The influence of cage positioning and cage type on cage migration and fusion rates in patients with monosegmental posterior lumbar interbody fusion and posterior fixation

Alexander Abbushi · Mario Čabraja ·
Ulrich-Wilhelm Thomale · Christian Woiciechowsky ·
Stefan Nikolaus Kroppenstedt

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Abstract In posterior lumbar interbody fusion, cage migrations and lower fusion rates compared to autologous bone graft used in the anterior lumbar interbody fusion procedure are documented. Anatomical and biomechanical data have shown that the cage positioning and cage type seem to play an important role. Therefore, the aim of the present study was to evaluate the impact of cage positioning and cage type on cage migration and fusion. We created a grid system for the endplates to analyze different cage positions. To analyze the influence of the cage type, we compared “closed” box titanium cages with “open” box titanium cages. This study included 40 patients with 80 implanted cages. After pedicle screw fixation, 23 patients were treated with a “closed box” cage and 17 patients with an “open box” cage. The follow-up period averaged 25 months. Twenty cages (25%) showed a migration into one vertebral endplate of <3 mm and four cages (5%) showed a migration of ≥ 3 mm. Cage migration was highest in the medio-medial position (84.6%), followed by the postero-lateral (42.9%), and the postero-medial (16%) cage position. Closed box cages had a significantly higher migration rate than open box cages, but fusion rates did not differ. In conclusion, cage positioning and cage type influence cage migration. The medio-medial cage position showed the highest migration rate. Regarding the cage type, open box cages seem to be associated with lower

migration rates compared to closed box cages. However, the cage type did not influence bone fusion.

Keywords Titanium cage · Cage position · Cage migration · Fusion

Introduction

A frequent cause for implant failure in monosegmental lumbar interbody fusion is cage migration into the vertebral endplates or the spinal canal [5, 8, 9, 15, 16]. This may lead to progressive spinal deformity, neurological deterioration, and non-fusion. The reason for this complication has not completely been researched. To prevent cage migration, the interface between the implant and the vertebral bone must have sufficient strength to resist the large in vivo loading. Biomechanical studies have shown that the strength of this interface varies across the surface of the endplate [11, 17]. Anatomical studies have shown that the density and thickness of the vertebral endplate increase towards the periphery. In summary, biomechanical and anatomical data indicate that the center of an endplate is the weakest part, and the postero-lateral region the strongest [11]. This concept was proven in cadaver studies. Labrom et al. [17] showed that two smaller titanium mesh cages placed postero-laterally in a cadaver spine provided superior construct rigidity in comparison to centrally placed interbody cages.

Furthermore, the contact area between cage and endplate depends on the cage's shape and size. Mostly, it is recommended to use large devices in order to increase the contact area and subsequently increase the failure load and therefore reduce cage migration. For this reason, plasma-pore coating was applied to closed box titanium cages in

A. Abbushi · M. Čabraja · U.-W. Thomale ·
C. Woiciechowsky · S. N. Kroppenstedt (✉)
Department of Neurosurgery,
Charité-Universitätsmedizin Berlin,
Campus Virchow-Klinikum,
Augustenburger Platz 1, 13353 Berlin, Germany
e-mail: skroppen@charite.de

order to increase the surface area of the cage. However, bone growth through the cage is impossible, so that fusion is achieved through an integration of the cage with the endplates, and bone growth between and around the cage. This concept differs from the concept of open box cages, which allows for bone growth through the cages, and which can be packed with morselized graft, e.g., harvested from the removed parts of the facets.

Because of these substantial anatomical and biomechanical findings, it is reasonable to hypothesize that cage migration may depend on cage positioning and cage geometry. However, to our knowledge, no published clinical studies have researched the influence of cage positioning and cage type on migration and fusion in order to verify the biomechanical data. Therefore, we conducted a retrospective study to address these questions.

