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Mini Review

Expandable Cervical Cages in Spinal Reconstruction: Balancing Recovery and Long-Term Health in Athletes

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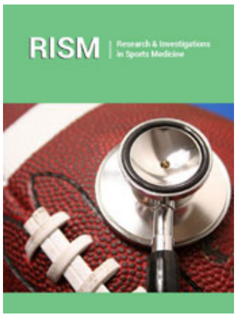
ISSN: 2577-1914



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Submission: February 26, 2025

Published: March 21, 2025

Volume 11 - Issue 2

How to cite this article: Rahul Kumar*, Chirag Gowda, Phani Paladugu, Yousef Younis, Kiran Marla, Nayana Gowda, Alex Ngo, Ajay Zheng, Ram Jagadeesan, Shashinath Chandrahasegowda and Tarikere Kumar. Expandable Cervical Cages in Spinal Reconstruction: Balancing Recovery and Long-Term Health in Athletes. Res Inves Sports Med. 11(2), RISM.000756. 2025.
DOI: 10.31031/RISM.2025.11.000756

Abstract

Orthopaedic surgeons are rapidly utilizing expandable cervical cages during spinal reconstruction procedures, but among elite athletes there is still the important question of recovery, mobility and sustainability. While expandable cages offer benefits, athletes often place very unique demands on their cervical spine and as such a more nuanced evaluation of whether the increased intraoperative adjustability provided by expandable cages translates into meaningful performance or health benefits is required. A thorough review of existing literature highlights significant limitations in study design, along with a paucity of high-quality, athlete-specific data. The long-term consequences of using expandable cages in a population that relies heavily on cervical function for sport-specific movements are important to consider and we argue that static cages or other conservative management techniques should not be left out of the equation when installing expandable cages for spinal operations. In all, a holistic approach blending static and expandable cages, and conservative or otherwise non-invasive techniques, should remain the standard of care for most athletes requiring cervical fusion.

Introduction

The cervical spine in high-performance athletes is subjected to extreme and often unpredictable loads, far exceeding those experienced in typical degenerative cases [1]. For example, a routine tackle in American Football can hyperflex regions C4-5 and C5-6, which are the most frequently involved regions in ventro-flexion injuries [2]. Expandable cages are often used to treat resulting spinal canal stenosis with cord compression, as well as any cervical fractures, from these types of injuries [3]. The theoretical benefits of expandable cages, particularly their capacity for intraoperative height and lordosis adjustment, must account for the unique cervical spine kinematics observed in elite athletes [4]. While these devices promise optimized sagittal alignment and potential reduction in subsidence rates, there is a paucity of high-quality, sport-specific data demonstrating their superiority in maintaining cervical function under the intense, repetitive, and high-velocity loads characteristic of both contact and non-contact sports [5]. Additionally, many of these movements are unpredictable, in-the-moment turns and twists, which can cause bodily damage in very niche ways [6]. As such, many clinicians are interested in whether an expandable cage's increased cost and purported biomechanical advantages translate to improved long-term outcomes, particularly in terms of adjacent segment degeneration rates, return-to-play timelines, and career longevity [7]. Before an operation, orthopaedic surgeons must account for the axial and rotational forces endemic to their patient's sport and position [8].

However, there is currently a lack of randomized controlled trials and long-term follow-up studies, specifically studies that follow professional athletes over time [9]. Moreover, the potential for micro-motion at the cage-endplate interface raises concerns about stability under the extreme loads experienced by athletes [10]. In all, the impact of this micro-motion on the overall biomechanics of the cervical spine, particularly in the context of the high-force movements common in many sports, remains inadequately characterized [11]. In this article, we discuss these factors, analyse current studies, and argue that while expandable cervical cages offer theoretical biomechanical advantages for spinal fusion in athletes, their clinical benefits require further testing and their long-term impact on adjacent segment health and career longevity is understudied [12]. Until a more comprehensive understanding of the long-term implications of expandable cages in professional sports is established, there is a risk of adopting a technology that may offer reduced practical benefit while potentially exposing athletes to unnecessary financial burden and surgical risks.

Biomechanical considerations

Expandable cervical cages in spinal fusion surgery can help correct cervical lordosis and potentially mitigate the risk of subsidence by optimizing endplate contact and load distribution [13]. In the operative room, surgeons can adjust height in situ, thereby theoretically restoring sagittal alignment and intervertebral spacing [14]. For many athletes, there is the issue of increased micro-motion at the cage-endplate interface, a significant risk factor for implant failure, delayed fusion, and Adjacent Segment Disease (ASD) [15]. Biomechanical studies have shown mixed results when comparing the flexibility of expandable cages to static cages or traditional bone grafts [16]. A study by Voronov et al. [6] compared the biomechanical stability of bilateral posterior cervical cages to Anterior Cervical Discectomy and Fusion (ACDF) [17], while another found no significant biomechanical differences between expandable and nonexpendable cages in the cervical spine [18]. In contrast, in the lumbar spine, Bakhaidar et al. [8] demonstrated that larger expandable cages provided better stability than smaller cages in Transforaminal Lumbar Interbody Fusion (TLIF) [19]. Specifically, in a unilateral model, the smallest cage resulted in 47.9% more motion at the L5-S1 level compared to the largest cage in flexion and 64.8% more motion in extension. These findings highlight how cage size and design influence biomechanical stability, yet they do not establish a consistent advantage of expandable cages over static alternatives in the cervical spine [20]. Consequently, many providers still doubt whether expandable cages effectively integrate into the cervical spine's kinetic chain, particularly under high-velocity movements where neuromuscular control plays a crucial role in maintaining stability [21].

