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ORIGINAL ARTICLE

'Rebound Phenomenon' – a Cause of Early Cage Back-out in Transforaminal Lumbar Interbody Fusion Surgery: Insights from Case Series of 1545 Patients

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Abstract

Study Design Retrospective case–control study.

Purpose To assess the various possible causative factors of cage retropulsion and the management strategies to be utilized for cage back-out following open transforaminal lumbar interbody fusion(TLIF) surgery in degenerative lumbar spine pathology.

Overview of Literature Factors like elderly age, low body mass index, placement of undersized cages, bony endplate damage and improper cage placement are several risk factors for cage back-out following TLIF surgeries. Despite this, lacunae remains regarding the other factors contributing to cage migration.

Methods We performed a retrospective analysis of prospectively collected data from patients who underwent TLIF surgery for degenerative disc disease with stenosis or instability between 2011 and 2024. We identified patients who presented with cage back-out and analysed the characteristics of these patients to elucidate the possible causes of cage retropulsion.

Results Among 1545 patients who underwent TLIF surgery, 16 patients (1%) experienced cage back-out. This included 11 single-level fusions and five two-level fusions, predominantly at the L4-L5 level. Eight patients had early cage back-out within 3 months, while four had back-out after 1 year. Eleven cases involved posterior migration, one case each for posterolateral and anterolateral migration, respectively. Twelve patients were managed conservatively, whereas four required revision surgery. We identified inadequate disc space preparation and "rebound phenomenon" as significant risk factors for early back-out, necessitating revision for optimal outcomes. Late back-out may benefit from conservative management due to the potential for partial union, with surgery reserved for refractory cases or those with neurological symptoms.

Conclusion Cage migration is a recognized and severe complication in TLIF surgery, potentially impacting patient outcomes. Our study found that intraoperative rebound phenomenon and inadequate discectomy or endplate preparation were significant risk factors for cage migration. Surgeons should consider these factors and patient-specific variables to optimize clinical outcomes in TLIF patients.

Keywords Interbody fusion · Transforaminal · Cage back-out · Complication · Rebound phenomenon

Introduction

Interbody fusion is considered the gold standard treatment strategy in the management of lumbar spine instability. Various techniques have evolved to establish the surgical goal of a solid bony fusion, and transforaminal lumbar interbody fusion (TLIF) is one of the most commonly performed and preferred surgical techniques globally [1, 2]. The key components of the surgery include direct decompression of the spinal canal and placement of an interbody device/cage. The interbody cage provides immediate mechanical stability to the affected segment, and distributes the load across

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the endplates, with cancellous bone grafts, enhancing the fusion process [3–6].

In TLIF, effective end plate preparation is the key to optimal cage placement. Careful attention is to be given to avoid endplate violation and to enhance the integration of the bone graft. Despite the appropriate surgical technique, interbody cage subsidence, loosening, migration, and non-union are several complications that could compromise the overall surgical outcomes [7–9]. The overall incidence of cage migration varies widely in the literature, ranging from 0.8–23% [10].

Factors like elderly age, low body mass index, placement of undersized cages, bony endplate damage and improper cage placement are several risk factors reported in the literature for cage back-out following TLIF surgeries [11–14]. Despite this, there are still a lot of lacunae regarding the other factors that could contribute to cage migration in TLIF. Our study aims to assess the various possible causative factors of cage retropulsion and the management strategies to be utilized for cage back-out following open TLIF surgery in degenerative lumbar spine pathology.

Material and Methods

This is a single-centre retrospective analysis of prospectively collected data from January 2011 to January 2024 with approval from the Institutional Ethical Committee and Institutional Review Board (IRB approval no: 2023/02/04). During this period, 1545 patients underwent open TLIF for lumbar degenerative pathology in our institute.