Methods

Patients

This retrospective study included 40 of 50 patients who had been diagnosed with monosegmental degenerative lumbar spondylolisthesis, and who had undergone a posterior lumbar interbody fusion (PLIF) with pedicle screw fixations between 1 January 2001 and 31 December 2002. Of the patients that were excluded from the study, three patients died because of another illness, two patients were also hospitalized for another disease, two patients did not want to return to our department, and three patients were excluded, because adequate clinical follow-up was not possible. In six out of the ten excluded patients, a ProSpace titanium block cage was implanted and in four patients an OIC titanium cage. Nineteen of the 40 patients were male, and 21 were female. The oldest patient was 79 years old, the youngest was 39 years old. The average age was 64 years. The body mass index (BMI) averaged 27.5 kg/m². Eight of the 40 patients were diagnosed with nicotine abuse (Table 1). No data regarding bone density were obtained from these patients. The patients were divided into two groups in accordance with the implanted intersomatic

Fig. 1 *Left* ProSpace cage manufactured by Aesculap, coated with a plasmapore surface with an electro-microscopic picture of the plasmapore surface. *Right* OIC titanium cage manufactured by Stryker

cages. Seventeen patients had a PLIF with additional pedicle screw fixation using the OIC titanium cage from Stryker and the XIA[®] stabilization system (Stryker, Kalamazoo, USA). Twenty-three patients had a PLIF with additional pedicle screw fixation using the ProSpace titanium block cage from Aesculap and the SOCON[®] stabilization clamping system (B. Braun Aesculap, Tuttlingen, Germany). Both pedicle screw systems resulted in rigid fixation.

Implants

The OIC titanium (Ogival Interbody Cage, titanium Ti6Al45) is an open box titanium cage (Fig. 1), which, in the studied patients, was packed with morselized graft harvested from the removed parts of the facets and the lamina after spinal canal decompression. The ProSpace from Aesculap is a closed box titanium cage, which is covered by a porous titanium coating (Plasmapore[®], Fig. 1). The implanted ProSpace cages were 26 mm long, 9 mm wide, and 7–13 mm high. The implanted OIC cages were 25 mm long, 11 mm wide, and 9–11 mm high. Due to the shape and design of the cages, the surface area available for bone contact for the two different implants cannot exactly be calculated and is not provided by the companies.

Indications and surgery

Before the surgery, each of the patients had been suffering from disabling lower back pain or neurological deficits with a limited walking distance caused by spinal claudication. The symptoms persisted for a minimum of 3 months of continuous specific conservative therapy with muscle strengthening and muscle control training. With regard to clinical and radiological findings, all 40 patients had been diagnosed with monosegmental degenerative spondylolisthesis grade I or II according to the Meyerding grading system. All patients had undergone a laminectomy

Table 1 Demographic data

	Total	ProSpace	OIC	<i>p</i>
Age (years)	64 (39–79)	64 (39–79)	63 (42–75)	0.894
Sex, m/f	19/21	9/14	10/7	0.337
BMI (kg/m ²)	28 (20–40)	28 (20–40)	27 (22–35)	0.358
BMI/M	26 (20–30)	25 (20–30)	27 (22–29)	0.200
BMI/W	29 (24–40)	30 (24–40)	29 (26–35)	0.776
Smoker/non-smoker	8/32	4/19	4/13	0.702

and dorsal pedicle screw fixation in addition to PLIF. Before implanting the cages, the degenerated disc was removed, the endplates were cleaned from cartilaginous layers and prepared carefully with dedicated instruments, i.e., rasps and curettes. Special attention was paid to preserve the vertebral endplates. Because the same surgical team performed the operations and the same instruments were used in both groups to clean the endplates, it can be assumed that the preparation of the endplates was equal. The OIC cages were packed with morselized graft harvested from the removed parts of the facets.

Fusion

Only 2 years after the surgery, we evaluated the bone fusion and the cage position. To this purpose, we took thin section helical computed tomography scans, static lumbar radiographs, and dynamic lumbar flexion–extension radiographs. The computed tomography scans were obtained with a Lightspeed CT made by GE in Milwaukee (slice thickness 0.5 mm, voltage 135 kV, amperage 250 am, rotation time 1.5 s), and were imaged in a three-dimensional manner using the spinal navigation software produced by Brainlab. For the radiographs, a high-potential generator (Revolution XRD, General Electric, Milwaukee, USA) was used. A segment was post-operatively considered to be fused if it met the following three conditions [19]:

- bridging bone between the endplates of the fused vertebral bodies outside the cage, visible in the plain static radiographs and in the thin section helical CT scans,
- no visible radiolucency around a cage, and
- no visible segment instability in the obtained dynamic flexion–extension radiographs, i.e., $\geq 5^\circ$ movement on lateral flexion and extension views.