Further, there is mixed evidence that expandable cages actually reduce subsidence rates; A prospective cohort study by Wu et al. found no significant difference in subsidence rates between expandable titanium cages and static poly ether ketone cages in transforaminal lumbar interbody fusion [22]. Similarly, a meta-analysis mentioned by Chang et al. [10] did not demonstrate any significant difference in cage subsidence between static and expandable cages [23]. Stress concentration analyses have shown that expandable cages may inadvertently increase localized stress at the implant-endplate interface due to their smaller initial contact area prior to expansion, potentially exacerbating subsidence risk under repetitive axial loading [24]. Many studies are designed using static loading conditions, which do not account for the complex multi-directional forces experienced in sports [25]. Studies comparing expandable cages with static designs have reported reduced rotational stiffness for expandable designs ($p<0.05$), potentially rendering them less suitable for patients undergoing high degrees of cervical rotation and stability [26]. Additionally, the lack of established thresholds for clinically significant micro-motion or subsidence further complicates cage selection [27].

Clinical outcomes and return to play, long-term adjacent segment health and career longevity

Recently published literature has shown that expandable cages do not significantly impact long-term post-operative outcomes compared to static cages [28]. Clinicians must evaluate patient-specific factors such as bone mineral density, pre-existing degenerative changes and cervical sagittal alignment, while considering sport-specific biomechanical loads-such as axial compression in linemen and rotational forces in pitchers-and potential long-term adjacent segment hypermobility, facet joint hypertrophy, and accelerated disc degeneration at juxta fused levels [29]. We believe expandable cervical cages, despite their purported biomechanical advantages, do not demonstrate clear superiority over static cages in long-term outcomes or career longevity for elite athletes due to the cervical spine's complex structure and nuanced fusion challenges [30]. Key ligamentous structures-including the Anterior Longitudinal Ligament (ALL), Posterior Longitudinal Ligament (PLL), ligamentum flavum, and capsular ligaments of the zygapophyseal joints-play essential roles in stability and motion control [31]. The C5-C6 and C6-C7 levels, which endure the most movement and biomechanical stress in sports, are particularly vulnerable to ASD post-fusion [32]. These are also the same levels that undergo the highest flexion-extension and axial rotation, making them especially prone to accelerated degeneration after fusion [33].

While expandable cages may optimize sagittal balance immediately after surgery, they do not mitigate the increased intradiscal pressures and shear forces at adjacent levels, which accelerate degeneration of the facet joints and intervertebral discs [34]. The fusion process-where fibrous tissue is gradually replaced by woven and then lamellar bone-takes time for proper maturation and remodelling, and premature loading can increase the risk of pseudarthrosis or adjacent segment degeneration [35]. From a surgical perspective, over-distraction, particularly in athletes with pre-existing cervical stenosis, can increase stress on posterior elements and facet joints, potentially leading to facet joint subluxation or accelerated arthrosis. Given the lack of clear long-term benefits, we must question the cost-effectiveness of expandable cages, which often carry a significant price premium over static cages and whether the marginal benefits justify the economic burden for recreational athletes. Moving forward, we believe future research should focus on sport-specific biomechanical analyses to develop more tailored surgical approaches. Until long-term, sport-specific studies provide more definitive answers, we remain cautious in universally adopting expandable cages for athletes, prioritizing evidence-based practice over marketing-driven innovation in the high-stakes world of sports medicine and spinal surgery.

Conclusion

Expandable cervical cages offer a great deal of intraoperative flexibility in restoring cervical spine alignment, with the additional utility in athletes who are under unique biomechanical stresses. They enable fine surgeon control of cervical lordosis and intervertebral height with the potential to reduce the risk of subsidence and implant failure. Their superiority over static cages has not been established in the literature, though. Specifically, questions about their long-term stability, effect on the health of the adjacent segment, and success in preserving sports performance and career longevity remain. The biomechanical complexities, including micro-motion at the cage-endplate interface and cervical spine stress distribution with athletic loading, are largely un investigated. Clinicians are therefore compelled to use expandable cages with cautious restraint, paying close attention to both patient-specific considerations such as the specific sport, position and biomechanical stresses of the individual athlete and to more general considerations such as cervical kinematics, bone quality and degenerative disease present preoperatively. The economic considerations, predicated on the typically greater expense of expandable cage technology, also demand close attention. In the absence of more extensive, athlete-specific longitudinal research, a conservative and cautious approach using both adjustable and fixed cage instrumentation, non-operative management and specialized rehabilitation strategies must remain the standard of care for professional athletes with cervical spinal reconstruction.

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