The outcomes after Anterior Lumbar Interbody Fusion(ALIF): Our experience

Ari Demirel (ari.demirel@hotmail.com)
Aalborg University Hospital: Aalborg Universitetshospital https://orcid.org/0000-0001-8388-8006
Renata Terzic
Aalborg University Hospital: Aalborg Universitetshospital
Jon Kaspersen
Aalborg University Hospital: Aalborg Universitetshospital
Søren Peter Eiskjær
Aalborg University Hospital: Aalborg Universitetshospital

Research Article

Keywords: ALIF, Spine, Disc degeneration, Bone union

Posted Date: May 23rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1540341/v1

Abstract

Background:

Anterior lumbar interbody fusion (ALIF) is a well-established treatment with various *advantages* and disadvantages. One specific advantage of ALIF combined with posterolateral fusion is the high union rate. Using poly-ether-ether-ketone (PEEK) cages for ALIF procedure takes advantage of the relative radiolucency of PEEK cages .The goal of this study was to determine the radiological outcomes and complications after ALIF surgery.

Methods:

Retrospective review of patients with ALIF (PEEK cage) surgery. Complications were noted. Bone union determined with Bridwell classification. Pre and post-operative X-rays, X-rays at the last follow-up reviewed. Anterior-posterior disc space height, segmental lordosis at the ALIF levels, lordosis of global lumbar columna measured.

Results:

56 patients (M:25, F:31) and 80 ALIF cages were reviewed. The respective median age of surgery and follow-up duration(months) for these subgroups were; 47(37-54) / 14(12-24), 45(40-52) / 22(14-27), 57(51-62) / 17(16-25). The number of complications associated with the anterior approach were 9/56 or 16,0%. Bridwell fusion status were; 1 in 72 cages, 2 in 6 cages and 4 in 2 cages. The anterior disc space height and posterior disc space height L3/L4, L4/L5, L5/S1 significantly increased from preoperatively to immediately postoperatively and compared to the distance at last follow up. The anterior disc space height and posterior disc space height L4/L5, L5/S1 decreased significantly from immediately postoperatively to last follow-up. In L4/L5, the decrease in posterior disc space height from immediately postoperatively to last follow up was insignificant. Only for the L5/S1 level did the segmental lordosis increase significantly from preoperatively to immediately postoperatively and compared to the angle at last follow-up. No significant changes were noted in the lordosis of global lumbar columna measurements.

Conclusions:

The use of ALIF (PEEK cage) with posterior fixation resulted in very low non-union rate (2,5%). The approach related complications are comparable to the literature.

Background

Anterior lumbar interbody fusion (ALIF) is a well-established treatment. The retroperitoneal approach

used for ALIF enables removal of all disc material and a release of the anterior structures enabling restoration of the height of the intervertebral space and sagital balance. The ALIF cage and a posterior pedicle screw system combination create a stable situation for bony union. There are specific complications associated with the ALIF approach: relaxation of the rectus muscle, vessel lesions, ureteral damage, retrograde ejaculation etc. [1]. However, one specific advantage of ALIF combined with posterolateral fusion is the high union rate. Non-union of the bone graft is only observed in on average 5% of cases [2, 3]. Combined with percutaneous posterior stabilization, the risk of posterior paravertebral musculature damage and dural tear is minimized[9]. Using poly-ether-ether-ketone (PEEK) cages for ALIF procedure takes advantage of the relative radiolucency of PEEK cages which eases the observation of anterior bone graft healing. PEEK cages have elasticity closer to bone than titanium and shows less subsidence - maybe at the cost of lower fusion rates and osteolysis.

This study reports on the use of a PEEK cage for ALIF (SynCage Evolution) at Aalborg University Hospital from 2014 to 2021 with emphasis on the pre- and postoperative radiological parameters and complications associated with the use of SynCage Evolution or attributed to the retroperitoneal approach.

Methods

We retrospectively reviewed 56 cases of ALIF where SynCage Evolution was used between 2014 and 2020. In this period, SynCage Evolution was the only anterior cage used.

All Danish patients have a unique personal identification number. Searching the national Danish registry resulted in a list of patients identified with their unique personal identifier. 56 patients fulfilled the criteria. The patient records were scrutinized for complications during surgery, in the perioperative period and through the 1-year outpatient control or to the last follow-up, whichever was later. Likewise, radiographs in the picture archiving and communication system (PACS) were reviewed and the radiographic measurements were recorded. The search for complications and radiograph measurements were recorded by the same unbiased observer (AD).