Patient Selection

We included patients undergoing open TLIF (single/ multi-level) surgery for lumbar disc disease/ instability/ stenosis with clinical/ radiological evidence of cage migration post-operatively. We excluded patients who had previous lumbar spine surgery, and patients with other techniques of interbody fusion, such as posterior lumbar interbody fusion (PLIF), anterior lumbar interbody fusion (ALIF), and oblique lumbar interbody fusion (OLIF). We also excluded patients undergoing surgeries for etiologies other than lumbar degeneration.

Surgical Technique

All the patients in our study underwent TLIF using the standard midline posterior approach. After paraspinal muscle dissection, pedicle screws were placed at appropriate levels. Laminectomy was then performed followed by discectomy and the interbody cage placement with morselized autologous bone grafts as described by Harms et al. We used autograft from the spinous process and lamina as the graft material within the cage and in the prepared disc space. Bilateral rods were placed with compression across the disc space. Closure was performed in layers with a subfascial drain. Post-operatively, mobilization was started on the first postoperative day and patients were followed up at 1, 3, 6, and 12 months post-operatively. At every visit, clinical and radiological evaluation was performed and recorded.

Data Collection and Analysis

The patient's demographic details, such as age, sex, and body mass index, along with clinical and radiological data that were prospectively collected were all retrieved from the patient records. Cage retropulsion/ back-out was defined as the movement of the posterior margin of the cage 2 mm or more beyond the posterior margin of the endplate of the inferior vertebral body in the lateral radiograph. Data analyzed include the patient symptomatology at the time of cage migration, the levels operated, the presence of spondylolisthesis/ transitional vertebral anatomy, the time interval between the index surgery and cage migration, anatomical characteristics of the disc space (pear-shaped or not), cage insertion technique used, and cage characteristics including the material (titanium/ PEEK), size, shape (rectangular/ banana shaped), and location of the cage (anterior/middle/ posterior) in the disc space.

Continuous variables were presented as mean and standard deviation, while categorical variables were presented as percentages. The statistical analysis was conducted using IBM SPSS Version 25 (Armonk, USA).

Results

Patient Demographics

Overall, sixteen patients (16/1545) had cage back-out during the study period. Seven patients (43.7%) were males and nine (56.3%) were females. The mean age of the cohort was 49 ± 9.2 years. The mean body mass index (BMI) of the cohort was 24.1 ± 2.7. Among the 16 patients, 5 were of normal bone mineral density (BMD), while 7 were osteopenic and 4 were osteoporotic, as shown in Table 1. Of the 16 cases, 62.5% were operated on by early career surgeons with less than 5 years of surgical training.

Surgical Data

10 patients underwent surgery for lumbar degenerative disc disease and stenosis. Five patients had associated instability due to degenerative listhesis, and lytic listhesis ($n = 1$). Eleven patients had single-level TLIF surgery, and five