Cage location and cage migration

To analyze different cage positions, we created a grid system in which the endplate was divided into four parts in the lateral and antero-posterior plain resulting in 16 rectangles. There were six possible cage fields (positions) for each side, because one cage covered two rectangles (Fig. 2). In cases, where a cage was crossing a field, the position of the cage was assigned to the field, which was covered most by the cage. Migration into the vertebral endplate was grouped into <3 or ≥ 3 mm. A migration into one vertebral endplate ≥ 3 mm was considered cage subsidence (Fig. 3, right).

Clinical, radiological, and functional examination

To evaluate the clinical and the functional follow-up, each patient underwent a clinical exam including a neurological examination prior to and 2 years after the surgery, which showed sensitivity deficits, muscle weakness, and the pain-free walking distance. In addition to the clinical findings, the functional status was measured 2 years after the surgery with the Oswestry disability index (ODI) and the visual analog scale (VAS).

Pre-operatively and post-operatively, the lumbar lordosis and the disc heights were measured with plain static radiographs. The percentage of vertebral slip was measured and graded according to the Meyerding grading system, and the intersegmental height was measured by dividing the height of the slipped vertebra through the disc space height. Instability was measured with dynamic lateral flexion–extension radiographs. If the vertebra had moved by more than 4.5 mm or 15%, the segment was considered to be unstable [21].

Fig. 2 *Left* grid system in which the endplate was divided into four parts in the lateral and antero-posterior plain. Six cage fields/positions (postero-lateral, medio-lateral, antero-lateral, postero-medial, medio-medial or antero-medial) are possible on each side, since one cage fills two blocks. *Right* CT scan with overlying grid system showing two cages in a medio-medial location, as classified by the grid system

Fig. 3 Lateral X-ray of a non-migrated OIC cage (*left*). CT scan in sagittal view of a migrated (*subsided*) Prospace cage (*right*)

Results

A comparison of the patient data showed there were no significant demographic differences between the patients who had a ProSpace implanted and the patients who had an OIC cage implanted. Table 1 shows the demographic data of all participating patients. Three patients were operated on levels L3/4, 32 on L4/5, and five patients on L5/S1. There was no difference between the ProSpace and the OIC group ($p = 0.851$) with regard to the distribution of the operated segments. The overall follow-up period was 23 months (ranging from 22 to 28 months). There was no significant difference between the two groups regarding the follow-up time ($p = 0.345$).

Cage location and cage migration

Twenty cages (25%) showed a migration into one of the vertebral endplates of <3 mm and four cages (5%) showed a migration of ≥ 3 mm (Table 2). There was an association between cage position and cage migration ($p < 0.001$). Cage migration was highest in the medio-medial position (84.6%), followed by postero-lateral (42.9%), and the postero-medial (16%) cage position. With regard to the cage type, 20 of 24 migrated cages (83%) were closed box cages and 4 of 24 (17%) were open box cages ($p = 0.002$). Of the four cages that showed a cage migration ≥ 3 mm (subsidence), two cages were located in the medio-medial position and two cages in the postero-medial position. No statistically significant correlation was found either between the pre- and post-operative follow-up lumbar lordosis angles and cage migration ($p = 0.085$ and $p = 0.791$, respectively) or in the pre- and post-operative follow-up segment angles ($p = 0.199$, $p = 0.482$).

Fusion

In accordance with the current definition of fusion, 31 patients showed intervertebral fusion (77.5%). There was no significant difference between the two groups (ProSpace group: 78.3%; OIC group: 76.5%). Nine of 40 patients (ProSpace: 5 patients, OIC: 4 patients) did not show a bridging bone formation from the end of one vertebra to the end of the other vertebra on the outside of the implanted cage. In two of the non-fused patients belonging to the OIC group, there was bone bridging inside the cage. In two of the five non-fused patients belonging to the ProSpace group, lucencies around the cages were visible. In these patients, the cages were located medio-medial. None of the flexion–extension radiograms showed signs of instability after surgery. Nine patients had shown an intersegmental instability before the surgery.

