

Posterior self-expanding stand-alone cage: outcomes in degenerative disc disease

Nia Atanasova Gecheva^{1,2}, Petar Lyubomirov Ilkov³, Konstantin Alexandrov Uzunov⁴

1 Faculty of Medicine, Medical University of Sofia, Sofia, Bulgaria

2 Clinics of Pediatric Orthopedics, Prof. B. Boychev University Hospital of Orthopedics, Sofia, Bulgaria

3 Department of Neurosurgery, Prof. B. Boychev University Hospital of Orthopedics, Sofia, Bulgaria

4 Department of Neurosurgery, University Multiprofile Hospital for Active Treatment and Emergency Medicine NI Pirogov, Sofia, Bulgaria

Corresponding author: Nia Gecheva, Medical University of Sofia, 15 Acad. Ivan Geshov Blvd., Sofia 1431, Bulgaria; Email: gecheva_nia@abv.bg

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Abstract

Introduction: Degenerative disc disease (DDD) and lumbar facet joint pathology are leading causes of chronic back pain, predominantly affecting older adults due to cumulative spinal degeneration. Lumbar spondylosis, a key manifestation of DDD, contributes to mechanical instability, radiculopathy, and neurogenic claudication, significantly impairing mobility and quality of life.

Aim: To investigate the efficacy of posterior lumbar interbody fusion with hydroxyapatite cages in improving functional outcomes and spinal stability in degenerative disc disease.

Materials and methods: A retrospective review of 57 patients (mean age: 42.29±11.26 years; 75% male) undergoing posterior lumbar interbody fusion (PLIF) for single- or two-level lumbar DDD with ≥16.76 months follow-up was conducted. Clinical outcomes were assessed using the Roland-Morris Disability Questionnaire (RMQ) and Oswestry Disability Index (ODI), while radiographic parameters included intervertebral disc height and fusion stability.

Results: Postoperative analysis showed a disc height increase (16.69 to 35.59), significant RMQ improvement (14.76 to 3.76), and ODI reduction (50.47% to 16.74%), reflecting a 34% disability improvement.

Conclusion: Minimally invasive PLIF with hydroxyapatite cages effectively restores spinal height, enhances stability, and improves functional outcomes, presenting a viable alternative to traditional fusion techniques.

Keywords

hydroxyapatite cage, lumbar, PLIF, radiological

Introduction

Degenerative disc and facet joint pathology within the lumbar spine represents a prevalent and debilitating condition, particularly prominent among the geriatric demographic. Despite extensive research, the epidemiology and pathophysiology underlying the manifestation of discopathy across various age demographics remain incompletely elucidated.

It has been observed that L5-S1 disc degeneration frequently occurs asymptotically early in life, with considerable variability in its clinical impact. While some individuals experience no functional impairment, others endure significant and incapacitating pain. The factors dictating this dichotomy remain obscure, despite various proposed pathophysiological mechanisms. Furthermore, the interplay between psychological predispositions and personality traits has been recognized as a determinant in both

symptom perception and the propensity to seek medical intervention.^[1] Notably, lumbar spondylosis manifests with a spectrum of symptoms, including mechanical back pain, radicular and claudicant manifestations, compromised mobility, and a concomitant reduction in overall quality of life. The anatomical integrity of the posterior column structures, encompassing the interspinous ligaments, articular synovial joints, and the joint capsule, plays an indispensable role in maintaining spinal stability and dictating postoperative prognoses.^[2,3]

Posterior lumbar interbody fusion (PLIF), initially delineated by Briggs and Milligan in 1942^[4] has since undergone iterative refinement and ascended to the status of a cornerstone surgical modality for addressing degenerative disc disease. PLIF entails the establishment of intervertebral fusion through a posterior approach, with indications encompassing the management of debilitating low back pain, particularly when at least two-thirds of the disc height remains preserved. Conversely, absolute contraindications to PLIF surgery comprise severe osteoarthritis, degenerative spinal cord stenosis, and a diminution of disc height by one-third relative to adjacent levels.^[5,6]

Aim

This study seeks to elucidate and juxtapose the perioperative and postoperative outcomes associated with minimally invasive standalone posterior interbody fusion in the context of treating degenerative disc disease.