Table 1 Characteristics of patients with cage back-out in our series

S no	Age	Sex	BMI	BMD (T-score)	Diagnosis	Surgical levels	Levels operated	Cage back-out level	Back-out Timing post-surgery	Cage material	Cage shape	Back-out direction	Management
1	43	Male	24.3	−1.2	LDD	One	L4-L5	L4-L5	3 months	Titanium	Bean	Posterior	Cage exit and revision
2	39	Male	21.2	−1.8	LDD	One	L4-L5	L4-L5	10 days	Titanium	Bean	Posterior	Cage exit and revision
3	44	Female	26.2	0.5	LDD	One	L4-L5	L4-L5	1 year 2 months	Titanium	Bullet	Posterior	Conservative
4	53	Male	19.8	−1.2	LDD*	Two	L4-L5, L5-S1	L4-L5	1 week	Titanium	Bean	Posterior	Cage exit and revision
5	58	Female	26.2	−2.1	Instability (Degenerative)	Two	L4-L5, L5-S1	L5-S1	1 year 6 months	Titanium	Bullet	Posterior	Epidural steroid
6	41	Male	24.6	−1.8	Instability (Degenerative)	One	L4-L5	L4-L5	1 year 3 months	Titanium	Bullet	Postero-lateral	Conservative
7	60	Female	20.8	−1.2	Instability* (Lytic)	One	L4-L5	L4-L5	3 months	Titanium	Bullet	Posterior	Conservative
8	62	Male	22.8	−2.2	Instability (Degenerative)	One	L4-L5	L4-L5	6 months	Titanium	Bean	Postero-lateral	Conservative
9	55	Female	26.5	−2.8	Instability (Degenerative)	Two	L4L5, L3L4	L4-L5	3 months	Titanium	Bean	Postero-lateral	Conservative
10	55	Male	27.1	0.8	LDD*	One	L4-L5	L4L5	8 months	Titanium	Bullet	Posterior	Epidural steroid
11	52	Female	23.6	−2.8	LDD	One	L4L5	L4L5	3 months	Titanium	Bean	Posterior	Epidural steroid
12	42	Female	20.2	−1.2	Instability (Degenerative)	One	L4L5	L4L5	6 months	Titanium	Bean	Posterior	Conservative
13	30	Female	24.9	−2.7	LDD	Two	L3L4, L4L5	L3L4	3 weeks	Titanium	Bullet	Postero-lateral	Cage exit and revision
14	56	Male	28.8	−1.0	LDD*	Two	L4L5, L3L4	L4L5	2 months	Titanium	Bullet	Posterior	Cage exit
15	55	Female	26.5	−3.2	LDD	One	L4L5	L4L5	11 months	Titanium	Bullet	Posterior	Conservative
16	39	Female	22.3	−2.2	LDD	One	L4L5	L4L5	1 year 3 months	Titanium	Bullet	Antero-lateral	Exit

BMD Bone Mineral Density, *BMI* Body Mass Index, *LDD* Lumbar Degenerative disc Disease,* These patients had a pear-shaped disc space

patients had double-level fusion. L4-L5 was the most common level involved in 14 patients. L5-S1 and L3-L4 were involved in one patient each. All the patients underwent fusion using static titanium interbody cages. Expandable cages were not used in any of our patients.

Timing of Presentation

Eight patients had an early back-out in less than 3 months from the index surgery. Two patients were in the immediate postoperative period (< 2 weeks), while others were at their 3rd-month follow-up. Four patients had a cage back-out 1 year after the index operation. Eleven cases involved posterior migration, one case each for postero-lateral and anterolateral migration as shown in Fig. 1 and Fig. 2**,** respectively. Most of the cases that presented early were operated on by early career surgeons (< 5 years of spine practice), and they noted a rebound phenomenon during the cage insertion that denoted inadequate disc space preparation, resulting in early cage retropulsion in the same tract of cage insertion, as illustrated in Supplementary File 1. Further, the late presenting cases were found to have patient factors that prevented fusion of the disc space, resulting in late cage back-out (> 1 year).

Management

Twelve patients in our study were managed conservatively with frequent follow-up, analgesics, and lumbar corset (three patients underwent lumbar epidural steroid injection). Four patients underwent revision surgery for cage back-out. In two patients, the retropulsed cage was removed and replaced using a larger size interbody cage from the contralateral side. In the other two patients, cage exit was performed, and an additional posterolateral fusion was performed in one patient, while an extension of the posterior instrumentation was performed in the other.

Discussion

TLIF surgery has been one of the important workhorses in managing the degenerative conditions of the lumbar spine. Neural decompression and achieving solid fusion are the primary goals of the surgery. However, there is always a risk of pseudoarthrosis and interbody cage migration, which could affect the overall patient outcomes. Cage migration could be in coronal (anterior/posterior)/ or sagittal (subsidence) planes. The posterior cage migration/ cage back-out is clinically highly significant as it could result in neurological deterioration [15]. This would necessitate a revision surgery, which could be technically challenging owing to the scarring, fibrosis, and adhesions from the previous surgery. There is also a higher incidence of complications from revision spine surgery [16–18]. Hence, it is crucial to understand and recognize the risk factors contributing to interbody cage migration. The factors contributing to cage back-out could be broadly categorized as patient factors (age, BMI, osteoporosis, indication for fusion), radiological factors (disc height, shape of the disc space), implant factors (implant material, size, and shape), and surgeon factors (adequacy of discectomy, end plate preparation, cage positioning).

