Editorial

Comparing expandable and static interbody cages in lumbar interbody fusion

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Low back pain unresponsive to conservative treatment options often leads to surgical modalities for a magnitude of lumbar pathologies including degenerative disc disease, spondylolisthesis, spinal stenosis, disc herniation and degenerative scoliosis. Treatment algorithms surrounding these pathologies include interbody fusion with the surgical goal of restoring spine balance, indirect decompression of the spinal foramina by regaining the disc height and improving fusion rate. The evolution of different surgical techniques and implant technology provides surgeons various options for each unique patient pathology. The purpose of this editorial is to review the advantages and disadvantages of surgical approaches, types of interbody cages and the evidence behind static and expandable cages.

For many years neutral static interbody cages were the gold standard implant for interbody fusions. They offered interbody fusion with the ability to restore disc height, foraminal height (FH), improve sagittal balance and aid in spinal fusion (1). Interbody fusion was predominantly done through a posterior or transforaminal approach which did not come without risks and limitations. Fixed height of the interbody cage and non-lordotic shape limited the restoration of anterior column height to anatomic levels and theoretically limiting pain reduction postoperatively (2). Furthermore, intervertebral distraction is usually required to allow for trialing and insertion of static interbody cage. This requires retraction of the nerve root with increased risk of dural tear and iatrogenic nerve root injury. Due to the need for trialing, end plates violation is a risk which could lead to subsidence and reoperation. Thus, lordotic expandable cages were brought into practice with hopes to combat these issues.

Expandable cages were designed to help surgeons combat the shortcomings of static cages previously discussed. Expandable cages would allow insertion of the device in a collapsed form without the need for trialing or vertebral distraction, minimizing the trauma to endplates and theoretically decreasing the risk of implant subsidence while obtaining optimal interbody heights (3). Larger cage footprints were made to allow more contact area to improve fusion rates and maintain the relationship between vertebral body endplates (4). Evolution to increase the lordotic morphology of these cages allowed restoration of lordotic curvature to improve segmental lordosis (SL) and sagittal balance. Sembrano *et al.* discussed radiographic changes when comparing lordotic and non-lordotic cages and found that lordotic cages resulted in a statistically significant increase in SL at the operative level, where non-lordotic cages did not change from preoperative SL levels (2). Anterior and posterior disc height (PDH) was significantly increased in both cohorts and noted that neither had any significant change to lumbar lordosis (LL) on a more regional level. These early results gave surgeons a viable option for interbody implants during lumbar fusions.

Interbody cages were initially posterior lumbar interbody fusions (PLIF) or transforaminal lumbar interbody fusions (TLIF) approach. Recent literature has come to favor a transforaminal approach over the posterior for several reasons. De Kunder *et al.* in a meta-analysis study compared PLIF to TLIF in patients undergoing surgery for spondylolisthesis. The authors reported that the TLIF had a lower complication rate, less blood loss, shorter operative time, and similar clinical outcomes with even slightly lower Oswestry Disability Index (ODI) scores (5). The PLIF technique typically requires more neural retraction compared to the TLIF approach which increases risk of nerve root injury, dural tears, and epidural fibrosis (5). Woodward *et al.* discussed the popularity of the open TLIF procedure as it helps facilitate spinal canal and foraminal decompression at all lumbar levels and can be performed in a minimally invasive surgical manner (MIS-TLIF) (1). The MIS-TLIF aims to mitigate tissue dissection through a unilateral laminectomy and facetectomy, reducing operative blood loss, enhancing postoperative recovery, reduced morbidity, length of hospital stay and minimizing risk to nerve roots and dura compared to open TLIF technique (1,6). Additionally, Alvi *et al.* discussed that expandable cages have a beneficial mechanism to obtain lordotic correction by anterior column lengthening while shortening the posterior column (7). Some of the shortcomings of TLIF and PLIF approaches can be overcome through anterior and the more recently lateral interbody fusions.

