# Collapse of Screw-Based Expandable Cages in Transforaminal Lumbar Interbody Fusion: A Retrospective Study

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## Abstract

**Background:** Transforaminal lumbar interbody fusion (TLIF) is a surgical procedure indicated in the treatment of degenerative disc disease, spinal stenosis, spondylolisthesis, and other lumbar spinal pathologies. Interbody cages used within TLIF provide structural support, but when expandable cages are utilized, collapse over time can compromise correction achieved intraoperatively. Understanding the progression of expandable cage collapse over time is critical for optimizing long-term outcomes in spinal fusion surgeries.

**Objective:** This study aims to assess the rate and progression of collapse of screw-based expandable cages used in TLIF procedures.

**Methods:** A retrospective chart review was conducted on patients who underwent a transforaminal lumbar interbody fusion (TLIF) at a single academic institution between January 2021 and January 2024. The study focused on cases utilizing the screw-based Altera™ titanium expandable cages (Globus Medical, Audubon, Pennsylvania, USA) placed along the vertebrae's anterior apophyseal rim. Radiographic measurements were taken from intraoperative and postoperative lumbar spine x-rays, both from the anteroposterior (AP) and lateral views. ImageJ software was used to calculate cage area ($mm^2$) and perimeter. The data was categorized into six time-groups (1-100, 101-200, 201- 300, 301-400, 401-500, and 501-600 days) to track collapse progression. Cage collapse was noted as the differentials calculated during each time group's previously reported periods.

**Results:** The study included a total of 79 patients, with an average collapse rate of 1.27 $mm^2$/day from the AP view and 0.17 $mm^2$/day from the lateral view. Collapse was highest in the early postoperative period (1-100 days) and decreased in the subsequent time groups, indicating that collapse slowed as the fusion construct stabilized.

**Conclusion:**
The findings suggest that the screw-based expandable cage experienced the most significant collapse early in the postoperative period, with a reduction in collapse rates following the first 100 days. This emphasizes the need for careful postoperative monitoring and highlights the potential for improving cage design to promote long-term stability in TLIF procedures and minimizing early cage collapse.

**Abbreviations**: TLIF = Transforaminal Lumbar Interbody Fusion; ODI = Oswestry Disability Index; VAS = Visual Analog Score.


## I. Introduction

Surgical management of lumbar spinal pathology has become increasingly prevalent over the past few decades in the United States, with cases of elective lumbar fusion increasing 62.3% between 2004 and 2015 [19]. Lumbar interbody fusion (LIF) is a frequently utilized surgical procedure in the management of various lumbar spinal pathologies including degenerative disc disease, spinal stenosis, and spondylolisthesis [1]. LIF procedure involves removal of the intervertebral disc at the involved spinal level, implantation of an interbody cage, and filling of the intervertebral space with a bone graft [2]. This intervention induces bone growth and subsequent fusion of the adjacent superior and inferior vertebral bodies with the intent of restricting motion and reducing associated symptoms.

Various lumbar interbody fusion approaches have been developed over the years with five primary approaches most commonly used - anterior lumbar interbody fusion (ALIF), interbody fusion anterior or oblique to psoas (OLIF/ATP), lateral or extreme lateral lumbar interbody fusion (LLIF/XLIF), transforaminal lumbar interbody fusion (TLIF), and posterior lumbar interbody fusion (PLIF) [1]. Amongst the various lumbar interbody fusion approaches, TLIF has become favored in many cases due to published evidence of higher fusion success rate, improved foraminal decompression, and efficacious discogenic pain management [2, 4, 14, 20, 21]. It should be noted however, that these proposed advantages are not universally substantiated and have been found to lack statistical significance by some studies comparing TLIF against other LIF approaches [3].

In addition to assessing clinical outcomes by surgical approach, an increasing focus has been placed on evaluating features of the implanted cage. A particular measure which has garnered notable attention is mechanical interbody cage collapse. Due to the articulating and actuating TLIF cage design, subsidence with regard to erosion of the interbody cage into adjacent vertebral bodies, has been well discussed in the literature [5, 6, 7, 8, 11]. There is, however, minimal data on cage collapse with regard to mechanical collapse of the cage itself. The dynamic nature of the lumbar spine and the mechanical forces exerted on expandable cage implants raise questions about the long-term stability of these devices and their potential for collapse within the disc space [9, 10].

This study aimed to investigate cage collapse over time as a result of mechanical cage collapse in a cohort of patients who underwent TLIF at a single institution. Results from this study provide insights into the temporal progression of cage collapse and its implications for spinal stability and fusion outcomes. Although there are numerous methods for comparing the advantages and drawbacks of various cage types, this study focuses on rates of cage collapse by mechanical collapse. Results from this study aim to provide greater insight into factors affecting interbody cage stability and contribute to the optimization of cage design and surgical techniques in an attempt to enhance long-term TLIF outcomes.