In all cases, the ALIF was combined with a posterior instrumented fusion performed as either a traditional open posterior approach (circumferential fusion, 360 degree) or using a percutaneous minimal invasive approach (270-degree fusion). In the former, bone graft was placed posterolaterally between the transvers processes. If necessary, decompression of the spinal canal was performed. In the latter, bone graft wasn't used posteriorly and decompression was only indirect by the ALIF procedure. If decompression were necessary and couldn't be performed by indirect decompression (anteriorly), a traditional pedicle screw system was used combined with posterior decompression – otherwise a percutaneous pedicle screw system was used. Up to three levels from L3-S1 were fused. The inclusion criteria were 1) ALIF procedure with SynCage Evolution at Aalborg University Hospital 2014–2020, 2) patients older than 18 years of age with back and/or leg pain, 3) no effect of conservative treatment for at least a duration of 3 months before the surgical procedure, 4) a diagnosis of degenerative disc disease or spondylolisthesis grade 1 or 2 (Meyerdings grading) or nonunion after an earlier attempt of posterolateral fusion (computed tomography(CT)/magnetic resonance imaging(MRI) and digital radiography). The exclusion criteria were 1) follow-up less than 1 year postoperatively, 2) inadequate or missing radiography, 3) osteotomy procedure at the lumbar spine, 4) patients with a medical condition affecting bone healing.

Firstly, anterior retroperitoneal approach was used for ALIF through a lateral paramedian incision on the left side with retraction of the rectus musculature either medially or laterally. The transverse fascia was incised and the retroperitoneal space was opened. After blunt dissection, the L5/S1 disc was approached between the iliac vessels. The L3/L4 and L4/L5 disc space was approached from the left side with retraction of the vessels medially. In all cases, the SynFrame® retractor was used. The disc space was opened with a rectangular incision and a total discectomy was performed. The endplates were prepared until punctiform bleeding from the endplates was observed. If necessary, a posterior release with resection of some or the whole of the posterior longitudinal ligament was undertaken. After sizing, the SynCage Evolution was packed with bone graft either allo-, autograft or a combination. The cage was then inserted under fluoroscopy control. Afterwards, all patients underwent posterior fixation with different pedicle screw systems. In 30 patients a percutaneous pedicle screw system was used – Viper 24 (DePuy Synthes) and Revolve 6 (Globus Medical). In the last 26 patients Expedium – DePuy Synthes(1), Legacy – Medtronic (1), Solera – Medtronic (1), Vitality – Zimmer Biomet (7) and XIA – Stryker (16) were used in a standard fashion.

Preoperative, immediately postoperative and at the least a 1-year radiographic control was undertaken. The radiographic control included anterior and lateral standing digital radiographs of the lumbar spine. On the digital radiographs, the following were measured at the 3 points in time indicated above: lordosis from the upper endplate of L1 to the endplate of S1, segmental lordosis at the ALIF levels from the upper endplate of the cranial level to the lower endplate of the caudal level with the obvious exception of the L5/S1 level, anterior and posterior disc space height according to Dabbs criteria [4, 5], subsidence and endplate fracture, assessment of fusion according to the criteria of Bridwell [6], listhesis grade according to Meyerding, and signs of adjacent level disease. To account for magnification differences, the length of the upper endplate of L3 from the anterior to the posterior corner was measured on each of the three radiographs. Based on this, a magnification factor could be calculated.

The data were registered in an Excel sheet and later imported into RStudio, R version 4.0.2. The variables are presented as mean and standard deviation (SD) or median and range. The significance level was set at p <

1. Non-parametric statistical analysis of the different outcomes was undertaken using Wilcoxon or Kruskal-Wallis rank sum test. Only base R functions were used. Tables were constructed using the gtsummary package and the tbl_summary function.

Results

See Table 1 for demographics, diagnosis, and other key figures. 80 cages inserted from L3 to S1: 7 at L3/L4, 34 at L4/L5 and 39 at L5/S1. SynCage Evolution cages with footprint medium or large used in most cases and a few with footprint small. The height of cages varied between 9-19mm and the built-in lordosis from 6°-19°.

