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Original Research Article

A Systematic Review of the Use of Expandable Cages in the Cervical Spine

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Abstract:
Expandable vertebral body replacement cages (VBRs) have gained significant utilisation in the field of orthopaedic surgery for the purpose of reconstructing the thoracolumbar spine subsequent to corpectomy procedures. Nevertheless, their utilisation in the cervical spine is less prevalent, and at present, no expandable cages available in the market have obtained clearance or approval from the US Food and Drug Administration for implementation in the cervical spine. The primary aim of this investigation was to conduct a comprehensive systematic review pertaining to the utilisation of expandable cages in the management of cervical spine pathology. The review specifically emphasised the assessment of fusion rates, deformity correction, complications, and indications associated with this treatment modality. A thorough literature search was conducted using the Medline database, resulting in the identification and inclusion of 24 relevant articles for the purpose of this review. The benefits of expandable cages encompass enhanced ease of implantation with reduced risk of end plate damage, minimised intraoperative manipulation of the device, and potentially heightened control over lordosis. They may confer notable benefits in instances characterised by compromised bone integrity, such as individuals afflicted with osteoporosis or those with radiated metastatic tumours. Nevertheless, it is crucial to acknowledge the potential hazard of excessive distraction, particularly in the cervical spine region. The limited height of these devices restricts their applicability in instances involving collapsed vertebrae. Additionally, it is important to consider that the expansion mechanism's hardware may impose limitations on the available surface area for fusion. The utilisation of expandable vertebral body replacements (VBRs) represents a valuable asset in the armamentarium for the surgical reconstruction of the anterior column of the cervical spine, demonstrating a satisfactory safety profile. While the advantages of employing expandable cervical cages in specific clinical scenarios are evident, it is not justifiable to adopt their extensive utilisation after all corpectomies. This is primarily due to the considerably higher expenses associated with expandable cervical cages when compared to structural bone grafts or non-expandable vertebral body replacements (VBRs). It is worth noting that these alternative options can be employed to attain comparable clinical outcomes.

Keywords: Expandable cage, Vertebral body replacement, Supplemental fixation, Cervical corpectomy, Biomechanics

Introduction

Expandable cages (ECs) are commonly employed in the field of orthopaedic surgery to facilitate the reconstruction of the anterior spinal column subsequent to corpectomy procedures. The indications for this procedure encompass spinal canal stenosis accompanied by spinal cord compression [1], fractures [2,3], spondylodiscitis [4], and metastases [5]. A cervical corpectomy is frequently indicated for the purpose of anterior spinal decompression in the management of degenerative spondylosis, traumatic injuries, primary or metastatic neoplasms, osteomyelitis, kyphosis or deformity, and ossification of the posterior longitudinal ligament (OPLL).

After undergoing corpectomy, it is necessary to perform reconstruction of the anterior column, which has been previously approached using various methods in medical literature. The solid anterior support offered by these devices demonstrates remarkable primary stability [6], while minimising the potential for end plate damage, reducing intraoperative manipulation, and potentially enhancing lordosis control when compared to non-expandable cages [7, 8]. They may confer notable benefits in instances characterised by compromised bone integrity, such as individuals diagnosed with osteoporosis or those afflicted with radiated metastatic tumours [8].

Nevertheless, it is crucial to acknowledge the potential hazard of excessive distraction, as well as the possibility of hardware constraints within the expansion mechanism that could restrict the available surface area for fusion [8].

The utilisation of expandable cages has been documented in the medical literature for a duration exceeding 10 years. However, their prevalence has been more prominent in posterolateral approaches to the thoracolumbar spine, while their application in the cervical spine has been comparatively restricted [9, 10]. The primary aim of this investigation was to conduct a comprehensive analysis on the utilisation of expandable cages in managing cervical spine pathology. The study specifically examined fusion rates, deformity correction, complications, and indications associated with this treatment approach. The intention behind this research was to provide valuable insights and recommendations to surgeons in their clinical decision-making process.

Methods

A thorough and extensive search was performed utilising the Medline database in order to identify all pertinent studies that document the utilisation of expandable cages in the cervical spine. A systematic literature review was performed using the MEDLINE database to identify relevant studies on expandable cages and distractible vertebral body replacements. The search terms used included "expandable cage," "expandable vertebral body replacement," "expandable VBR," "distractable cage," "distractable vertebral body replacement," "distractable VBR," "distractible cage," "distractible vertebral body replacement," and "distractible VBR." The search was limited to articles published between January 1, 1990, and October 31, 2022, as expandable cages were not utilised prior to this period.

