fortune Journals

Research Article

JOURNAL OF SPINE RESEARCH AND SURGERY

ISSN: 2687-8046

Anterior Lumbar Interbody Fusion (ALIF): Complications and radiological outcomes

Ari Demirel[1], Renata Terzic[1], Jon Kaspersen[1], Efe Levent Aras[1], Søren Peter Eiskjær[1*]

Abstract

Introduction: Anterior lumbar interbody fusion (ALIF) is a well-established treatment. Using poly-ether-ether-ketone (PEEK) cages for ALIF procedure take advantage of the relative radiolucency of PEEK cages .The goal of this study was to determine the radiological outcomes and complications after ALIF surgery.

Materials & 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 and global lumbar lordosis were 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 the 3 subgroups were as follows: 47(37-54) /14(12-24) (disc degeneration), 45(40-52) /22(14-27) (listhesis), 57(51-62) /17(16-25) (non-union). Number of complications associated with the anterior approach was 9/56 or 16%. Bridwell fusion status was classified as 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. 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.

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.

Keywords: ALIF, PEEK Cage, Disc degeneration, Fusion status

Abbrevations: 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**

Introduction

Lumbar interbody fusion is a well established treatment for several spinal disorders - especially degenerative pathologies but also for the treatment of spinal fractures, infections and metastases. Anterior lumbar interbody fusion (ALIF) has shown its worth for patients with discogenic low back

Affiliation:

[1]Aalborg University Hospital, Orthopaedics Department-Spine Section, Aalborg/Denmark

***Corresponding author:**
Søren Peter Eiskjær, Aalborg University Hospital, Orthopaedics Department-Spine Section, Aalborg/Denmark.

Citation: Ari Demirel, Renata Terzic, Jon Kaspersen, Efe Levent Aras, Søren Peter Eiskjær. Anterior Lumbar Interbody Fusion(ALIF): Complications and radiological outcomes. Journal of Spine Research and Surgery 5 (2023): 58-64.

Received: June 10, 2023
Accepted: June 19, 2023
Published: July 04, 2023

Demirel A, et al., J Spine Res Surg 2023
DOI:10.26502/fjsrs0059

pain, spinal stenosis and in patients with sagital imbalance. The retroperitoneal approach used for ALIF enables total removal of all disc material and a release of the anterior structures with a concomitant restoration of the height of the intervertebral space by direct implant insertion. The ALIF cage and a posterior pedicle screw system combination create a stable situation for high fusion rates[1]. There are specific complications associated with the ALIF approach: surgical site infections, neurological complications, vascular complications, and urinary tract infections[2]. Despite the complications, high union rate is the specific advantage of ALIF in combination with with posterolateral fusion[3]. Moreover, there are previous studies in the literature reporting low hardware failure in the long term[4].

Different materials have been utilized for the ALIF procedure such as titanium and poly-ether-ether-ketone (PEEK)[5]. Using PEEK cages for ALIF procedure takes advantage of the relative radiolucency of the peek cages which facilitates the observation of the bony healing inside the cages. Moreover, PEEK cages have a similar elasticity to bone which compared to titanium results in a decrease in the amount of cage subsidence[6].

To the best of our knowledge, there are limited number of reports regarding the complications and radiological outcomes related to ALIF surgery with PEEK cage. Therefore, the aim of this study was to report the complications and radiological outcomes of patients treated with ALIF using a specific PEEK cage (SynCage Evolution).

Materials & Methods

We retrospectively reviewed 56 patients who had ALIF surgery between 2014 and 2020 at Aalborg University Hospital. The patient records were scrutinized for complications together with radiographic images from the picture archiving and communication system (PACS). The identification of complications and radiographic measurements were recorded by the same unbiased observer.

Preoperative and immediately postoperative radiographic images before discharge were obtained plus at the least a 1year radiographic control. The radiographic control included anterior and lateral standing digital radiographs of the lumbar spine. On the digital radiographs, the following were measured: global lordosis measured between the upper endplate of L1 and upper endplate of S1, segmental lordosis measured between the upper endplate and lower endplate of the specific ALIF segment. For the L5/S1 level segmental lordosis was measured between the upper endplate of L5 and upper endplate of S1. Anterior and posterior disc space height were measured according to Dabbs criteria[7,8], subsidence and endplate fracture were identified and fusion were assessed according to the criteria of Bridwell[9]. Listhesis were graded according to Meyerding, and lastly signs of adjacent level disease were identified. In order to avoid miscalculations, a magnification factor was calculated by measuring the length of the upper endplate of L3.

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-value <0,05. Wilcoxon signed rank test and Kruskal Wallis test were applied for non-parametric statistical analysis of the different outcomes. Only base R functions were used. Tables were constructed by using the gtsummary package and the tbl_ summary function.