Being a relatively common surgery in the adult and elderly population, the effect of age on cage subsidence and migration has been less reported in the literature [11]. A recent study showed that age is an independent risk factor for cage subsidence following TLIF surgery in the early postoperative period [19] and concluded that elderly patients undergoing lumbar fusion surgeries should be closely monitored, especially in the early postoperative period. In our study, the mean age of the population was 48 years and hence, we could not associate elderly age as a risk factor for cage back-out. In general, obesity and high body mass index (BMI) have been reported to be associated with various complications following spine surgery [20–22]. However, Lee et al. in their study, showed a direct relationship between a lower BMI and a higher incidence of the cage back-out. The authors postulated that in patients with a higher BMI, the axial force acting across the cage-bone interface would be higher, resulting in compressive loading, thereby having a protective effect on the cage from migration. A similar mechanism of improving the stiffness in axial compression at the cage site is the addition of posterior pedicle screw fixation in TLIF surgery and this strategy reduces the pseudoarthrosis rate following instrumented fusion surgeries [23–25]. Osteoporosis is another important factor complicating the results of fusion surgeries. Park et al. in their prospective study of 784 patients undergoing TLIF, observed that osteoporosis is a significant ($p < 0.001$) risk factor for both cage subsidence and cage migration [13]. This is primarily because, in patients with low bone mass, there is a reduced loading capacity of the vertebral endplates contributing to cage migration.

Regarding the radiological factors, a recent meta-analysis showed that a pear-shaped disc is one of the important independent risk factors for cage back-out following lumbar fusion surgery [26, 27]. This is primarily because of the unequal contact of all four corners of the interbody cage with the endplate. As a result, a smaller surface area of contact increases the stresses on the bony endplate. Thus, the cage becomes inherently unstable, and with flexion–extension or rotational motions, there is a higher chance for cage displacement. In our study, four patients had a pear-shaped disc space and all of them had a cage back-out, and one of those patients had an associated listhesis. Hence, a careful preoperative evaluation of the radiographs should be performed.