The identical search terms were subsequently employed in a Google Scholar query. The analysis encompassed scholarly literature encompassing case reports, case series, retrospective reviews, prospective observational studies, and prospective controlled trials. However, it is worth noting that no prospective controlled trials were found during the search. Based on the specified search criteria, a total of 165 manuscripts were identified in the academic database. Excluded from consideration were articles that did not encompass the utilisation of the cervical spine and those that were not written in the English language. After applying the specified criteria, a total of 24 pertinent studies were identified, out of which 20 studies included clinical data. The citations of the pertinent studies were also examined, however, no additional studies that satisfied the predetermined criteria for inclusion and exclusion were found.

Results

A comprehensive review of the pertinent literature is presented, encompassing studies from references [1-20]. The manuscripts were categorised according to the specific variant of expandable vertebral body replacement (VBR) employed. Various vertebral body replacements (VBRs) utilised in the cervical spine have been documented in the medical literature. These include the Anterior Distraction Device (ADD), ADDplus, Cervilift, Synex Expandable Cervical Cage (ECC), Tecorp-C, Osteotech VBR, and Titanium Porous Surface (TPS) VBR. The utilisation of Attention Deficit Disorder (ADD) or ADDplus was documented in a total of nine scholarly investigations. The Synex device was examined in two academic studies, while the Tecorp-C device was evaluated in three academic studies. The TPS device was investigated in two academic studies, whereas the cervilift device was explored in one academic study. Additionally, the Osteotech device was examined in one academic study. It is worth noting that the specific type of cage employed was not specified in four academic studies. All patients in the study underwent either the placement of an additional anterior plate, posterior supplemental fixation, a combination of both, or a vertebral body replacement (VBR) procedure with incorporated anterior fixation, such as the ADDplus or TPS. However, it is worth noting that two patients in the study conducted by Alfieri et al. [1] were treated solely with a VBR procedure, without any additional fixation methods.

A total of 333 patients underwent the utilisation of expandable vertebral body replacements (VBRs) in the cervical spine. The most prevalent indication observed was degenerative spondylosis, accompanied by trauma, osteomyelitis, tumour, deformity, and OPLL, which were frequently documented as well. The vertebral body replacements (VBRs) were employed for the purpose of reconstructing a single level in 130 individuals, two levels in 86 individuals, three levels in 19 individuals, four levels in 3 individuals, and the specific number of levels was not specified for 95 individuals. While the fusion rates were not explicitly documented in eight studies, the evaluation of fusion was typically conducted by observing the absence of movement on flexion-extension radiographs. Four studies employed computed tomography (CT) scans to evaluate fusion outcomes. Based on the aforementioned criteria, the fusion rates reported in the literature varied between 79% and 100% during a follow-up period ranging from 9 to 41 months. A total of nine scholarly investigations were conducted to assess the sagittal alignment subsequent to the insertion of cages, which are orthopaedic devices used in spinal surgeries. These studies documented noteworthy enhancements in the cervical lordosis, ranging from 4° to 22°.

The occurrence of subsidence was identified as the prevailing adverse event, with reported rates ranging from 0% to 43%. However, it is important to note that surgical revision was typically unnecessary in cases of subsidence. A surgical revision was deemed necessary for a patient who exhibited a smoking habit subsequent to the excessive removal of the end plate [20]. Arts and Peul [2] documented the most notable subsidence rate, reaching 43%, accompanied by a reoperation rate of 20% due to hardware failure. It is worth noting that all of these instances were associated with the implantation of the TPS device. Additional documented complications encompassed fractures of the vertebral body in the adjacent segment necessitating surgical intervention, temporary paralysis of the C5 nerve root due to excessive stretching of the intervertebral cage, temporary difficulty in swallowing (dysphagia), unintended tears in the protective covering of the spinal cord (durotomy), and injury to the oesophagus.

Discussion

In the last decade, there has been a significant surge in the utilisation of expandable cages for the purpose of cervical spine reconstruction subsequent to corpectomy. Based on current understanding, this manuscript represents the initial comprehensive analysis of the utilisation of expandable or distractible vertebral body replacement devices in the cervical spine.

The conventional gold standard for the reconstruction of the anterior column of the cervical spine is tricortical iliac crest autograft, renowned for its remarkable fusion rate. However, it is accompanied by a considerable complication rate and notable morbidity at the donor site, with complications or morbidity observed in as much as 90% of cases [15, 18]. In a recent scholarly review, a study documented a complication rate of 19% for the iliac crest donor site. The reported complications encompassed various medical issues such as infection, hematoma, fracture, and scarring [12]. While the utilisation of structural allograft has effectively alleviated certain complications, an alternative approach involves employing immobilised cages composed of materials such as titanium mesh, PEEK, or carbon fibre. Lied et al. [16] conducted a prospective, non-randomized study that compared the utilisation of autograft and polyetheretherketone (PEEK) interbody cages in the context of anterior cervical discectomy and fusion (ACDF). The study revealed comparable clinical outcomes between the two approaches, but noteworthy adverse effects associated with the autograft group, specifically in terms of donor site morbidity.