Material and methods

This retrospective case study evaluated outcomes of posterior lumbar interbody fusion (PLIF) for degenerative disc disease in 57 patients (75% male, 25% female) treated between 2015 and the present, each with ≥ 12 months of follow-up. Inclusion criteria comprised single-level L4-L5 or L5-S1 degeneration without osteoporosis or prior surgery, while patients with spinal stenosis, severe spondylolisthesis, advanced disc collapse, or multi-level disease were excluded. All procedures were performed by a single senior spine surgeon using a standardized technique. Only patients with complete preoperative and postoperative clinical and radiographic data and at least 12 months' follow-up were included to minimize attrition bias. Clinical and radiographic assessments were conducted preoperatively and at 6 and 12 months, including disc height index (modified Farfan method), fusion stability, and outcomes measured by the Roland-Morris Disability Questionnaire, Oswestry Disability Index, and Odom's criteria.^[7,8] All patients were admitted to two hospital departments, with healthcare activities covered by the National Health Insurance Fund in compliance with European regulations; the retrospective study was approved by the Dean of the Medical Faculty, and all necessary precautions were taken

to ensure patient anonymity in accordance with institutional ethical standards.

Operative technique

Under general anesthesia, the patient was positioned prone with legs flexed to restore physiological lordosis and optimize access to the L4/L5 or L5/S1 intervertebral space (**Fig. 1**). Through a 2.5–3 cm incision, the paraspinal musculature was bluntly dissected following fasciectomy, and under microscopic visualization, the ligamentum flavum, partial vertebral arch, and medial facet joint were resected to achieve neural decompression by mobilizing the thecal sac and nerve roots from fibrotic adhesions with removal of extruded disc material. Trial cages were fluoroscopically assessed before definitive hydroxyapatite cages were bilaterally inserted into the intervertebral space, with hemostasis secured and layered closure performed. Final fluoroscopic confirmation verified accurate cage placement, with posterior lumbar interbody fusion restoring intervertebral height, achieving decompression, and preserving posterior support structures (**Figs 2, 3**).

Results

Data were available on 57 patients with a median follow up of 16.76 months. The mean patient age during the surgery was 42.29 ± 11.26 years. Forty-two patients had a single level procedure and 15 patients had a two-level procedure. Disc height was expressed as the disc height index (DHI), based on the method of with modifications, calculated as: $[(Ha + Hp)/(Ds + Di)] \times 100$. The index was measured preoperatively and at 6-month follow-up as $\Delta DHI < -20\%$ is considered severe discal height diminution.^[9] The mean result for RMQ was also pre-operatively (14.76) and post-operatively (3.76) evaluated, thus proving a significant clinical improvement which is also statistically valid. Another grading scale, the Oswestry disability index, is also considered for the current study.^[10] It was developed by Jeremy Fairbank and Graham Pynsent in Oswestry, England in 1980 and considered one of the best accepted tools for the assessment of low back pain and is calculated in percents: 0% to 4%: minimal disability, 4% to 15%: mild disability, 15% to 24%: moderate disability, 24% to 34%: severe disability, and 35% to 50%: complete disability. The mean preoperative outcomes yielded a value of $50.47\% \pm 12.05$, with a predominance observed in the male cohort, while the mean postoperative outcomes demonstrated a significant reduction to 16.76, indicating a notable improvement of 34% (**Table 1**).