## II. Methods

### Data Collection

A retrospective chart review was conducted, assessing patients that underwent transforaminal lumbar interbody fusion (TLIF) at a single academic institution from January 2021 to January 2024. There were a total of 103 patients, of which 92 had the screw-based Altera™ cages, and 11 had non-screw-based expandable cages placed. Of the patients identified, 81 screw-based cages were included in the radiographic analysis. Patients were excluded if they had fewer than two postoperative lateral and anteroposterior lumbar spine x-rays or if the cages were not visible in the available radiographs. The 11 non-screw-based cases were excluded from the final data set due to small sample size.

Reviewers utilized ImageJ software for radiograph image analysis due to its accessibility as an open-source program and popularity for the processing and analyzing scientific images[ 22]. We calibrated the radiographic image scales using the known diameter of a placed pedicle screw shank for each procedure. We subsequently used the analysis function of ImageJ to measure the area and perimeter by outlining each visible cage present in the patient. Each cage served as a separate data point regardless of the patient in which it was placed. At various postoperative time points, these measurements were performed on all available lumbar radiographs, including lateral and anteroposterior lumbar views.

Since it cannot be assumed that the cage in the anteroposterior view is parallel to the plane of the image, or the lateral view perpendicular, the maximum area error was calculated using the largest possible angle offset between a patient and the x-ray machine. The maximum angle offset was measured as 15°. Using a designated research x-ray machine, the maximum area error was calculated by tilting the cage by 15° and calculating the percentage area change. The maximum area error was calculated as 24%.

## III. Results:

The average rate of cage collapse following the TLIF procedure was observed to be 1.665 $mm^2$/day from the anteroposterior (AP) view and 0.184 $mm^2$/day from the lateral view. Concerning the proportion of the original area, the average rate of collapse was 0.21$mm^2$/day from the AP view, compared to 0.04$mm^2$/day from the lateral view. These values indicate the relative progression of collapse assessed from different radiographic angles.

Due to variability in the timing of postoperative imaging, with follow-up X-rays occurring on different days for each patient, the data was categorized into groups based on elapsed time to facilitate consistent comparison across cases. The postoperative X-rays were categorized into six groups based on total time elapsed from the day of surgery: 1-100 days, 101-200 days, 201-300 days, 301-400 days, 401-500 days, and 501-600 days. A stratified analysis of collapse progression over time was performed. Results demonstrated that the magnitude of collapse decreased as the postoperative period lengthened. The rate of collapse was highest in the 1-100 days groups and progressively declined across each subsequent group. Although the rate reduced with time, collapse was observed in every group. This implies a positive second derivative, suggesting that the rate of cage collapse slowed as the healing process advanced. This gradual decrease in cage collapse rate from early postoperative periods may result from progressive stabilization of the fusion construct over time.

## IV. Discussion:

Although static cages were once the preferred cage type in spinal fusion, recent literature supporting equal or superior outcomes for expandable cages have led to decreased use. Outcomes based on the number of implanted cages (unilateral versus bilateral) and cage features such as expandable versus static screw-based cages or straight versus banana-shaped cages have also been reported [11, 10, 12, 13, 23]. One of the primary clinical outcomes studied when comparing cage types is the rate of successful lumbar interbody fusion, with expandable cages representing a safe and effective alternative to static cages [24]. When determining which cage type to implement, superior clinical outcomes and ease of surgical implantation are frequently cited as major determining factors [16]. Expandable cages are becoming more popular due to improvements seen in clinical outcome measures including Oswestry disability index (ODI), visual analog score (VAS) for leg and back pain, and maintenance of neuroforaminal height over time [17]. TLIF procedures performed with static cages are also associated with iatrogenic nerve root injury induced during intervertebral distraction. Expandable cages do not usually require intervertebral distraction as they are introduced in their compressed, smaller profile form, consequently reducing their risk for nerve root injury. The ease of expandable cage implantation compared to static cages has also played an important role in surgeon preference over time [21].

### Limitations:

Postoperative imaging is a fluctuating procedure dependent on the patient's schedule and hospital availability. Therefore, direct comparison of cage imaging proved challenging as patients had scans performed at various post-operative periods. Additionally, because the study was conducted at a single academic institution, patient sample size was limited to 103.