Table 1
Demographics and Key Figures Syncage Patients

Demographics and Key Figures Syncage Patients			
Characteristic	**Discdeg. N = 33**[1]	**Listh. N = 16**[1]	**Nonunion N = 7**[1]
Age_Surgery	47(37–54)	45(40–52)	57(51–62)
Gender			
Female	20(61)	10(62)	1(14)
Male	13(39)	6(38)	6(86)
Degree_Fusion			
270	25(76)	6(38)	0(0)
360	8(24)	10(62)	7(100)
Cage_Numbers			
1	18(55)	12(75)	6(86)
2	12(36)	3(19)	1(14)
3	3(9.1)	1(6.2)	0(0)
Follow_Up_M	14(12–24)	22(14–27)	17(16–25)
[1]Median (IQR); N(%)			

Spondylolisthesis classified as isthmic in all 16 cases and graded as Meyerding 1 in 5 cases and as 2 in 11 cases. Post-operatively, one patient had a non-union at two levels. This patient continued to use non-steroidal anti- inflammatory drugs (NSAIDs) during first year after surgery – contradictory to the given advice. The patient got

reoperated with a posterior approach by insertion of TLIF cages and bone graft after removal of as much as possible of the two SynCage Evolution cages. These were the only complications directly associated with SynCage Evolution. The non-union rate was 1.8 percent of patients (1/56) or 2.5 percent of cages (2/80).

Bridwell fusion status was classified as 1 in 72 cases (cages) (90%) and as 2 in 6 cases (7.5%) and as 4 (definitely a non-union) in the 2 above mentioned cases (2.5%).

There were seven peri-operative complications in 7 patients, three of which required reoperation.

Complications due to anterior approach (intraoperatively) were 3 venous lesions which were sutured immediately and caused minimal bleeding. In two patients, one pedicle screw was misplaced causing radicular pain and necessitating a second operation a few days after initial surgery (2/56 patients (3.6%) and 2/272 pedicle screws (0.7%)). It was possible to correctly place the two screws at the second operation. The two misplaced screws missed medially and didn't cause muscle weakness or paralysis. There was one postoperative renal dysfunction registered – normalized with fluid therapy after a few days. Lastly, there was one rupture of the rectus abdominis and transverse fascia which needed mesh augmentation.

There were additionally sixteen complications in 16 patients beyond the peri-operative period and through the follow-up period. One loose pedicle screw was removed. One superficial infection of the anterior incision was treated successfully with debridement and antibiotics. Four relaxations/paresis of the left rectus abdominis musculature were registered. One posterior deep infection was treated successfully with removal of the pedicle screws and rods on one side and debridement and antibiotics for 6 weeks. In 7 cases, the posterior instrumentation was removed after 1 year because of discomfort related to the posterior instrumentation. These reoperations weren't indicated because of implant loosening/failure, non-union or infection. The removal of the posterior instrumentation didn't change the complaints of patients and we don't consider this as a complication. Two adjacent level degenerations were registered and treated with fusion ± decompression.

The magnification factor from preoperatively to immediately postoperatively was mean/SD 0,68/0,35 and from preoperatively to last follow-up 0,89/0,32.

The height changes and changes in segmental lordosis are shown in Table 2 to Table 5. The number of unknown (= missing) or missing in Tables 2 to 5 is a result of the fact that obviously not all 56 patients were fused on all 3 levels – only 80 cages were inserted in the 56 patients.

Table 2
Changes in intervertebral/disc height level by level (Dabbs method)

Height Changes All levels, 80 cages			
Characteristic	N = 56[1]	N = 56[1]	N = 56[1]
Ant. Height Change L3-L4 Preop to immediately Postop*	10.24(4.00)[49]		
Ant. Height Change L3-L4 Preop to last Postop*	9.3(5.3)[49]		
Ant. Height Change L3-L4 immediately Postop to last Postop	-0.97(1.80)[49]		
Post. Height Change L3-L4 Preop to immediately Postop*	4.34(2.11)[49]		
Post. Height Change L3-L4 Preop to last Postop*	3.94(3.92)[49]		
Post. Height Change L3-L4 immediately Postop to last Postop	-0.40(2.64)[49]		
Ant. Height Change L4-L5 Preop to immediately Postop**		9.9(5.8)[22]	
Ant. Height Change L4-L5 Preop to last Postop**		8.0(6.0)[22]	
Ant. Height Change L4-L5 immediately Postop to last Postop**		-1.91(2.60)[22]	
Post. Height Change L4-L5 Preop to immediately Postop**		4.8(3.5)[22]	
Post. Height Change L4-L5 Preop to last Postop**		4.1(3.7)[22]	
Post. Height Change L4-L5 immediately Postop to last Postop		-0.70(2.28)[22]	
Ant. Height Change L5-S1 Preop to immediately Postop**			10.4(6.8)[17]
Ant. Height Change L5-S1 Preop to last Postop**			8.4(6.0)[17]
Ant. Height Change L5-S1 immediately Postop to last Postop**			-2.0(3.3)[17]
Post. Height Change L5-S1 Preop to immediately Postop**			4.56(3.46)[17]
Post. Height Change L5-S1 Preop to last Postop**			3.22(2.94)[17]
Post. Height Change L5-S1 immediately Postop to last Postop**			-1.33(2.38)[17]