One potential drawback associated with non-expandable ventricular balloon catheters is the inherent difficulty in achieving optimal placement. These immobilised devices or grafts are commonly manufactured with predetermined dimensions and end plate angles, necessitating intraoperative modifications of the cage to achieve an optimal fit [2, 9]. If the medical device undergoes trimming, it is imperative to ensure its proper positioning in the appropriate rotation to prevent the potential development of a deteriorating kyphosis. The non-expandable vertebral body replacements (VBRs) must be firmly inserted, which may result in heightened distraction forces on the vertebral end plates. This, in turn, increases the likelihood of end plate damage and cage subsidence, as indicated by previous research [18]. The potential for end plate damage may also arise in the event of intraoperative cage removal or repositioning. Moreover, the enhancement of lordosis may pose increased difficulty when dealing with the fixed vertebral body replacements (VBRs).

One notable benefit of expandable vertebral body replacements (VBRs) for cervical spine reconstruction lies in the device's inherent ease of placement in its non-expanded state. While this approach may offer potential advantages in terms of posterolateral positioning in the thoracolumbar spine, it is hypothesised to decrease the likelihood of harm to neighbouring anatomical structures in the cervical region. Additionally, there is a theoretical reduction in the risk of injury to the vertebral end plates during the placement process [11]. Furthermore, the medical devices are commonly offered in a modular configuration, encompassing a variety of core diameters (typically ranging from 12 to 16 mm, as commonly employed in the cervical spine), heights, endcap footprint, size, shape, and angle. The extensive array of available choices offers substantial versatility for the surgeon in fabricating an optimally sized and contoured structure for the corpectomy defect [5]. The Vertebral Body Replacements (VBRs) are commonly fabricated using titanium, although certain variations utilising Polyether Ether Ketone (PEEK) are also accessible. Moreover, a considerable number of the medical devices are specifically engineered for the purpose of supplementation with an anterior plate or posterior fixation. Furthermore, it is worth noting that certain devices also feature an integrated anterior fixation system [7].

The majority of the studies conducted in this field consisted of case series or retrospective reviews that focused solely on reporting the outcomes of expandable cage utilisation. However, it is worth noting that there was only one study group that conducted a comparative analysis between the outcomes of using a distractible cage and employing structural autograft along with a fixed PEEK cage [13]. Although the evaluation of fusion rates and sagittal alignment was not conducted, the study revealed comparable neurologic outcomes across

all reconstruction methods. However, it is worth noting that the static polyetheretherketone (PEEK) cage exhibited significantly higher levels of subsidence compared to the other two groups.

Biomechanics and supplemental fixation

The cervical spine exhibits a distinctive biomechanical profile in contrast to the thoracolumbar spine, characterised by notable flexion/extension, lateral bending, axial rotation, and compression/distraction [5, 11]. Moreover, it is devoid of the reinforcement provided by the rib cage, which is a characteristic feature of the thoracic spine.

Due to the distinctive biomechanical properties associated with the utilisation of expandable cages, a significant apprehension arises regarding the potential for excessive cage distraction. This could potentially lead to neurological impairment or structural harm. In the study conducted by Yoganandan et al. [14], tensile loads were applied to intact human cadavers until failure occurred. The results indicated a mean failure load of 3.4 kilonewtons (kN) with a mean distraction of 21.3 millimetres (mm). Additionally, it was discovered that the cervical spine exhibited heightened sensitivity to axial tensile loads, specifically at the C6-7 level. This observation was made when examining an explanted O-T3 spine, which demonstrated a notably reduced average failure load of 1.6 kN during a distraction of 27.1 mm. The aforementioned data suggests that in the cervical spine, there is a higher susceptibility to injury due to excessive expansion of the cage. This is attributed to the fact that a significantly lower force is required to achieve a greater distraction. While there is a lack of documented catastrophic failures of the spinal column resulting from overdistraction in the medical literature, it is worth noting that two instances of neurologic injury have been reported. As an example, Arts and Peul [2] documented a case study involving a patient who experienced transient C5 palsy as a result of excessive cage distraction. Similarly, Shen et al. [3] reported a case study involving a patient who suffered from a lumbar nerve root injury due to excessive expansion of the cage.