## V. Conclusion:

Cage collapse is a vital contributor to spinal instability over time and warrants close postoperative monitoring to improve long-term spinal stability in spinal fusion surgery. This study described a novel method for measuring postoperative collapse rates of expandible cages in TLIF cases. We also provided screw-based expandable cage collapse rates in a cohort of TLIF patients treated at a single academic institution. Findings from this comparative analysis help elucidate patterns in expandable cage collapse across the postoperative timeline. This study ultimately aims to contribute to understanding the dynamics of screw-based expandable interbody cages in TLIF procedures and their stability and functionality over time.

**Disclosures**:
The authors have no financial disclosure or conflicts of interest that may be referenced in this study.

References:

1. Mobbs, R. J., Phan, K., Malham, G., Seex, K., & Rao, P. J. (2015). Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MITLIF, OLIF/ATP, LLIF and ALIF. Journal of spine surgery (Hong Kong), 1(1), 2–18. https://doi.org/10.3978/j.issn.2414-469X.2015.10.05. PMID: 27683674

2. Gum, J. L., Reddy, D., & Glassman, S. (2016). Transforaminal Lumbar Interbody Fusion (TLIF). JBJS essential surgical techniques, 6(2), e22. https://doi.org/10.2106/JBJS.ST.15.00003. PMID: 30237931

3. Wasinpongwanich, K., Nopsopon, T., & Pongpirul, K. (2022). Surgical Treatments for Lumbar Spine Diseases (TLIF vs. Other Surgical Techniques): A Systematic Review and Meta-Analysis. Frontiers in surgery, 9, 829469. https://doi.org/10.3389/fsurg.2022.829469. PMID: 35360425

4. Rickert, M., Rauschmann, M., Fleege, C., Behrbalk, E., & Harms, J. (2015). Interkorporelle Fusionsverfahren an der Wirbelsäule. Die Entwicklung aus historischer Sicht [Interbody fusion procedures. Development from a historical perspective]. Der Orthopade, 44(2), 104–113. https://doi.org/10.1007/s00132-015-3076-1. PMID: 25626703.

5. Chang, C. C., Chou, D., Pennicooke, B., Rivera, J., Tan, L. A., Berven, S., & Mummaneni, P. V. (2020). Long-term radiographic outcomes of expandable versus static cages in transforaminal lumbar interbody fusion. Journal of neurosurgery. Spine, 34(3), 471–480. https://doi.org/10.3171/2020.6.SPINE191378. PMID: 33186902.

6. Parisien, A., Wai, E. K., ElSayed, M. S. A., & Frei, H. (2022). collapse of Spinal Fusion Cages: A Systematic Review. International journal of spine surgery, 16(6), 1103–1118. https://doi.org/10.14444/8363. PMID: 36289005.

7. Malham, G. M., Parker, R. M., Blecher, C. M., & Seex, K. A. (2015). Assessment and classification of collapse after lateral interbody fusion using serial computed tomography. Journal

of neurosurgery. Spine, 23(5), 589–597. https://doi.org/10.3171/2015.1.SPINE14566. PMID: 26207320.

8. Subramanian, T., Merrill, R. K., Shahi, P., Pathania, S., Araghi, K., Maayan, O., Zhao, E., Shinn, D., Kim, Y. E., Kamil, R., Song, J., Dalal, S. S., Vaishnav, A. S., Othman, Y., Steinhaus, M. E., Sheha, E. D., Dowdell, J. E., Iyer, S., & Qureshi, S. A. (2023). Predictors of subsidence and its Clinical Impact After Expandable Cage Insertion in Minimally Invasive Transforaminal Interbody Fusion. Spine, 48(23), 1670–1678. https://doi.org/10.1097/BRS.0000000000004619. PMID: 36940252.

9. Mica, M. C., Voronov, L. I., Carandang, G., Havey, R. M., Wojewnik, B., & Patwardhan, A. G. (2018). Biomechanics of an Expandable Lumbar Interbody Fusion Cage Deployed Through Transforaminal Approach. International journal of spine surgery, 12(4), 520–527. https://doi.org/10.14444/5063. PMID: 30276113.

10. Jain, S., Eltorai, A. E., Ruttiman, R., & Daniels, A. H. (2016). Advances in Spinal Interbody Cages. Orthopaedic surgery, 8(3), 278–284. https://doi.org/10.1111/os.12264. PMID: 27627709.

11. Lin, G. X., Kim, J. S., Kotheeranurak, V., Chen, C. M., Hu, B. S., & Rui, G. (2022). Does the application of expandable cages in TLIF provide improved clinical and radiological results compared to static cages? A meta-analysis. Frontiers in surgery, 9, 949938. https://doi.org/10.3389/fsurg.2022.949938. PMID: 36034361.