Surgical Intervention

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 (270degree 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 was not used posteriorly, and decompression was only indirect by the ALIF procedure. If decompression were necessary and could not be performed entirely 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 PEEK cage (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. The diagnoses for the patients were: Disc degeneration, spondylolisthesis and non-union of previous fusion surgery.

An anterior retroperitoneal approach was used for the ALIF procedure 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. The disc space was opened with a rectangular incision and a total discectomy was performed. The endplates were prepared

Demirel A, et al., J Spine Res Surg 2023
DOI:10.26502/fjsrs0059

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 ALIF was packed with bone graft either allo-, autograft or a combination. The cage was then implanted under fluoroscopy control. Footprint medium or large used in most of the cases. The height of cages varied between 9-19mm and the built-in lordosis from 6°-19° 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 and XIA – Stryker (16) were used in a standard fashion.

Results

The baseline characterics and study population (n=56) are shown in Table 1. In total of 80 cages were implanted : 7 at the L3/L4 level, 34 at the L4/L5 level and 39 at the L5/S1 level.

Spondylolisthesis was 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 the 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 ALIF cages. These were the only complications directly associated with ALIF. 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 (rate of misplaced pedicle screws: 2/56 patients (3.6%) and 2/272 pedicle screws (0.7%)). The two misplaced screws were misplaced medially but did not 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 during 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/pareses 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. The removal of the posterior instrumentation due to discomfort did not change the complaints of these patients. Two cases with adjacent level degenerations were registered and treated with fusion ± decompression. The height changes and changes in segmental lordosis are shown in Table 2 to Table 5. The magnification factor from

Table 1: Demographics and Key Figures

Demographics and Key figures Syncage Patients			
Diagnosis	**Discdeg. N=33[1]**	**Listh. N=16[1]**	**Non-union N=7[1]**
Age[1]	47(37–54)	45(40–52)	57(51–62)
Gender[2]			
Female	20(61%)	10(62%)	1(14%)
Male	13(39%)	6(38%)	6(86%)
Degree of fusion[2]			
270	25(76%)	6(38%)	0(0)
360	8(24%)	10(62%)	7(100%)
Cage Numbers[2]			
1	18(55%)	12(75%)	6(86%)
2	12(36%)	3(19%)	1(14%)
3	3(9%)	1(6%)	0(0)
Follow-up months[1]	14(12–24)	22(14–27)	17(16–25)

1Median (IQR); [2]N(%)

Citation: Ari Demirel, Renata Terzic, Jon Kaspersen, Efe Levent Aras, Søren Peter Eiskjær. Anterior Lumbar Interbody Fusion(ALIF): Complications and radiological outcomes. Journal of Spine Research and Surgery 5 (2023): 58-64.

Demirel A, et al., J Spine Res Surg 2023
DOI:10.26502/fjsrs0059

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)		
Ant. Height Change L3-L4 Preop to Last Postop*	9.3(5.3)		
Ant. Height Change L3-L4 Immediately Postop to Last Postop	-0.97(1.80)		
Post. Height Change L3-L4 Preop to Immediately Postop*	4.34(2.11)		
Post. Height Change L3-L4 Preop to Last Postop*	3.94(3.92)		
Post. Height Change L3-L4 Immediately Postop to Last Postop	-0.40(2.64)		
Ant. Height Change L4-L5 Preop to Immediately Postop**		9.9(5.8)	
Ant. Height Change L4-L5 Preop to Last Postop**		8.0(6.0)	
Ant. Height Change L4-L5 Immediately Postop to Last Postop**		-1.91(2.60)	
Post. Height Change L4-L5 Preop to Immediately Postop**		4.8(3.5)	
Post. Height Change L4-L5 Preop to Last Postop**		4.1(3.7)	
Post. Height Change L4-L5 Immediately Postop to Last Postop		-0.70(2.28)	
Ant. Height Change L5-S1 Preop to Immediately Postop**			10.4(6.8)
Ant. Height Change L5-S1 Preop to Last Postop**			8.4(6.0)
Ant. Height Change L5-S1 Immediately Postop to Last Postop**			-2.0(3.3)
Post. Height Change L5-S1 Preop to Immediately Postop**			4.56(3.46)
Post. Height Change L5-S1 Preop to Last Postop**			3.22(2.94)
Post. Height Change L5-S1 Immediately Postop to Last Postop**			-1.33(2.38)

[1]Mean (SD)

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)		
Change in segmental Lordosis L3-L4 Preop to Last Postop	-1,6(4.8)		
Change in segmental Lordosis L3-L4 Immediately Postop to Last Postop	-0.5(5.8)		
Change in segmental Lordosis L4-L5 Preop to Immediately Postop		1.4(6.0)	

[1] Mean (SD)

Citation: Ari Demirel, Renata Terzic, Jon Kaspersen, Efe Levent Aras, Søren Peter Eiskjær. Anterior Lumbar Interbody Fusion(ALIF): Complications and radiological outcomes. Journal of Spine Research and Surgery 5 (2023): 58-64.