[1]Mean (SD)[N missing]

All Heights increasing or (decreasing) significantly from preop to immediately Postop to last follow-up are marked with * ($p < 0.05$* or $p < 0.001$**) Significant decreases only from immediately Postop to last follow-up.Wilcoxon rank sum test.

Table 3
Changes in segmental Lordosis level by level.

Changes in Lordosis All Levels			
Characteristic	**N = 56**[1]	**N = 56**[1]	**N = 56**[1]
Change in segmental Lordosis L3-L4 Preop to immediately Postop	-2.1(7.0)[49]		
Change in segmental Lordosis L3-L4 Preop to last Postop	-1,6(4.8)[49]		
Change in segmental Lordosis L3-L4 immediately Postop to last Postop	-0.5(5.8)[49]		
Change in segmental Lordosis L4-L5 Preop to immediately Postop		1.4(6.0)[22]	
Change in segmental Lordosis L4-L5 Preop to last Postop		0(8)[22]	
Change in segmental Lordosis L4-L5 immediately Postop to last Postop		1.3(5.5)[22]	
Change in segmental Lordosis L5-S1 Preop to immediately Postop			5(9)[17]
Change in segmental Lordosis L5-S1 Preop to last Postop			4(8)[17]
Change in segmental Lordosis L5-S1 immediately Postop to last Postop			0.6(6.2)[17]

[1]Mean (SD)[N missing]

Table 4
Changes in anterior and posterior intervertebral distance all levels grouped together (Dabbs Method)

	Change in Ant. Inter-vertebral Distance			**Change in Post. Inter-vertebral Distance**		
Characteristic	**Last Follow-Up, N = 168**[1]	**Preop, N = 168**[1]	**p-value**[2]	**Last Follow-Up, N = 168**[1]	**Preop, N = 168**[1]	**p-value**[2]
Syncage_Ant_Height	16(13–20)	9(7–10)	**< 0.001**			
Unknown	88	88				
Syncage_Post_Height				7.40(5.77–10.17)	4.30(3.50–5.40)	**< 0.001**
Unknown				88	88	

[1]Median(IQR)

[2]Wilcoxon rank sum test

Table 5
Changes in segmental Lordosis all levels grouped together

	Change in Lordosis Pre- to immediately Postop			Change in Lordosis Pre- to last Postop		
Characteristic	**Immediately Postop, N = 168**[1]	**Preop, N = 168**[1]	**p-value**[2]	**Last follow-up, N = 168**[1]	**Preop, N = 168**[1]	**p-value**[2]
Segmental_Lordosis_Preop_to_immediately_Postop	23(17–29)	19(15–27)	0.068			
Unkown	88	88				
Segmental_Lordosis_Preop_to_Last_Follow_Up				24(16–27)	19(15–27)	0.13
Unkown				88	88	

[1]Median(IQR)

[2]Wilcoxon Rank Sum Test

Tables 2 and 3. So while there potentially were 168 levels (3 x 56), only 80 were fused. This results in 88 unknown (168 – 80) in Tables 4 and 5. The anterior and posterior intervertebral distance L3/L4 significantly increased from preoperatively to immediately postoperatively and compared to the distance at last follow up ($p < 0.05$) but not from immediately postoperatively to last follow-up. The anterior and posterior intervertebral distance L4/L5 increased significantly from preoperatively to immediately postoperatively and compared to last follow up ($p < 0.001$). The anterior distance L4/L5 decreased significantly from immediately postoperatively to last follow-up ($p < 0.001$) but the posterior intervertebral distance didn't ($p = 0.09$). The anterior and posterior intervertebral distance L5/S1 increased significantly preoperatively to immediately postoperatively and at last follow up and decreased significantly from immediately postoperatively to last follow-up ($p \leq 0.001$).