12. Alvi, M. A., Kurian, S. J., Wahood, W., Goyal, A., Elder, B. D., & Bydon, M. (2019). Assessing the Difference in Clinical and Radiologic Outcomes Between Expandable Cage and Nonexpandable Cage Among Patients Undergoing Minimally Invasive Transforaminal Interbody Fusion: A Systematic Review and Meta-Analysis. World neurosurgery, 127, 596–606.e1. https://doi.org/10.1016/j.wneu.2019.03.284. PMID: 30954733.

13. Sebaaly, A., Kreichati, G., Tarchichi, J., Kharrat, K., & Daher, M. (2023). Transforaminal lumbar interbody fusion using banana-shaped and straight cages: meta-analysis of clinical and radiological outcomes. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 32(9), 3158–3166. https://doi.org/10.1007/s00586-023-07797-z. PMID: 37326836.

14. de Kunder, S. L., van Kuijk, S. M. J., Rijkers, K., Caelers, I. J. M. H., van Hemert, W. L. W., de Bie, R. A., & van Santbrink, H. (2017). Transforaminal lumbar interbody fusion (TLIF) versus posterior lumbar interbody fusion (PLIF) in lumbar spondylolisthesis: a systematic review and meta-analysis. The spine journal : official journal of the North American Spine Society, 17(11), 1712–1721. https://doi.org/10.1016/j.spinee.2017.06.018. PMID: 28647584.

15. Woodward, J., Koro, L., Richards, D., Keegan, C., Fessler, R. D., & Fessler, R. G. (2022). Expandable versus Static Transforaminal Lumbar Interbody Fusion Cages: 1-year Radiographic Parameters and Patient-Reported Outcomes. World neurosurgery, 159, e1–e7. https://doi.org/10.1016/j.wneu.2021.11.056.

16. Lewandrowski, K. U., Ferrara, L., & Cheng, B. (2020). Expandable Interbody Fusion Cages: An Editorial on the Surgeon's Perspective on Recent Technological Advances and Their Biomechanical Implications. International journal of spine surgery, 14(s3), S56–S62. https://doi.org/10.14444/7127. PMID: 33122184.

17. Boktor, J. G., Pockett, R. D., & Verghese, N. (2018). The expandable transforaminal lumbar interbody fusion - Two years follow-up. Journal of craniovertebral junction & spine, 9(1), 50–55. https://doi.org/10.4103/jcvjs.JCVJS_21_18. PMID: 29755237.

18. Daher, M., Aoun, M., El Sett, P., Kreichati, G., Kharrat, K., & Sebaaly, A. (2024). Unilateral vs Bilateral Cages in Lumbar Interbody Fusions: A Meta-Analysis of Clinical and Radiographic Outcomes. World neurosurgery, S1878-8750(24)00528-X. Advance online publication. https://doi.org/10.1016/j.wneu.2024.03.142.

19. Martin, B. I., Mirza, S. K., Spina, N., Spiker, W. R., Lawrence, B., & Brodke, D. S. (2019). Trends in Lumbar Fusion Procedure Rates and Associated Hospital Costs for Degenerative Spinal Diseases in the United States, 2004 to 2015. Spine, 44(5), 369–376. https://doi.org/10.1097/BRS.0000000000002822. PMID: 30074971.

20. Vahedi, P., Gholghasemi, M., & Rymarczuk, G. (2024). Radiological and Clinical Outcomes of Transforaminal vs. Posterior Lumbar Interbody Fusions: A Systematic Review. Turkish neurosurgery, 34(2), 175–183. https://doi.org/10.5137/1019-5149.JTN.42926-22.2. PMID: 38497172.

21. Elgafy H, Behrens K. Comparing expandable and static interbody cages in lumbar interbody

fusion. J Spine Surg. 2023 Mar 30;9(1):1-5. doi: 10.21037/jss-23-5. Epub 2023 Feb 14. PMID: 37038415; PMCID: PMC10082432.

22. Abràmoff, M. D., Magalhães, P. J., & Ram, S. J. (2004). Image processing with ImageJ. Biophotonics international, 11(7), 36-42.

23. Daher M, Aoun M, El-Sett P, Kreichati G, Kharrat K, Sebaaly A. Unilateral Versus Bilateral Cages in Lumbar Interbody Fusions: A Meta-Analysis of Clinical and Radiographic Outcomes. World Neurosurg. 2024 Jun;186:158-164. doi: 10.1016/j.wneu.2024.03.142. Epub 2024 Mar 30. PMID: 38561031.

24. Woodward J, Koro L, Richards D, Keegan C, Fessler RD, Fessler RG. Expandable versus Static Transforaminal Lumbar Interbody Fusion Cages: 1-year Radiographic Parameters and Patient-Reported Outcomes. World Neurosurg. 2022 Mar;159:e1-e7. doi: 10.1016/j.wneu.2021.11.056. Epub 2021 Nov 18. PMID: 34801752.