Reviews

Anterior cervical discectomy and fusion (ACDF) with and without plating: A comparison of radiological and clinical outcomes

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Abstract

Treatment for degenerative disc disease of the cervical spine primarily aims to decompress neural structures and preserve the former height of the disc space and foramina. Popular methods include anterior cervical discectomy and fusion (ACDF) using cages with plates or without plates (standalone cages). However, it is still debatable whether a plate is necessary for enhanced treatment outcomes. This paper reviews current literature reports, adding insights from the authors' experience. A literature search was performed with keywords related to ACDF with or without cervical plating. We analyzed the titles and abstracts to identify all potentially relevant studies. Out of these, a total of 28 original research and 5 systematic reviews/meta-analyses met our inclusion criteria. The success of surgery for cervical disc disease depends fundamentally on the appropriate decompression of neural structures. This is the main determinant of postoperative clinical improvement measured according to scales capturing changes in pain intensity and quality of life. An ideal replacement for natural components of the human body does not exist, even though more and more refined solutions are developed every year. A comparison of treatment outcomes using non-plated (standalone) cages and cage + plate systems requires separate analysis of radiological and clinical outcomes. Both methods have their advantages and disadvantages. Radiological outcomes are slightly better with cage + plate systems, and clinical outcomes are comparable.

Key words: anterior cervical discectomy and fusion, standalone cervical cages, cervical plates, self-anchoring cervical cages, ACDF outcomes

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Introduction

The cervical segment of the spinal column is a complex anatomical and biomechanical structure. It exhibits the highest degree of mobility among all spinal segments, making it a pivotal component in the preservation of overall sagittal balance and functional integrity. The curvature of the cervical segment is shaped by a range of factors, such as muscle tone distribution in the neck and the shoulder girdle or the shape of the thoracic and lumbosacral segments. The curvatures of individual spinal segments influence each other. Regrettably, similar to other spine regions, the cervical segment is susceptible to degenerative alterations that may necessitate surgical intervention. The primary aim of the treatment for degenerative disc disease of the cervical spine is to decompress neural structures and preserve the former height of the disc space and foramina. Anterior cervical discectomy without the simultaneous insertion of a graft or cage is not recommended because there is a possibility of future instability and kyphotic malalignment of the cervical spine.[1] Anterior cervical discectomy and fusion (ACDF) is currently the gold standard for surgical treatment of degenerative disc disease of the cervical spine. An interbody implant should have a size that produces a tight interference fit and maximizes the dimensions of the graft–vertebral body interface. Popular methods include an ACDF using a standalone cage or a cage with a cervical plate. However, it is still debatable whether a plate is necessary for enhanced treatment outcomes. Both methods have their advantages and disadvantages. Most surgeons believe that plating is not necessary for single-level surgery, but operations on multiple levels require additional strengthening of the fixation obtained using a cervical plate. This paper reviews current literature reports, with insight added from the authors' experience. Anterior cervical plates may increase interbody fusion rates and stability, maintain or improve cervical sagittal alignment, and prevent subsidence, particularly in multiple-level ACDFs. However, anterior plating may also be associated with potential disadvantages and complications. The complications associated with plate fixation consist of esophageal soft tissue damage, neurovascular injuries and dysphagia. The success of surgery for cervical disc disease depends fundamentally on the appropriate decompression of neural structures. This is the main determinant of postoperative clinical improvement measured using scales which show changes in pain intensity and quality of life.

Objectives

The aim of this study was to compare the clinical and radiological outcomes of ACDF with a standalone cage to ACDF performed with a cage with a cervical plate.