Statistical analysis

Both the paired t-test and Wilcoxon signed-rank test were employed to evaluate pre- versus postoperative outcomes, allowing assessment under both parametric and non-para-

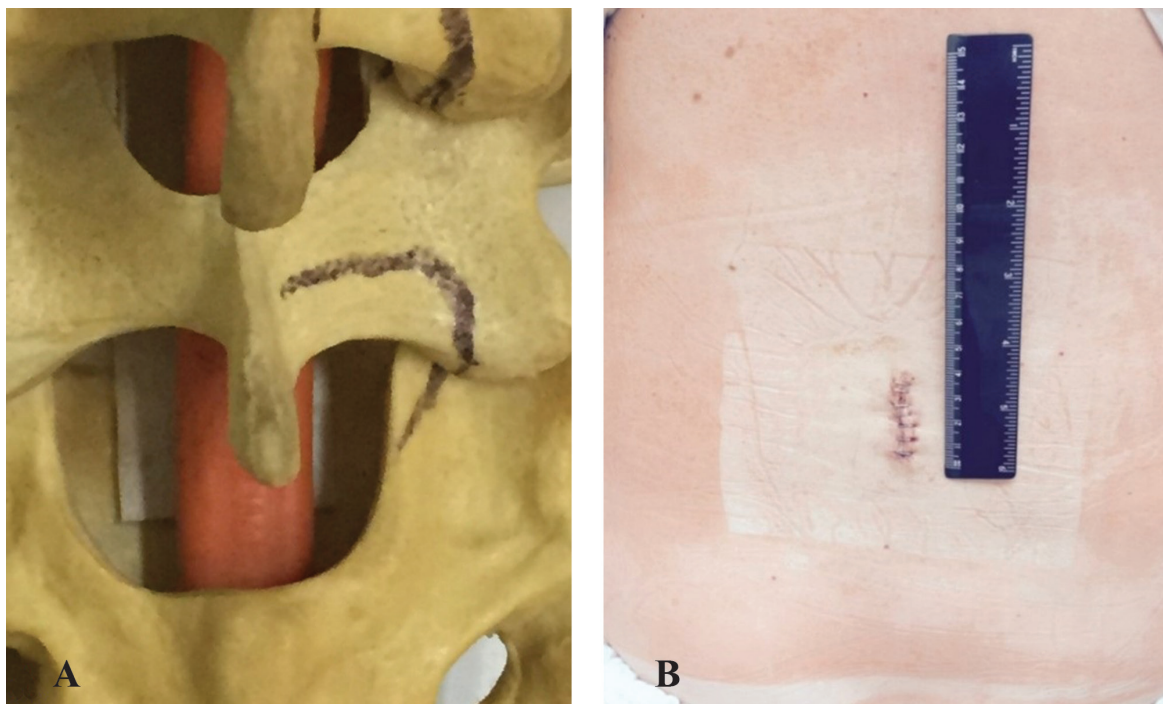


Figure 1. The 2.5–3 cm incision with access to the paraspinal musculature; (A) The 2.5–3 cm incision - model approach; (B) The 2.5–3 cm incision - skin incision.