Clinical, radiological, and functional follow-up

The pain-free walking distance increased significantly after surgery in both groups (Table 3). The degree of the spondylolisthesis, lumbar lordosis, and the intersegmental space height did not significantly differ between the two groups before and after surgery (Table 3). In the ODI, 27 patients had a “minimal or moderate disability” (0–39%), and 13 patients had a “severe, crippling, bed bound disability” (40–100%). The VAS showed a mean of 38.5 points out of 100, 2 years after the surgery (ranging from 0 to 80). The two scores have a significant correlation (Spearman’s $\rho = 0.86$). There are no significant differences in the outcomes of the two groups in the ODI and in the VAS evaluation ($p = 0.810$, Mann–Whitney U test). Patients with a cage subsidence or who did not fulfill the

Table 2 Distribution of the 80 implanted cages by cage position, cage migration, and non-fusion

Cage position	Antero-medial	Medio-medial	Postero-medial	Antero-lateral	Medio-lateral	Postero-lateral	Total
Total							
Cage position	3 (3.8%)	13 (16.3%)	45 (56.2%)	1 (1.3%)	4 (5%)	14 (17.5%)	80 (100%)
Cage migration	0	11 (84.6%)	7 (15.6%)	0	0	6 (42.9%)	24 (30%)
No fusion	0	5 (38.5%)	6 (13.3%)	0	2 (50.%)	5 (35.7%)	18 (22.5%)
Closed box (ProSpace)							
Cage position	3 (6.5%)	10 (21.7%)	19 (41.3%)	1 (2.1%)	2 (4.3%)	11 (23.9%)	46 (100%)
Cage migration	0	10 (100%)	4 (21.1%)	0	0	6 (54.5%)	20 (43.5%)
No fusion	0	4 (40%)	2 (10.5%)	0	0	4 (36.4%)	10 (21.7%)
Open box (OIC)							
Cage position	0 (0%)	3 (8.8%)	26 (76.4%)	0 (0%)	2 (5.8%)	3 (8.8%)	34 (100%)
Cage migration	0	1 (33.3%)	3 (11.5%)	0	0	0	4 (11.8%)
No fusion	0	1 (33.3%)	4 (15.4%)	0	2 (100%)	1 (33.3%)	8 (23.5)

Table 3 Walking distance and radiological data

	Before surgery	After surgery	<i>P</i>
Walking distance (m)			
Total	170 (5–900)	3,569 (100–5,000)	<0.001
ProSpace	146 (5–500)	3,755 (100–5,000)	<0.001
OIC	201 (10–900)	3,329 (300–5,000)	<0.001
Olisthesis (%)			
Total	22 (7–44)	6 (0–28)	<0.001
ProSpace	22 (8–44)	7 (0–28)	<0.001
OIC	22 (7–39)	5 (0–27)	<0.001
Lumbar lordosis (°)			
Total	33 (12–58)	36 (15–69)	0.008
ProSpace	34 (12–58)	37 (18–69)	0.027
OIC	31 (15–54)	34 (15–48)	0.139
Slipped vertebra height/disc space height (quotient)			
Total	4.7 (2.3–16.5)	3.7 (2.0–14.0)	<0.001
ProSpace	5.1 (2.7–16.5)	3.9 (2.1–14.0)	0.001
OIC	4.3 (2.3–8.8)	3.5 (2.0–6.4)	0.011

current criteria for a solid bone fusion also did not show significant inferior results than the other patients.

With regard to patient satisfaction, 40 out of 40 patients would retrospectively choose the surgery again as their preferred therapy. Thirty-five patients believe they have a better life quality 2 years after the surgery.

Discussion

Posterior lumbar interbody fusion using interbody devices is an effective and widely used technique for treating degenerative spinal instability. However, major complications such as cage migration into the adjacent vertebral bodies and dislocation into the spinal canal are well-known

complications [5, 8, 9, 15, 16]. Cage migration might result in the loss of lumbar lordosis, a narrowing of the disc space and foraminas, a direct compression of dural sac and the nerve roots, as well as a lower fusion rate. In the event of a cage migration, revision surgery, which is technically challenging, is frequently required [5, 9].