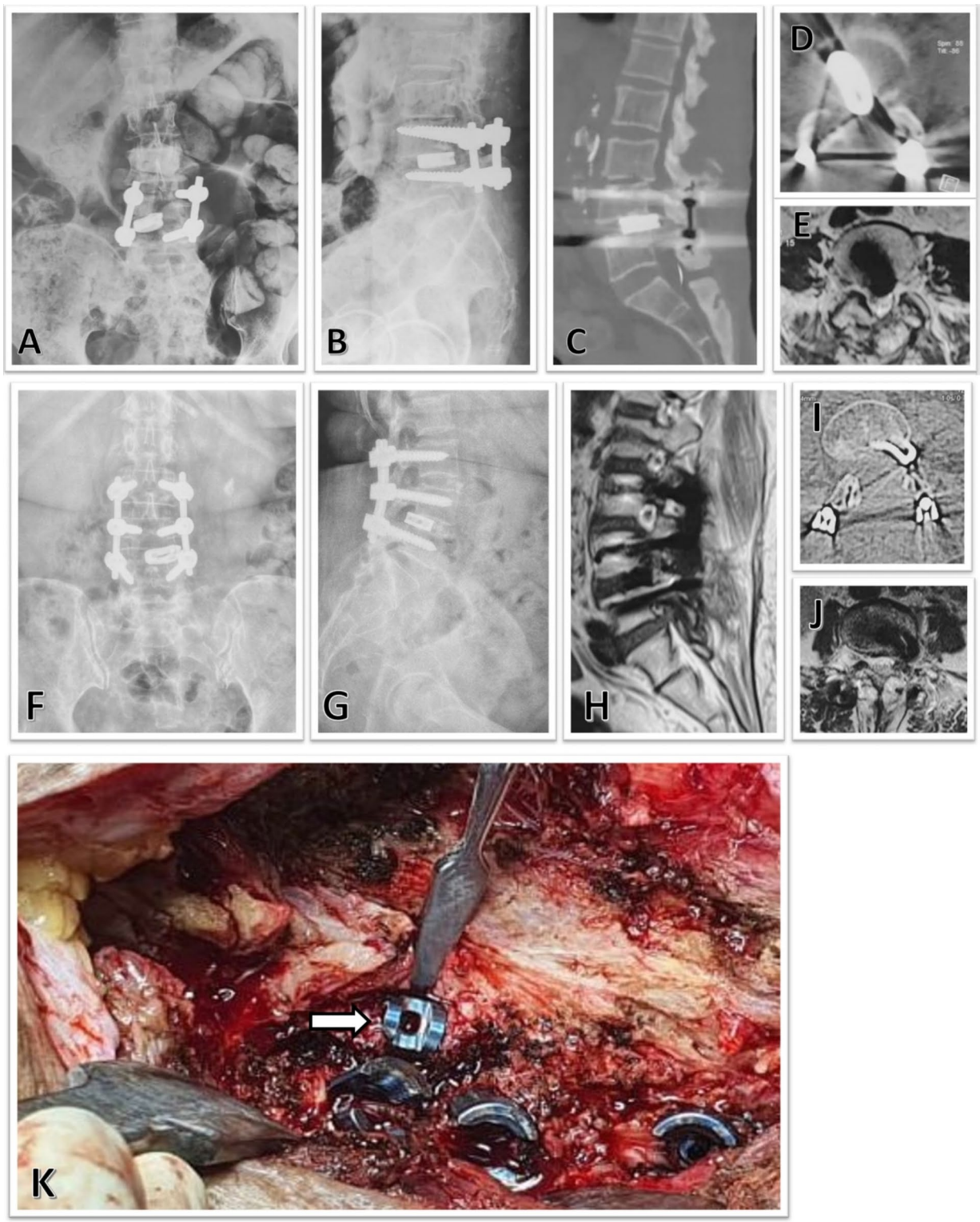


Fig. 1 **A**–**E** Illustrative case showing the radiographs (**A**, **B**), computed tomography images (**C**,**D**), and magnetic resonance imaging (**E**) of late cage back-out in the posterior direction causing radiculopathy that settled with conservative management; **F**–**J**, Illustrative case showing the radiographs (**F**,**G**), magnetic resonance imaging (**H**,**J**), and computed tomography images (**I**) of late cage back-out in the postero-lateral direction causing radiculopathy that settled with conservative management; **K** early cage back-out in the posterior direction that required revision surgery. Arrows point the backed-out cage medial to the pedicle screws in the midline