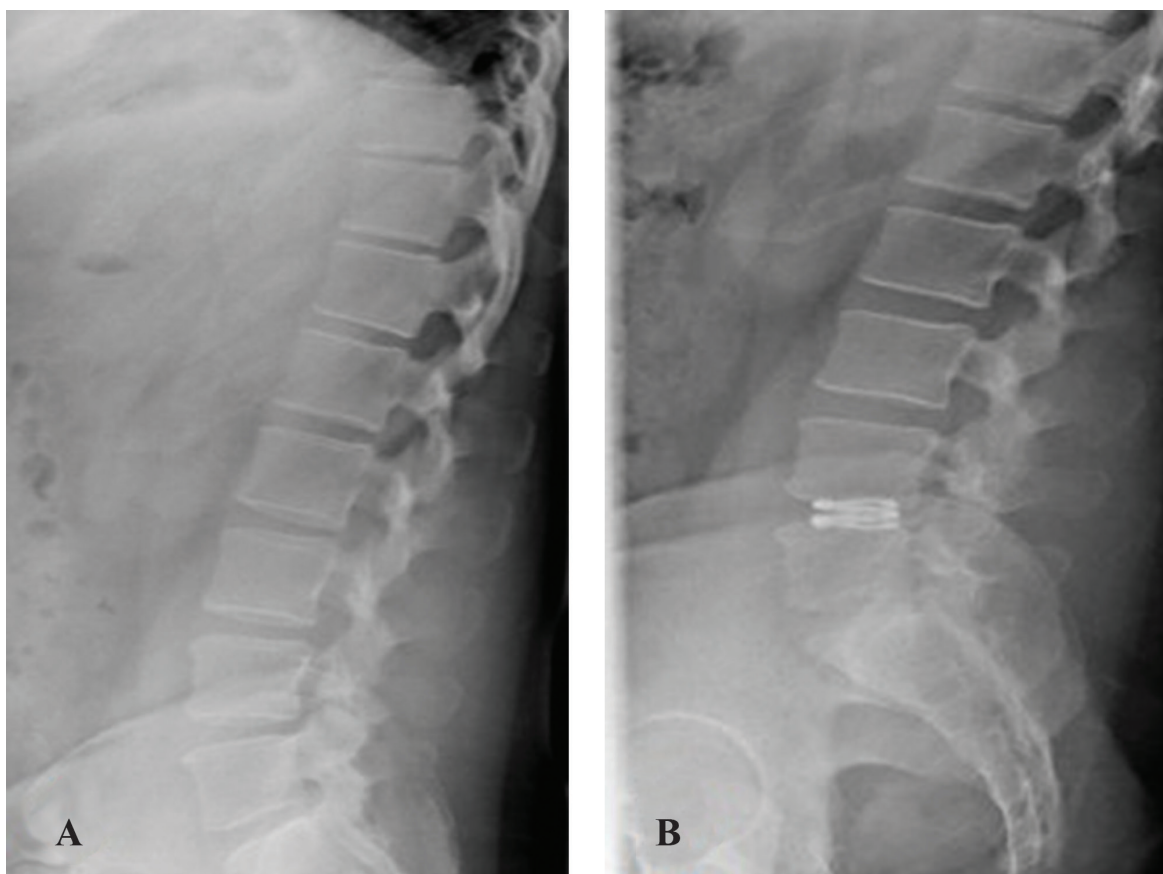


Figure 2. Pre- and post-operative X-ray results after incorporation of a standalone cage with a year of follow-up; (A) Pre-operative X-ray of a patient with single level discal hernia; (B) Postoperative X-ray results after incorporation of a standalone cage with a year of follow-up.