The anterior lumbar interbody fusion (ALIF) is done through a retroperitoneal approach that allows access to the lumbar interverbal disc. Macki *et al.* discussed the ability to place lordotic expandable cages more anteriorly providing the greatest lordotic correction (3). Additional studies noted similar fusion rates of ALIF to 90.1% and subsidence rates of 4.9% with favorable and statistically significant improvements in patient reported outcome (PRO) scores of legs and back pain thought to be attributed to increases in FH, disc height, and intervertebral lordotic angle (3,8). Also, the ALIF approach compared to the posterior approaches (TLIF/PLIF) avoids paraspinal muscle trauma with minimal blood loss and shorter operative time and allows larger implant footprints due to improved access to the intervertebral space (9-11). However, it does not come without its own limitations such as requiring assistance for access by either a general/vascular surgeon, iatrogenic injury to bowel or superior hypogastric sympathetic plexus/sacral splanchnic nerve plexus leading to retrograde ejaculation and sterility in male patients, urinary retention, thrombophlebitis, warm leg sensation, and selective access to only L3-S1 levels (3). On the contrary, the lateral lumbar interbody fusion (LLIF) can minimize many of these previously mentioned shortcomings to the ALIF. Macki *et al.* discussed the elimination of retraction of nerve roots and direct entry into the neuroforamen and intervertebral space (3). Li *et al.* found that expandable cages through a LLIF technique demonstrated significant improvements in mean visual analogue scale (VAS) for back and leg pain at 6 and 24 months postoperative, and ODI at all timeframes up to 24 months postoperative, in addition to a lower rate of cage subsidence (12). Sembrano *et al.* compared LLIF, ALIF, TLIF and posterior spinal fusion (PSF) which demonstrated a statically significant improvement from preoperative to postoperative SL, LL, anterior disc height (ADH) and PDH across all groups except PSF with ALIF having the greatest mean change from preoperative levels (2). The value of these findings allows spine surgeons the opportunity to utilize each approach based on the anatomic correction needed for each patient.

With pleasure, we further discuss the paper by Kucharzyk *et al.* "The effect of expandable versus static lordotic interbody implants in minimally invasive spine surgery: PROs, sagittal alignment and restoration of disc height and foraminal height" (13). In their retrospective review of 100 patients across multiple lumbar pathologies (degenerative disc disease, spondylolisthesis, spinal stenosis, disc herniation, and degenerative scoliosis) the authors aimed to investigate multiple outcome metrics clinically and radiographically over a two-year postoperative period following MIS-TLIF with either a static polyether-ether-ketone (PEEK) spacer or an expandable interbody spacer. Radiographically the authors found ADH, PDH, average disc height, FH, and SL improved significantly more in the expandable group at each follow up until two years ($P<0.001$). All heights were found to be maintained throughout the two years in both groups and were within normal parameters found in healthy normal lumbar intervertebral discs. Examination of the PROs revealed improvement relative to baseline in both the ODI and VAS back pain score which were significantly more favorable in the expandable group at all study visits and the difference became evident as early as 3 months postoperative and sustained the discrepancy until two years postoperative. The VAS leg pain score significantly improved in the expandable group only at two years when compared to the static group. This study also did a subgroup analysis across the different diagnoses that found similar statically significant findings favoring the expandable cohort over the static in all outcome measures including ADH, PDH, average disc height, FH, SL, ODI, and VAS back pain. VAS leg pain scores were only significant in the subgroup of patients that received expandable cages with spondylolisthesis. The safety outcomes regarding this study demonstrated no intraoperative complications in either group. At two years the expandable cage group had lower incidence of nonunion (6% *vs.* 12% in static group) and revision surgery (4% *vs.* 8% in static group). Even though neither of these findings were statistically significant they demonstrate a relative risk of 0.5 for both outcomes.

The study by Kucharzyk *et al.* brings forward additional evidence regarding the utility and benefits of expandable versus static interbody cages when used in the MIS TLIF technique (13). Many previous investigations have contradictory results for each cohort making it difficult for surgeons to guide their surgical decisions. We would like to further analyze the context of the radiographic and clinical outcomes of this study into the context of current literature.

