result in both groups, confirmed by a senior radiologist, was surprising but not unique in the literature.[25,26] A possible explanation could be that the small number of patients reduced the likelihood of observing patients without fusion.[12,18,21] Furthermore, nonunion could have been a possible cause of patient dropout, so that

FIG. 5. In the *upper* part of the figure, a banana-shaped titanium cage filled by autologous bone commonly used in TLIF approaches is shown. In the *lower* half, a lordotic-shaped titanium cage filled by bone substitute used in ALIF is represented.

patients, because of persistent pain or other complaints, could have been referred to other centers.

Clinical Outcome

The mean 3-month postoperative ODI score was 25% ± 12% (median 24%) in group 1 and 35.5% ± 9.3% (median 36%) in group 2. ODI/VAS improvement was observed in 98% of patients in group 1 and in 92% of group 2 at last follow-up. Although the ALIF group experienced a faster improvement and in the TLIF group the functional improvement between 3 and 12 months was significant (p < 0.05), no significant differences emerged between the two groups at last follow-up. This result appears to emphasize the role of interbody fusion in the treatment of discogenic pain.[1,18,20] Moreover, we found an early median time of return to work in the ALIF group (2.4 vs 3.2 months) compared to the TLIF group. These data could be explained because of the advantages of the anterior approach (more anatomical) but there is not strong evidence supporting this assumption[20–22,25] (Table 3).

Limitations

The limitations of this study are the retrospective design and the small sample size, even if homogenous. Although we selected the pool of patients according to our standard criteria for choosing the approach, it could represent a possible selection bias that could be improved by further randomized studies. The involvement of a single institution and, moreover, a single surgeon may be a weak-

ness (without comparison), but also a strength because of a reduction in technical variations or surgical bias. The rate of fusion we have observed at the final follow-up, confirmed by an independent senior radiologist, is anecdotal, although this was not the main goal of the study. Given the limited sample sizes, the data regarding fusion rate cannot be generalized.

Conclusions

Although a clinical benefit was achieved earlier in the ALIF group (faster return to work) compared with the TLIF group in this study, both procedures improved functional outcomes at last follow-up without a significant difference between the groups. ALIF procedures showed significantly (p < 0.0001) lower blood loss and shorter surgical duration when compared to TLIF. ALIF allows a powerful intervertebral disc distraction with significantly better segmental lordosis restoration, especially in collapsed discs, in comparison to TLIF (p < 0.001). Further prospective studies are necessary to evaluate complications and fusion rates in larger series, as well as possible influencing factors of ADD development between anterior and posterior approaches.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Bassani, Querenghi, Peretti. Acquisition of data: Morselli, Bassani, Querenghi, Nuara. Analysis and interpretation of data: Morselli, Bassani, Querenghi, Nuara, Peretti. Drafting the article: Morselli, Bassani. Critically revising the article: Morselli, Bassani. Reviewed submitted version of manuscript: Morselli, Bassani, Sconfienza, Peretti. Statistical analysis: Morselli, Nuara. Radiological analysis: Sconfienza.

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