Only for the L5/S1 level did the segmental lordosis increase significantly from preoperatively to immediately postoperatively and compared to the angle at last follow-up ($p \leq 0.005$). This was mainly caused by a significant increase in lordosis for the patients with degenerative disease compared to the two other diagnostic categories ($p = 0.03$).

Comparing percutaneous posterior instrumentation to traditional pedicle screw systems, we weren't able to show any significant differences neither for the changes in intervertebral distances nor for the changes in segmental lordosis.

The difference in global lordosis from preoperatively (mean/SD 47.7/12.8) to last follow-up was mean/SD -0.53/7,8 (non-significantly decreased) – in 17 patients this distance couldn't be measured on the available radiographs at the last follow-up.

Discussion

This study corroborates the low number of non-unions after ALIF registered in other studies [3, 7, 8]. This may be attributed to the wide footprint of the ALIF cage and the complete removal of disc material which is only possible with the anterior approach.

The number of complications associated with the anterior approach were 9/56 or 16,0%. The 5% rate of venous lesions is comparable to other studies [9]. In one patient with a very thin muscle fascia, it was almost unavoidable that the fascia had to be augmented with a mesh. We didn't register ureter damage or retrograde ejaculation. The relaxation/paresis of the rectus abdominis is frequently seen after a retroperitoneal approach via the lateral paramedian approach and didn't result in any reoperations [10] – surprisingly this complication is often not included in the list of complications after ALIF. The number of complications associated with the anterior approach is comparable to the literature [1]. We didn't encounter any nerve damage caused by the anterior approach or the cage insertion. Reported complication rates are highly variable across studies from 14.5–38% [1] - probably reflecting the retrospective nature of most studies as well as our study.

The two medially-oriented screws which revised a few days after initial surgery caused radicular pain for a prolonged period. Before removal of the posterior instrumentation in the above mentioned 7 cases, MRI and CT was undertaken. Fusion of the anterior graft was confirmed; implant loosening and breakage were ruled out. The posterior complication rate can then be calculated as 4/56 or 7.1%.

This study showed that the use of PEEK anterior cages results in a lasting and important increase in disc height/intervertebral distance both posteriorly and anteriorly at all levels. This was highly significant when all cages were grouped together. This must improve foraminal height and supports indirect decompression. Some of the increase in intervertebral distance is lost in the first year after surgery. However, the amount of subsidence is low and the resulting increase remains statistically significant. PEEK cages have an elastic modulus nearer bone than titanium implants. Studies showed less subsidence for the PEEK cages compared to titanium [7, 11].

The global lordosis was unchanged. However, these patients weren't in need of deformity surgery. The mean lordosis was within reasonable ranges preoperatively. Only for the L5/S1 level did the segmental lordosis change (increase) significantly. This is mainly explained by a significant increase for the degenerative group and to a lesser extent for the spondylolisthesis group. When all levels were grouped together the increase was almost significant from preoperatively to immediately postoperatively and a tendency was also evident at last follow-up. The non-union cases with prior posterior surgery were almost unchanged after surgery. Any increase in lordosis requires that the cages chosen will increase the lordosis – this comes at a price. All other things being equal, a cage with more lordosis and without screw fixation will be more prone to an anterior translation. Secondly, the amount of lordosis which can be achieved depends on the amount of release which is possible at the level being treated.Percutaneous pedicle screw systems functioned as well as the traditional pedicle screw systems when posterior decompression was unnecessary. The paravertebral musculature and surgical trauma can be minimized this way [12].

The limitations are the retrospective nature of the study and the lack of patient reported outcomes. Most other studies of ALIF cages are on the same level of evidence as our study. However, the randomized controlled trials often don't report the radiographic results in detail [13]. The strength of our study is a precise measurement of the radiographic results of ALIF with PEEK cages. This made possible by the advent of digital radiography and helped further by the radiolucency of the PEEK cages.

Conclusions

The use of a PEEK cage SynCage Evolution with posterior fixation resulted in a very low nonunion rate of 2.5%. The approach related complications are comparable to the literature. The intervertebral height measured according to Dabbs increased highly significantly both anteriorly and posteriorly supporting indirect decompression. The mean subsidence was 1-2mm in the first year after surgery depending on the level. A subsidence rate of 1–2 mm probably has no clinical relevance as the increase in height was still statistically significant at last follow-up. The segmental lordosis increased significantly at the L5/S1 level but was unchanged at the levels L3/L4 and L4/L5.

Grouped together, lordosis tended to increase.