It is hypothesized that the restoration of normal anatomic radiographic parameters, specifically fused segment angle and disc height, correlate with improved PRO scores (14,15). Pain generators come from compression of the intervertebral space, vertebral endplates, facet joints, and nerve roots. The study by Kucharzyk finds significant improvements between preoperative and postoperative radiographic changes favoring expandable cages over static cages that are maintained throughout 2-year follow up, but literature supporting significantly improved radiographic changes favoring one cage type has not been as clearly delineated (13). Armocida *et al.* reported in a retrospective study of 65 patients (40 static, 25 expandable) over 1 year found there to be no significant changes between each groups' SL, ADH, PDH (6). Alvi *et al.* found with their meta-analysis of 12 studies including 706 patients there to be a statistically significant increase in disc height for the static group over the expandable group but significant difference in SL favoring expandable cages over static (7). Canseco *et al.* retrospectively reviewed 240 patients undergoing MIS TLIF with either static or expandable PEEK cages for comparison up to one year and found no radiographic outcome differences except PDH being significantly favorable in the static group (16).

Additional studies have found contradictory results that support the findings of Kucharzyk *et al.* Hawasli *et al.* retrospectively reviewed 48 patients undergoing MIS-TLIF using crescent shaped expandable cages to have greater and more sustained increases in disc height, FH, SL than the static group at final follow up (15). A meta-analysis by Lin *et al.* provided a direct analysis between expandable and static cages where expandable cages were associated with improved functional outcomes and restored PDH and FH in patients with TLIF. The authors reported no statistically significant differences in SL, LL, pelvic parameters, cage subsidence, or fusion rate (17).

Kucharzyk *et al.* reported that improvement in both ODI and VAS back pain to be significantly more favorable in the expandable cage group at all study visits up to two years and the VAS leg pain to be improved in expandable cage group only at 2 years (13). Massie *et al.* reviewed 44 patients undergoing MIS TLIF for spondylolisthesis and found correction of segmental angle and sagittal vertical axis at the 90-day visits (18). In the same study they correlated radiographic improvement to be associated with greater improvements in ODI and back pain scores. Lin *et al.* found a statistically significant and substantial difference in ODI score at final follow up for expandable cage over static cage, however there was no significant difference between static and expandable groups VAS back and leg scores at final follow up (17). Woodward *et al.* also noted significant reduction in both expandable and static cohort ODI and numeric pain rating scale at 1 year in a review of 120 patients undergoing TLIF (1). These findings suggest that expandable cages may be advantageous in improving short- and long-term PROs.

An ideal feature during the evolution of expandable cages was to create an implant that required less endplate preparation, insertion without trialing or vertebral space distraction that would put the endplates at risk for integrity violation. Chang *et al.* studied 178 patients retrospectively that were subcategorized into static versus expandable and posterior column osteotomy (PCO) bilaterally or unilaterally that underwent TLIF and found a higher incidence of cage subsidence in the expandable group versus the static (19.7% *vs.* 5.4%) (19). The unilateral facetectomy group had a 5.65 times higher rate of subsidence than the bilateral PCO group (26.8% *vs.* 4.8%). Endplate violation was also found to be 6.1% in static and 17.7% in expandable in the same study. The authors believe the PCO group may allow for greater distraction and correction of lordotic curvature with release of posterior elements however it is negated by higher subsidence due to less mobility of the disc space and inadequate posterior compression (19). When endplates get disrupted, it can put the implant at risk of subsidence and potential pseudoarthrosis and revision surgery. Cage subsidence has been documented at rates up to 18.9% in static and 20.7% in expandable cages after TLIF (17). Kucharzyk reported lower nonunion rates in the expandable compared to static group (6% *vs.* 12%) and lower revisions surgery rates (4% *vs.* 8%) which was statistically insignificant. Even with the variable rates of subsidence previously noted, fusion rates have been reported to be similar between groups (13). The meta-analysis by Alvi *et al.* found fusion rates to be 75% in expandable and 90% in static (P=0.3) and noted that the type of bone graft affects fusion which was not well documented in many of the studies (7). Other studies found fusions rates in expandable cage patients from 88.7–96% and 90–94.7% in static (15,17,19).

Kucharzyk *et al.* provides valuable data and insight into the utility of expandable interbody cages during MIS TLIF procedures (13). This study demonstrates the versatility of its success across a multitude of lumbar pathologies with promising results favoring expandable cages improving important radiographic and PRO measurements leading to optimal patient outcomes. It has been postulated that greater improvement in radiographic parameters correlates with improved outcome measurements which this study attests to. With two years' follow up, this study contributes to the literature by outlining that expandable cages can provide patients across multiple pathologies with improved clinical and radiographic outcomes.

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