Demirel A, et al., J Spine Res Surg 2023
DOI:10.26502/fjsrs0059

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

Change in segmental Lordosis L4-L5 Preop to Last Postop				0(8)		
Change in segmental Lordosis L4-L5 Immediately Postop to Last Postop				1.3(5.5)		
Change in segmental Lordosis L5-S1 Preop to Immediately Postop					5(9)	
Change in segmental Lordosis L5-S1 Preop to Last Postop					4(8)	
Change in segmental Lordosis L5-S1 Immediately Postop to Last Postop					0.6(6.2)	
	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**			
Unkown	88	88				
Syncage-PostHeight				7.40(5.77–10.17)	4.30(3.50–5.40)	**<0.001**
Unkown				88	88	

1Median(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	**Immadiately Postop,N=168[1]**	**Preop, N=168[1]**	**p-value[2]**	**Last follow up, N=168[1]**	**reop,N=168[1]**	**p-value[2]**
Segmental Lordosis Preop to Immediately Postop	23(17–29)	19(15-27)	0.068			
Unknown	88	88				
Segmental Lordosis Preop to Last Follow Up				24(16-27)	19(15-27)	0.13
Unknown				88	88	

1Median(IQR) [2]Wilcoxon Rank Sum Test

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

Surely not all 56 patients were fused on all 3 levels – only 80 cages were implanted in the 56 patients. 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 did not ($p = 0.09$). 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 ($p = 0.03$).

When comparing percutaneous posterior instrumentation to traditional pedicle screw systems, we were not able to show any significant differences neither for the changes in intervertebral distances nor for the changes in segmental lordosis. The mean subsidence was 1-2mm in the first year after surgery depending on the level.

The global lordosis was 47.7° (12.8)1preoperatively and the difference in between the last follow-up and preoperative was -0.53°(7.8)1, which was non-significant. We were unable to measure global lordosis in 17 patients in the last follow- up due to the lack of visualization of L1.

Demirel A, et al., J Spine Res Surg 2023
DOI:10.26502/fjsrs0059

Discussion

In this study, we sought to elucidate the radiological outcomes and complications in patients undergoing an ALIF procedure. We registered a low number of non-unions after ALIF in the current study(1.8% of patients or 2.5% of cages)., which is similar or better compared to other published studies[3,7,8]. Formica et al.[3] reported an overall ALIF fusion rate 94.5% in their systematic review, which was similar to our finding, Increased fusion rates is probably attributed to the wide footprint of the ALIF cage and total removal of all disc material with the anterior approach. There is well- documented evidence in the literature that higher fusion rates correlates with less pain and better functional outcome.

In our cohort analysis we had 4/56 (7%) peri-operative and 5/9 (9%) post-operative complications associated with the anterior approach. There are several reports in the literature demonstrating a wide range of complication rates after ALIF procedure[1,3]. A global complication rate of 13% is reported in a systematic review by Formica et al. after analyzing 21 studies. This is at level with our complication rate. Noretto et al.[9] reported a vascular lesion rate around 5% which is at the same level as the rate in the current study. The venous lesions were sutured immediately and did not result in any long-term complications or increased length of stay in hospital. In contrast to other studies in the literature we have not observed ureter damage, retrograde ejaculation, or nerve damage related to the anterior approach in our study population. In one patient with a very thin muscle fascia, it was almost unavoidable that the fascia had to be augmented with a mesh. The paresis of rectus abdominis is frequently seen after a retroperitoneal approach via the lateral paramedian approach and did not result in any reoperations[10]. Surprisingly this complication is often not included in the list of complications after ALIF. Reported complication rates are highly variable across studies from 17.7–33.3% [1] - probably reflecting the retrospective nature of most studies and heterogeneity of the patients (several different diagnoses).

Minimal invasive surgery (MIS) techniques have become increasingly popular in order to decrease the surgical trauma and enhance patient recovery[15]. However this technique is not complication free and there have been reports of mispositioning of screws and lack of sagittal corrections of lumbal lordosis. Weiss et al.[16] concluded in a recent systematic review of MIS-TLIF study concluded that there are lower complications compared to traditional open techniques, however the majority of complications were screw malposition , radiculitis and incidental durotomy. In our cohort we had a comparable rate of dura lesions and screw malposition (0,7% of all implanted screws).