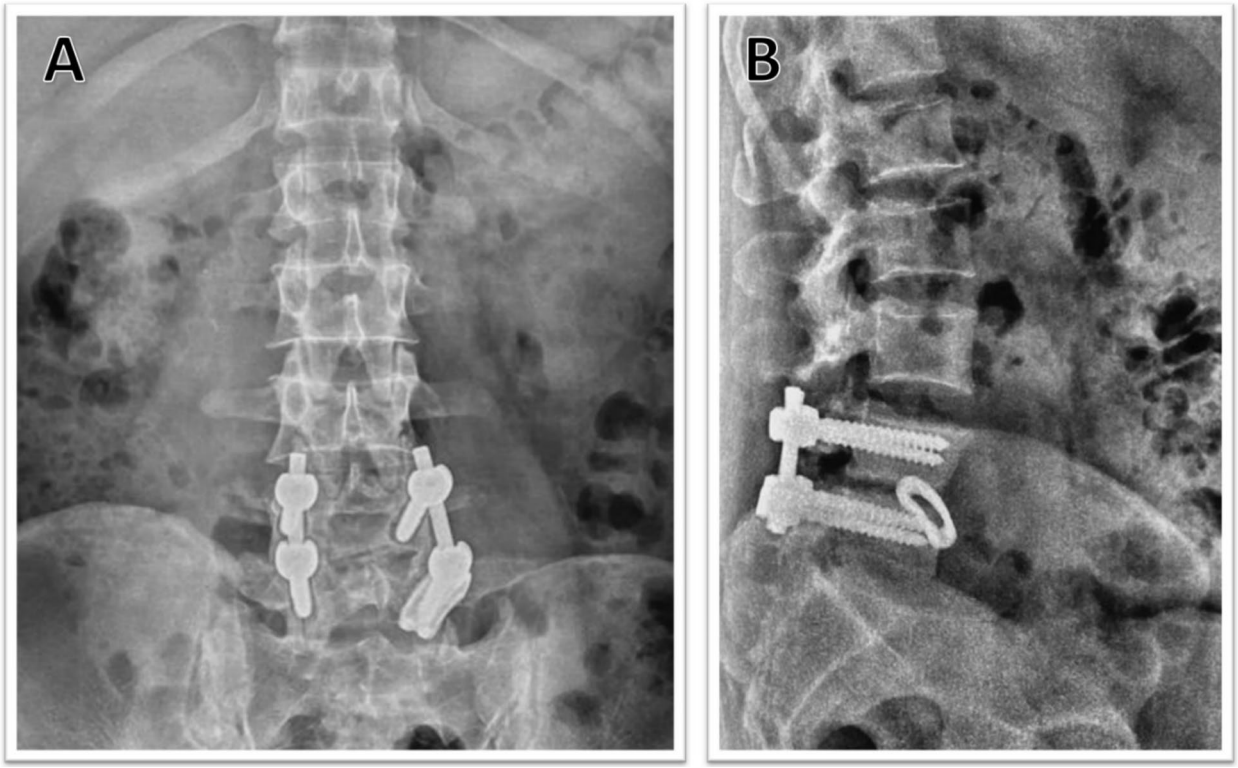


Fig. 2 Illustrative case showing the anteroposterior (**A**) and lateral (**B**) radiographs of the cage back-out in the anterolateral direction that was managed with revision surgery requiring cage exit through the lateral retroperitoneal approach

Intra-operatively, in these cases, it is crucial to prepare for parallel end plates or use alternative cage designs and position the cage as much anteriorly as possible, with proper endplate decortication, and also ensure a snug-fitting cage by appropriate sizing and axial compression using pedicle screws.

All the patients in our study underwent fusion using titanium interbody cages. Titanium implants are generally preferred in orthopaedic use because of their biocompatibility, elasticity modulus, and better osteointegration [28, 29]. However, Polyether ether ketone (PEEK) interbody cages are now widely popular owing to their biomechanical properties and the radiolucent nature of the implants [30, 31]. Studies from Cansecco and Massaad have shown that in terms of cage subsidence, both these materials are equally comparable, with no significant difference [32, 33]. Apart from the biomaterial, there is a wide variety of shapes and geometry of lumbar interbody cages available in the market [34]. Banana/bean- and bullet/box-shaped cages are the commonly preferred types in clinical use. Theoretically, the banana/bean cages were designed to be placed more anteriorly and establish a greater lumbar lordosis than the bullet/box cages. Also, a wider and more contoured shape of the banana/bean cage could distribute loads more evenly across the vertebral end plates. However, Gelfand et al. [35] observed that there is no significant difference in subsidence or fusion rates between the two cage types. Our cohort had an equal distribution of both bean and bullet cages without any predilection for back-out based on the cage geometry.

Early cage back-out (< 3 months) was seen in four patients in our study. Several important causes of the early cage back-out include: inadequate disc removal, improper positioning of the cage, damage to the bony endplates, and an undersized interbody device. Before cage insertion, it is always important to make sure that the trial cage can reach an adequate depth in the disc space, after a thorough discectomy. Intra-operatively, we could also check whether a "bouncing back" phenomenon occurs during cage insertion. This signifies that the disc has been incompletely removed necessitating further disc removal. This would aid in a more anterior placement of the cage. Biomechanical studies have also shown that the stability of the cage increases when the placement is more anterior to the centre of rotation of the vertebral endplates, [36]. In addition, the strength and stiffness of the vertebral endplates vary according to the different anatomical zones within the endplate. The centre of the vertebral endplates is considered the weakest zone compared to the peripheral parts of the endplate [37]. Abbushi et al. in their study categorized the endplates into six anatomical zones and observed that cages placed in the medio-medial