Abbreviations

Anterior lumbar interbody fusion
ALIF
poly-ether-ether-ketone
PEEK
computed tomography
CT
magnetic resonance imaging
MRI
non-steroidal anti- inflammatory drugs
NSAIDs
picture archiving and communication system
PACS
standard deviation
SD

Declarations

Ethics approval and consent to participate: This study(project ID-number: *2021-117*) had the necessary approvals from Region Nordjylland and Aalborg University Hospital as *kvalitetsprojekt.*

Consent for publication: All authors consented for submitting the paper to BMC Musculoskeletal Disorders.

Availability of data and material: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors have no other conflict of interest to declare except the funding.

Funding: This study had been funded by Johnson and Johnson. The role of Johnson and Johnson was to fund the study in order to examine overall treatment results after ALIF surgery. Johnson and Johnson had no other role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contributions: All authors(AD, RT, JK, SPE) contributed to the study conception and design. Material preparation, data collection and analysis were performed by all authors(AD, RT, JK, SPE). The first draft of the manuscript was written by SPE and revised by AD. All authors(AD, RT, JK, SPE) commented on previous versions of the manuscript. All authors(AD, RT, JK, SPE) approved the final manuscript.

Acknowledgements: Not Applicable.

References

1. Mortazavi A, Mulalem W, Dowlati E, et al. Anterior lumbar interbody fusion: single institutional review of complications and associated variables. Spine J. 2021;21:1–9. doi:10.1016/j.spinee.2021. 09.010.
2. Formica M, Quarto E, Zanirato A, et al. ALIF in the correction of spinal sagital misalignment. A systematic review of literature. Eur Spine J. 2021;30:50–62. doi:10.1007/s00586-020-06598-y.
3. Ni J, Zheng Y, Liu N, et al. Radiological evaluation of anterior fusion using PEEK cages with adjacent vertebral autograft in spinal deformity long fusion surgeries. Eur Spine J. 2015;24:791–9. doi:10.1007/s00586-014-3745-5.
4. Dabbs VM, Dabbs LG. Correlation between disc height narrowing and low back pain. Spine. 1990;15:1366–9. doi:10.1097/00007632-199012000-00026.

5. Abdollah V, Parent EC, Battie MC. Reliability and validity of lumbar disc height quantification methods using magnetic resonance images. Biomed Tech. 2019;64:111–7. doi:10.1515/bmt-2017-0086.
6. Eck KR, Lenke LG, Bridwell KH, et al. Radiographic assessment of anterior titanium mesh cages. Spinal Disord. 2000;13:501–9. doi:10.1097/00002517-200012000-00006.
7. Verma R, Virk S, Qureshi S. Interbody fusion in the lumbar spine: A review. HSSJ. 2020;16:162–7. doi:10.1007/s11420-019-09737-4.
8. Norotte G, Barrios C. Clinical and radiological outcomes after stand-alone ALIF for single L5-S1 degenerative discopathy using a PEK cage filled with hydroxyapatite nanoparticles without bone graft. Clin Neurolog Neurosurg. 2018;168:24–9. doi:10.1016/j.clineuro.2018.01.037.
9. Feely A, Feely I, Clesham K, et al. Is there a variance in complication types associated with ALIF approaches? A systematic review. Acta Neurochir. 2021;163:2991–3004. doi:10.1007/s00701-021-05000-0.
10. Yamada M, Maruta K, Shioriji Y, et al. Atrophy of the abdominal wall muscles after extraperitoneal approach to the aorta. J Vasc Surg. 2003;38:346–53. doi:10.1016/s0741-5214(03)00119-8.
11. Rao PJ, Phan K, Giang G, et al. Subsidence following anterior lumbar interbody fusion (ALIF): a prospective study. J Spine Surg. 2017;3:168–75. doi:10.21037/jss.2017.05.03.
12. Gang R, Eiskjaer SP, Kaspersen J, et al. Microdialysis of paraspinal muscle in healthy volunteers and patients underwent posterior lumbar fusion surgery. Eur Spine J. 2009;18:1604–9. doi:10.1007/s00586-009-1021-x.
13. Christensen FB, Hansen ES, Eiskjaer S, et al. Circumferential lumbar spinal fusion with Brantigan cage versus posterolateral fusion with titanium Cotrel-Dubousset instrumentation: a prospective, randomized clinical study of 146 patients. Spine. 2002;27:2674–83. doi:10.1097/00007632-200212010-00006.