Eck et al. [8] reported that in 14% of patients in whom titanium mesh cages were implanted into the anterior column in combination with dorsal instrumentation subsidence incurred within a 2-year follow-up. In a further study on spondylolisthesis treated with PLIF using BAK cages with a follow-up of more than 2 years, cage migration was seen in 16.7% (subsidence 9.5%, retropulsion 7.2%) of the cases with no additional posterior instrumentation and in 0% of the cases with additional posterior instrumentation [5]. Cage subsidence was diagnosed, if the cage sank into the adjacent vertebral body by 2 mm or more compared with previous radiographs. Cage retropulsion was diagnosed, if cage moved 2 mm or more in a posterior direction compared with previous radiographs. In the present study and after a follow-up of approx. 2 years, 30% of the cages had migrated into the vertebral endplates. Twenty-five percent of the cages had migrated into the vertebral endplates by <3 mm, and 5% of the cages had migrated by ≥3 mm. There was no cage migration into the spinal canal.

There are several factors that can cause cage migration. Patient-related factors such as severe obesity or reduced load-bearing capacity of the vertebral endplates due to low bone mineral density increase the risk for implant migration [18]. The median age of both groups, the BMI, and the distribution of smoker versus non-smoker did not differ in the present study. However, not all possible patient-related factors could be finally excluded, because, for example, the data of this study do not include information about osteoporosis or bone mineral density. These variables have not been measured.

Endplate preparation techniques might also affect cage subsidence. The importance of preserving vertebral bone endplates to prevent cage migration has been emphasized by several authors [14, 16, 18]. Conversely, because preserving the vertebral endplate only presents a minimal mechanical advantage [12], other authors recommend complete removal of the bone endplate to allow for a better fusion [12, 22]. In the present study, vertebral bone endplates were preserved during the endplate preparation.

Another controversial issue concerning cage migration is the cage position. Mapping the structural properties of the lumbosacral vertebral endplates in a human cadaveric model [11] has shown that there is regional rigidity of lumbar and sacral endplates varies significantly. In general, the lumbar and sacral posterior endplate regions are stronger than the anterior ones, and the lumbar lateral regions are stronger than the central ones. The strongest region is located postero-laterally, just in front of the pedicles, with more than twice the strength of the central endplate. In addition, another biomechanical study demonstrated that a dorso-lateral placement of interbody cages in combination with a pedicle screw system results in a 20% higher failure loads than a central cage placement, although the results were not statistically significant [17]. Thus, under in vitro settings, a cage placement in the dorso-lateral regions seems to have the advantage of minimizing subsidence when compared to a central or ventral cage placement.

However, in the clinical setting, it is still not clear which cage position is the best to avoid cage migration in PLIF surgery, because in vivo loads of the lumbosacral spine are complex and biomechanical investigations do not fully reflect the in vivo loading conditions [17].

In the present study, cage migration was highest with a rate of 84.6%, if the cage position was medio-medial. A postero-lateral positioning resulted in the second highest migration rate of 42.9%, and the postero-medial placement migration rate was 15.6%. Only eight cages were placed either antero-laterally, antero-medially, or medio-laterally. There was no migration from these positions. Thus, the present findings concur with the biomechanical studies [11, 17] showing that the central regions are the weakest part of the endplates. Cage placement in this region resulted in the highest migration rate. However, although the biomechanical studies showed that the postero-lateral region is stronger than the postero-medial region, the migration rate in the present study was lower for postero-medial placements. A possible explanation for these findings might be that for postero-lateral placements the facet joints had to be removed, whereas for a postero-medial placement, it is not necessary to completely remove the facet joint. Total facetectomy for decompression and cage insertion purposes is destabilizing, and this destabilization might contribute to

the probability of cage migration. Although no migration was found for anterior cage placements, these positions could not be reliably evaluated due to the low number of cases.