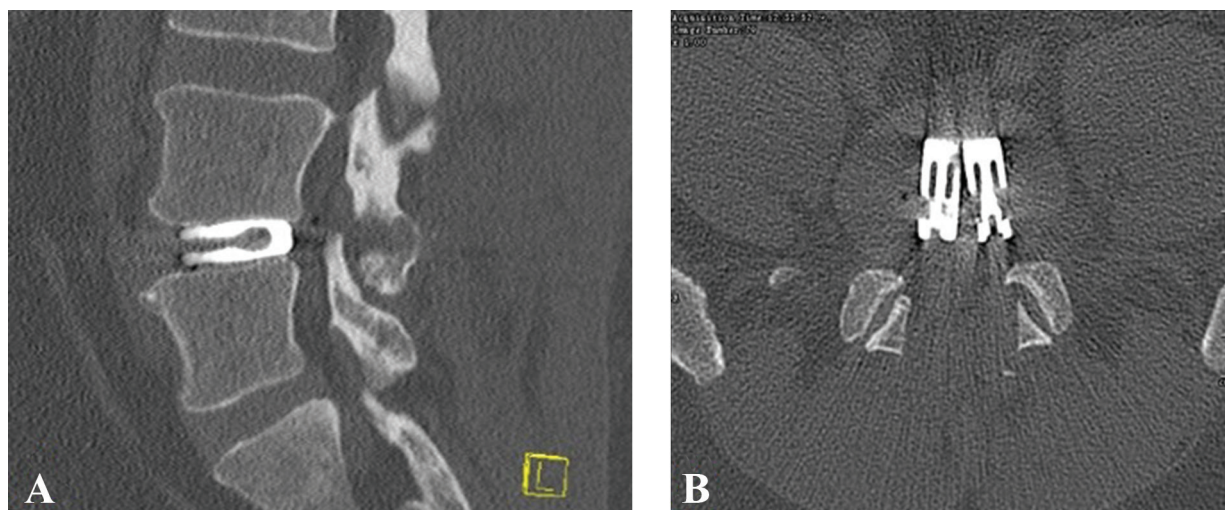


Figure 3. A 2-year follow-up CT scan; (A) Sagittal view; (B) Transversal view.

Table 1. Patient characteristics

Characteristic	Value*
Number of patients	57
Male/Female	43/14
Mean age at follow-up (yrs)	42.29±11.26
Number of prior lumbar disc surgeries	0 (none had a prior surgery)
Level of surgery:	
Both levels	15
L4–L5	6
L5–S1	36
Mean preop Farfan DHI	16.69±6.65
Median preop RMDQ score	14.76±2.41
Mean preop Oswestry index	50.47±12.05
Mean postop Farfan DHI	35.59±15.69
Median postop RMDQ score	3.76±1.48
Mean postop Oswestry index	16.74± 4.62
Preop working status	
Working w/ few or no restrictions	13
Working w/ many restrictions	40
Unable to work	4
Mean follow-up period in months	16.75±4.62

*Pre- and post-operative results using Farfan DHI, RMDQ score and Oswestry index.

Table 2. Summary of statistical test results

Measure	Paired t-test <i>p</i> -value	Wilcoxon Signed-Rank <i>p</i> -value
Oswestry Index	3.89×10 ⁻⁸	0.000015
Farfan DHI	2.32×10 ⁻⁴	0.000031
RMDQ	5.29×10 ⁻⁹	0.000015

metric conditions. Analyses revealed statistically significant improvements across all measures, with notable reductions in Oswestry Disability Index scores, increases in Farfan Disc Height Index, and enhanced Roland-Morris Disability Questionnaire outcomes, thereby confirming the clinical effectiveness of the intervention (Table 2).

Discussion

Lumbar interbody fusion offers several theoretical advantages compared to other fusion techniques, including enhanced biomechanical stability, improved fusion rates, and the potential for restoring intervertebral disc height and sagittal balance.^[11] Achieving normal spinal lordosis necessitates consideration of multiple parameters, primarily the alignment of spinal and pelvic parameters. Duval-Beaupère was among the earliest researchers to introduce pelvic incidence (PI) as a critical determinant of sagittal spinal balance, a concept later expanded upon by Roussouly, who categorized patients into four distinct types.^[12] Building on these foundational studies, Barrey and Darnis^[13] developed an algorithm for optimizing lordosis restoration during fusion surgery.

The attenuation of lordosis has been attributed to factors such as diminished intervertebral disc height and degeneration of interspinous ligaments. Jackson proposed that reduced spinal lordosis, particularly at the L4-L5 and L5-S1 levels—accounting for approximately two-thirds of total lumbar lordosis—is associated with low back pain.^[14] Posterior lumbar interbody fusion (PLIF), first introduced by Cloward in 1953, was designed as a surgical intervention for degenerative disc disease.^[15,16] Cloward emphasized that the ideal surgical technique should not only restore intervertebral height but also achieve rigid immobilization of adjacent vertebral bodies. His surgical concept revolved around the placement of a robust intervertebral graft to replace the degenerated disc, thereby ensuring spinal stability.

ty and biomechanics. Over time, refinements to PLIF have incorporated autologous iliac crest bone grafts and banked allografts, with further developments documented by Lin and colleagues.^[17-20]

While some researchers, including Dandy, proposed that nucleus pulposus curettage alone might induce spontaneous arthrodesis, others sought improvements in PLIF by optimizing grafting techniques. Akamaru et al.^[21] conducted a study analyzing lumbar interbody fusion at L4-L5, investigating various sagittal alignments. Their findings indicate that fusion with sagittal misalignment poses a risk factor for adjacent segment degeneration following PLIF.