While expandable vertebral body replacements (VBRs) do possess various advantages compared to fixed devices or structural bone grafts, existing evidence does not demonstrate a significantly distinct biomechanical profile for these implants. For example, Kandziora et al. [20] conducted a comprehensive investigation on the biomechanical properties of the Synex-C expandable cage, utilising both titanium and PEEK materials. The study involved a comparison with tricortical autograft and a titanium mesh cage, employing a C4 cadaveric corpectomy model. The objective of the reconstruction procedure was to reinstate the preoperative vertical dimension. The efficacy of the implants was assessed in isolation, in conjunction with an anterior plate, and in combination with anteroposterior supplemental fixation. There were no observed disparities in the range of motion or stiffness between the expandable and non-expandable devices. However, it is worth noting that the expandable cage exhibited notably reduced motion and increased stiffness compared to the structural autograft specifically in rotational movements. The inclusion of an anterior plate resulted in a notable reduction in range of motion and an increase in stiffness when compared to using a standalone implant for all three types of reconstruction. Furthermore, the addition of posterior supplemental fixation further decreased the range of motion, resulting in stiffness that was up to 102% greater than that observed with the anterior plate alone. Nevertheless, this particular model solely evaluated a single-level reconstruction, without incorporating any angulation of the device end plates.

Another form of fixation involved the utilisation of cages, such as the ADDplus or TPS, which integrated anterior fixation screws within the cage structure. Although there is a lack of biomechanical data pertaining to these devices, it is generally observed that they exhibit comparable rates of subsidence and fusion when compared to the ADD cage combined with an anterior plate. Nevertheless, Cabraja et al. [8] documented an 11% pseudoarthrosis incidence necessitating revision with the anterior disc degeneration (ADD) plus technique, along with an elevated subsidence rate when compared to the ADD cage combined with an anterior plate.

Another study evaluated the impacts of various fixation combinations in a two-level cervical corpectomy model with a structural allograft reconstruction [15]. The study revealed that the utilisation of combined anterior plating and posterior fixation, as well as posterior fixation in isolation, demonstrated a significantly higher degree of rigidity compared to the utilisation of anterior plating alone. Nevertheless, no discernible distinction was observed between the implementation of anterior-posterior supplementation and the exclusive utilisation of posterior fixation. In a related study, Koller et al. [12] conducted research on the impacts of various fixation combinations in a two-level cervical corpectomy model, incorporating a reconstructive technique involving a distractible cage. The study revealed that the utilisation of anterior plating as a standalone technique exhibited a notably enhanced range of motion in flexion-extension, lateral bending, and axial rotation, in comparison to the utilisation of posterior fixation with lateral mass screws alone or the combined approach of anterior plating and lateral mass screw fixation. The 360-degree construct demonstrated statistical similarity

to the lateral mass screw-only construct, with the exception of axial rotation, where the 360-degree construct exhibited significantly reduced motion. These disparities have been clinically observed, wherein a 9% failure rate was noted when a two-level corpectomy was reconstructed solely with anterior plate supplementation. Furthermore, this failure rate escalated to 50% when a three-level corpectomy was reconstructed with only anterior plate supplementation [17].

The notable enhancement in fixation resulting from the inclusion of an anterior plate and/or posterior supplementation suggests that, even in the case of a single-level corpectomy, it is advisable to employ certain forms of supplementary fixation. This was observed in the existing literature as all patients underwent the placement of an anterior plate and/or posterior fixation, with the exception of two patients. In our clinical setting, it is customary to employ solely an anterior plate for a single-level corpectomy. However, in the case of a two-level corpectomy, it is frequently necessary to implement supplementary posterior fixation in instances of compromised bone integrity, particularly in patients afflicted with metastatic pathology. It is postulated that a vertebral body replacement (VBR) encompassing three or four levels necessitates posterior supplementation in order to ensure sufficient stability of the construct.

Conclusion

According to this systematic review, the utilisation of expandable vertebral body replacements (VBRs) represents a valuable asset in the armamentarium for the reconstruction of the anterior column of the cervical spine, while maintaining an acceptable safety profile. The primary benefit lies in the enhanced ease of implantation, which carries a reduced risk of end plate damage, minimised intraoperative device manipulation, and the potential for improved control over lordosis. They may provide significant benefits in scenarios characterised by compromised bone integrity, such as individuals diagnosed with osteoporosis or those with radiated metastatic tumours. The modular nature and customizable features of these interventions may facilitate reduced localised stress transmission to the vertebral body, while optimising the alignment of the end plate to minimise subsidence. Notwithstanding their inherent benefits, it is imperative to acknowledge the potential peril of excessive diversion, particularly in the cervical spine. Furthermore, the utilisation of these devices may be constrained in instances involving collapsed vertebrae due to their minimum height requirements. Additionally, the extent of hardware employed in the expansion mechanism restricts the available surface area for fusion procedures. While the advantages of employing expandable cervical cages in specific clinical scenarios are evident, it is not justifiable to adopt their extensive utilisation subsequent to all corpectomies, primarily due to their considerably higher expenses in comparison to structural bone grafts or non-expandable vertebral body replacements (VBRs), despite yielding similar clinical outcomes.

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