The endplate morphology and the size, shape, and elasticity modulus of cages can also affect cage migration. Deeply concave or other forms of irregularly shaped endplates as well as a small cage size reduce the contact area between the cage and the bone surface. The smaller the surface contact area, the higher the stress on the endplate [7, 10–12, 18]. A cadaveric study demonstrated significant higher failure loads when the cages covered 40% of the endplate surface area opposed to 20% [23]. In the present study, two types of titanium cages were used, an open box cage (OIC titanium) and a plasmapore-coated closed box cage (ProSpace). A comparison of the two different cage types revealed a higher migration rate for the closed box cages (30 vs. 12%). The two types of cages had a similar length (closed box: 26 mm vs. open box: 25 mm) and width (closed box: 9 mm vs. open box: 11 mm). Due to the shape and irregular surface of both cages and the fact that the open box cage was impacted with autologous bone graft, the contact area to the bone face of both cage types could not be reliably evaluated [1]. About the rigidity of fixation of the two pedicle screw systems used, according to the information of the companies, tests have been performed according to ASTM F1717 and ASTM F1798 requirements. The test results of the static compressive bending corpectomy tests are 302 N for the XIA[®] system and 672 N for the SOCON[®] system. The results for the fatigue compressive bending corpectomy tests are 240 N for the XIA[®] system and 301 N for the SOCON[®] system. Taken together, both pedicle screw systems resulted in rigid fixation and according to biomechanical test results the rigidity of the SOCON[®] system is higher than the rigidity of the XIA[®] system. Theoretically, a lower rate of cage migration can be expected when using a more rigid pedicle screw system. Thus, the higher rate of cage migration seen with the closed cages cannot be explained by the use a less rigid pedicle screw system. Thus, the reason for the different migration rates remains unclear.

Another major consideration for PLIF, in addition to cage migration, is the interbody bone fusion rate. In reported series, the bone fusion rate of PLIF using cages impacted with autologous bone ranged between 86 and 100% [2–4, 6, 13, 20, 24]. In the present study, two different titanium cages were used. The implanted closed box titanium cages are covered by a porous titanium coating (Plasmapore[®]). This porous coating creates an osteoconductive surface. In contrary to the implanted open box titanium cages, bone can grow into the cage surface. Thus, “fusion” can take place without bony bridging from one endplate to the other. On the other hand, a potential

disadvantage might be that the cage cannot be packed with bone [1]. In the present study, the fusion rates between both groups did not differ significantly (total: 77.5%; closed box: 78.3% vs. open box: 76.5%), but are lower than those reported. The different fusion rates might be explained by several factors. In contrast to other studies, no additional bone graft, osteoconductive or osteoinductive materials were put in the interbody space in the present study, and for fusion, bridging bone formation around the cages extending to the vertebral cortical margin in the intervertebral space was required. In order to compare the fusion rate of both cages used in the present study, i.e., closed box versus open box cages impacted with autologous bone, bone fusion density inside the cage itself was not considered as fusion. Also, the cage position might influence fusion rates. In the study of Kim et al. [13], it was found that intervertebral bone fusion after PLIF occurred only inside the cages (rectangular carbon fiber cages impacted with autologous laminar bone chips), and in the posterior intervertebral space. There was no definite bone fusion mass in the anterior intervertebral space. Thus, for a successful bone fusion, beside complete exposure of the vertebral endplates, an anterior placement of the cages for creating sufficient posterior intervertebral space for bone growth has been recommended [13]. In the present study, 73.8% of the cages were placed posteriorly, which might also explain the lower fusion rate. In two patients, the cages were placed in an anterior position, and the fusion rate was 100%. Due to the low number of cages, it is not possible to come to a reliable conclusion. The present study has also shown that cage migration did not significantly influence fusion rates. However, using the open or closed box cage, cage placement in the postero-medial position showed the lowest migration and highest fusion rate.

In this study, regarding the newly introduced grid grading system, we believe that it could become an efficient research tool to investigate the influence of cage position on cage migration and interbody fusion. Based on this study, further clinical studies with larger patient populations should be undertaken to address the possible additional impact of either patient-related variables such as osteoporosis or cage-related variables such as cage design or cage material on cage migration in detail.

Conclusions

Our data show that the cage position has an influence on cage migration. The medio-medial cage position showed the highest migration rate. Regarding the cage type, the presently used titanium open box cage seems to be associated with lower migration rates compared to the closed box cage. Cage migration and cage type show no

significant influence on bone fusion. The lowest migration and highest fusion rate were seen in the postero-medial position. Thus, we would suggest a posterior medial cage placement for PLIF. In the present study, the number of cages placed in an anterior position is too low to make a definitive conclusion about migration and fusion rates.

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