position had the highest incidence of displacement and migration [38]. Hence, preserving the integrity of the osseous endplate, especially in the central and anterior zones is considered critical in avoiding cage subsidence and nonunion. Several authors have also emphasized that any damage to the bony endplate could affect the stability of the interbody cage resulting in cage migration [11, 13]. Expandable interbody cages were initially designed and considered important in this regard, as these cages could be introduced even in collapsed disc heights, without needing much trailing or endplate distraction, thereby reducing the risk of endplate damage [39, 40]. However, a meta-analysis by Lin et al. showed that there is no statistically significant difference between a static and an expandable cage in terms of subsidence [40]. Also, the placement of undersized cages could result in early displacement of the cage. This is because the undersized interbody device fails to restore the tensile stress in the annulus and the surrounding ligamentous structures that aid in holding the cage in place. Hence, the primary stability of the cage is compromised even in the early postoperative period contributing to retropulsion.

In our study, 5/16 patients with cage back-out had more than one level fusion. The lumbar spine is considered an important mobile segment of the spine as the majority of our daily activities, including forward bending happen in the lumbar region. When TLIF involves more spinal segments, the biomechanics of the lumbar spine are significantly altered and Kimura et al. showed that including more fusion segments is one of the significant risk factors for cage back-out [16]. Twelve patients with a cage back-out were managed conservatively (three patient had an epidural steroid injection) in our study. None of these patients developed neurological deterioration following cage migration.

We believe that patients who elicited rebound phenomenon on trial or cage insertion intraoperatively resulted in early (< 1 month) back-out of the cage, with a significant distance of > 3 mm, through the same tract of insertion than compared to other factors, which resulted in late retropulsion. For the same, we believe that patients who present early < 1 month with cage retropulsion should be subjected to revision surgery with cage retrieval, revision discectomy and thorough end plate preparation with reinsertion of an adequately sized cage. We analysed the surgeon factors and found that most of the early back-outs were noted in surgeries performed by early-career surgeons probably due to surgical insufficiency in disc preparation. Patients with late presentations > 3 months, had minimal migration of the cage with partial or complete union responding to symptomatic management such as selective root block or epidural steroid, though very late presentations (> 4 years) with associated implant failure may be revised as necessitated. The late back-outs noted were due to patient factors causing fusion failure and cage-related complications.

Our study has several limitations. Firstly, it is a single-centre study with a smaller sample size. Hence, it is difficult to draw significant conclusions from our study as the statistical power could be low. Hence, we need larger multicentric studies to validate our results. Though patient factors like BMI and osteoporosis were reported in our study, other important contributing factors such as sarcopenia were not considered in the study, hence, interpretation of our results should be done with caution. Furthermore, clinical outcomes like clinical grading or scores like VAS, ODI, and patient satisfaction scores were not analysed in our study. However, considering the importance of cage migration and back-out in TLIF surgeries, our study has analysed the critical contributing factors and discussed the various strategies to be considered to avoid this catastrophic complication.

Conclusion

Cage migration is one of the well-known and devastating complications in TLIF surgery that could potentially affect patient outcomes. In our study, we observed that the intraoperative rebound phenomenon and inadequate discectomy or endplate preparation were significant risk factors for cage migration. Thus, the surgeon should be aware of the various patient-specific variables and the surgical risk factors for cage back-out in patients undergoing TLIF to optimise their clinical outcomes.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s43465-025-01493-4.

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Data Availability Data generated in the study will be made available upon reasonable request to the authors.

Declarations

Conflict of Interest The authors declare no conflicts of interest.

Ethical Approval Obtained with document approval no: 2023/02/04.

Informed Consent Informed consent was obtained from all patients involved in the study.

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