Donor bone grafting, while serving as an alternative in PLIF, introduces concerns related to transmissible infections (HIV, hepatitis), prolonged graft incorporation times, technical difficulties in shaping bony channels, and challenges in obtaining sterile allografts of appropriate dimensions. Additionally, postoperative segmental instability, graft migration, and neural compromise present significant risks, with graft collapse further complicating outcomes.

The introduction of pedicle screw fixation by Harrington and Tullos in 1969 marked a significant advancement in spinal surgery, offering improved stability and support.^[22] However, this technique necessitates greater surgical exposure, larger skin incisions, and presents a relatively high screw malposition rate (up to 42%). In this study, a distinct approach was employed, utilizing expandable standalone cages without additional osteosynthetic materials. This strategy resulted in reduced operative time, preservation of the paraspinal musculature, and diminished radiation exposure. The expandable cage, featuring height adjustability through a controlled mechanism, facilitated precise restoration of spinal lordosis with an overall expandability of 15 degrees, while an integrated locking system prevented cage rotation within the intervertebral space. Successful spinal fusion requires graft material with osteogenic, osteoinductive, and osteoconductive properties to support bone formation, differentiation, and vascularized ingrowth. In this study, porous hydroxyapatite was utilized as a synthetic graft owing to its biocompatibility, structural uniformity, and osteoconductive capacity mediated by Ca^{2+} and PO_4^{3-} ion release that enhances osteogenesis.^[23]

Hydroxyapatite cages further allow for minimally invasive surgical approaches, reducing posterior structural damage and preserving facet joints—critical factors in achieving successful fusion.^[24,25] However, despite these advantages, potential drawbacks include limited osseointegration due to the bioinert nature of hydroxyapatite, which may contribute to nonunion, subsidence, and migration, with reported complication rates between 3% and 10% in prominent studies.

Fusion assessment criteria differ among authors, with some defining it as the absence of segmental mobility and others relying on imaging modalities such as CT to assess implant lucency. In this study, flexion-extension radiography demonstrated no abnormal mobility in 100% of cas-

es, indicating successful fusion. Lequin et al.^[26] reported moderate clinical outcomes, with 46% of patients achieving good recovery and significant pain reduction, although many had a history of multiple prior discectomies. Similarly, Costa et al.^[27] evaluated 119 patients with degenerative disc disease treated with standalone titanium-threaded cages and observed significant one- and two-year improvements, including a reduction of back pain VAS scores to 26 and favorable functional outcomes in 94% of cases.

This study demonstrates that posterior lumbar interbody fusion provides significant functional improvement and radiographic fusion in degenerative disc disease, supporting its role as an effective and durable surgical option for symptom relief and spinal stabilization.

Conclusion

In summary, this study provides a detailed evaluation of lumbar interbody fusion techniques for degenerative disc disease, demonstrating the efficacy of expandable standalone cages and the osseointegrative potential of porous hydroxyapatite graft material. These findings contribute to the evidence base guiding surgical decision-making and advance clinical strategies for optimizing outcomes in spinal fusion.

Ethical approval

This retrospective study was granted an official approval by the Dean of the Medical Faculty of Sofia Medical University.

Ethical statements

- The authors declared that no clinical trials were used in the present study.
- The authors declared that no experiments on humans or human tissues were performed for the present study.
- The authors declared that written informed consent was obtained from all patients in the study as required by the National Health Insurance Fund and European regulations.
- The authors declared that no experiments on animals were performed for the present study.
- The authors declared that no commercially available immortalized human and animal cell lines were used in the present study.

Conflict of interest

The authors have declared that no competing interests exist.

Use of AI

Generative AI was not used for this manuscript.

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Author contributions

All authors have contributed equally.

Data availability

All data used are referenced or included in the article.

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