The two medially-oriented screws revised a few days after initial surgery caused radicular pain for a prolonged period. Before removal of the posterior instrumentation for 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%.

We have demonstrated in our study the use of PEEK anterior cages results in a significant restoration of disc height/ intervertebral distance both posteriorly and anteriorly at all levels, which was statistically significant when all cages were grouped together. Therefore, a significant foraminal height and support were achieved and indirect decompression were evident. Achieved disc height and increased intervertebral distance were marginally decreased in the first year after surgery. However, the amount of subsidence was low and we maintained statistically significant disc height after one year. The low subsidence rate was probably due to the PEEK cages elastic modulus properties, which is more like the elastic modulus of bone in comparison to titanium implants. This is corroborated by several other studies [7,11]. We could not demonstrate significant restoration of global lordosis in our cohort. This was mainly due to the fact that our patient cohort had a reasonable mean global lordosis preoperatively. Moreover, in 17 patients the L1 upper endplate was not visualized on the radiographs making it impossible to measure the global lumbar lordosis. For segmental lordosis, only L5/S1 showed statistical increase. 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 the last follow-up. The non-union cases with prior posterior surgery were almost unchanged after surgery. The built in lordosis of the cage to be used should be chosen cautiously, as all other things being equal, a cage with more lordosis and without screw fixation will be more prone to an anterior translation. Moreover, 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].

There are several limitations of this study. Firstly, the retrospective nature of the study, secondly the lack of patient reported outcomes, which does not allow us to evaluate patients' subjective well-being. Despite the limitations there are several strengths of our study. Firstly, a precise measurement of the radiographic results of ALIF with PEEK cages. This is made possible by the advent of digital radiography and helped further by the radiolucency of the PEEK cages. Secondly, the primary author of the study were not involved in any of the treatment of patients, hopefully reducing the observer bias. Lastly, there is a 100% follow-up

of all patients as the Danish health care system allows us to retrieve all patient data via the unique social security number.

Conclusion

The use of a (PEEK) ALIF cage with posterior fixation resulted in a very low non-union 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 segmental lordosis increased significantly at the L5/S1 level but was unchanged at the levels L3/L4 and L4/L5.

Acknowledgements

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.

Ethics approval and consent to participate:

This study(project ID-number: 2021-117) had the necessary approvals from Region Nord and Aalborg University Hospital (quality assurance project=.

Consent for publication:

All authors consented for submitting the paper to Journal of Spine Research and Surgery.

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.

Conflict of interests:

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

References

1. Mortazavi A, Mulalem W, Dowlati E, et al. Anterior lumbar interbody fusion: single institutional review of complications and associated variables. Spine J 21 (2021): 1-9.
2. Mobbs RJ, Phan K, Malham G, et al. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 1 (2015): 2-18.
3. Formica M, Quarto E, Zanirato A, et al. ALIF in the correction of spinal sagital misalignment. A systematic review of literature. Eur Spine J 30 (2021): 50-62.
4. 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 24 (2015): 791-799.
5. Dabbs VM, Dabbs LG. Correlation between disc height narrowing and low back pain. Spine 15 (1990): 13661369.
6. Abdollah V, Parent EC, Battie MC. Reliability and validity of lumbar disc height quantification methods using magnetic resonance images. Biomed Tech 64 (2019): 111-117.
7. Eck KR, Lenke LG, Bridwell KH, et al. Radiographic assessment of anterior titanium mesh cages. Spinal Disord 13 (2000): 501–509.
8. Verma R, Virk S, Qureshi S. Interbody fusion in the lumbar spine: A review. HSSJ 16 (2020): 162-167.
9. 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. 2 168 (2018): 24-29.
10. Feely A, Feely I, Clesham K, et al. Is there a variance in complication types associated with ALIF approaches? A systematic review. Acta Neurochir 163 (2021): 2991-3004.
11. Yamada M, Maruta K, Shioriji Y, et al. Atrophy of the abdominal wall muscles after extraperitoneal approach to the aorta. J Vasc Surg 38 (2003): 346-353.
12. Rao PJ, Phan K, Giang G, et al. Subsidence following anterior lumbar interbody fusion (ALIF): a prospective study. J Spine Surg 3 (2017): 168-175.
13. 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 18 (2009): 1604-1609.
14. 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 27 (2002): 2674-2683.
15. Hammad A, Wirries A, Ardeshiri A, et al. Open versus minimally invasive TLIF: literature review and metaanalysis. J Orthop Surg Res 14 (2019): 229.
16. Weiss H, Garcia RM, Hopkins B, et al. A Systematic Review of Complications Following Minimally Invasive Spine Surgery Including Transforaminal Lumbar Interbody Fusion. Curr Rev Musculoskelet Med 12 (2019): 328-339.