Materials and methods

This paper reviews current literature reports and also offers insight from the authors' experience. Relevant published studies indexed in MEDLINE were first identified using PubMed and then reviewed by the authors. A literature search was performed with keywords related to ACDF with or without cervical plating, such as "anterior cervical discectomy and fusion", "standalone cages", "cervical plates", "self-anchored cervical cages", "zero-profile cervical cages", "cervical alignment", "subsidence", "fusion rate", and "ACDF outcomes". We studied the titles and abstracts of identified articles and full texts of all potentially meaningful academic papers. Out of these, 28 original research articles and 5 systematic reviews/meta-analyses met our inclusion criteria necessary to compare the radiological and clinical outcomes of surgery for cervical disc disease using standalone cages or cages with cervical plates. Then, we supplemented the analyzed literature with other original contributions, review articles and case reports that do not directly compare ACDF with standalone cages and ACDF with cage + plate, but do describe important aspects of surgery for cervical disc disease such as subsidence, adjacent segment disease (ASD), cervical alignment, types of interbody implants and cervical plates, materials that implants are made of, and complications after ACDF. In our experience, original reports contain more practical advice and information, while meta-analyses/systematic reviews are more mathematical/statistical in nature, analyzing large numbers of cases. Radiological outcome refers to parameters such as fusion rate, IDH, subsidence, and cervical alignment, assessed based on postoperative imaging. Clinical outcome refers to the changes in parameters assessing the quality of life and pain. When comparing the radiological and clinical results of ACDF with standalone cages compared to cage + cervical plating, the type of implant and the technique of implant fixation in the interbody space should also be considered. The recently popular zero-profile implants consisting of a cage fixated to the adjacent vertebral bodies with screws introduced through the implant are usually included in the same group as typical standalone cages, which are placed in the interbody space without using additional fixation. There are, undoubtedly, differences between these 2 types of implants that affect their biomechanics. Nevertheless, to ensure a common methodology and a large number of studies needed to compare treatment outcomes, authors often do not draw finer distinctions concerning the type of interbody implant, the material used to produce the implant, the implant's surface area, the presence or absence of spikes/serration for anchoring in the interbody space, or the presence or absence of a dedicated space to be filled, for example, with fusion-promoting hydroxyapatite. To make a more systematic comparison of individual groups, we grouped reports concerning typical standalone cages and zero-profile cages, also known as self-anchoring or self-locking cages.[2,3] Similarly, most studies comparing ACDF procedures with standalone cages or cages + plates did not distinguish between the distinct types of plates, i.e., wide plates fixed to each vertebral body with 2 screws or narrower plates fixed to each vertebral body with 1 screw. The most significant difference between traditional cage and plate structures and the zero-profile implant is that the zero-profile implant uses no additional plate fixed to the anterior surface of the vertebral body.

Results

The ACDF is a commonly used and successful surgical treatment for patients with cervical disc disease. Neural decompression should be combined with interbody stabilization or additional placement of a cervical plate. The neurosurgeon and orthopedist communities have not yet developed an unequivocal position on the necessity of cervical plating with ACDF procedures. It has been questioned whether plate fixation is necessary, especially in single-level fusion, irrespectively of its disadvantages. Most surgeons believe that plating is not necessary for single-level surgery, but operations on multiple levels require additional strengthening of the fixation obtained using a cervical plate. This is not done to prevent spinal instability but to strengthen the cage, expedite fusion and preserve the postoperative height of the disc space near-physiological cervical alignment.[4–7] At the same time, awareness of the postoperative complications believed to be related to the presence of an anterior plate has been contributing to a rising interest in non-plated techniques such as standalone cages. It has been shown that the design of zero-profile implants provides a similar degree of biomechanical stability conferred by anterior plating, simultaneously avoiding increased retraction and anterior bulk connected with plating.

Cervical cages and plates

At present, the most commonly used interbody cages in cervical spine procedures comprise of polyetheretherketone (PEEK) implants, titanium-coated PEEK cages and titanium implants. Apart from the type of material, the implants are made of, their shape and surface morphology also play an essential role in obtaining fusion.[8] Implant surface morphology can be two-dimensional (2D) or three-dimensional (3D). Most 2D surfaces have irregularities emulating indentations produced by the action of osteoclasts. These indentations generally serve to promote a beneficial response of bone tissue to such morphology.[9,10] For better anchoring in the interbody space, implant manufacturers offer implants with corrugated surfaces and additional protruding titanium spikes placed (immersed) in upper and lower implant surfaces. Furthermore, the so-called hybrid implants are also available, comprising an interbody cage connected to a plate (cage and plate as one device). In contrast to 2D implants, the porous surfaces of 3D implants are characterized by an interconnected porous spatial network to enhance bone integration and produce mechanical locking (entanglement) of bone and implant surfaces.[11–13] Unlike traditional titanium implants, more recent 3D titanium implants build with porous surfaces produced with laser 3D print technologies are not a source of significant artifacts in postoperative magnetic resonance imaging (MRI) assessment, thus allowing for a detailed postoperative evaluation of the anatomical structures of the cervical spine. The PEEK implants with a porous surface manufactured with 3D technology are relatively new on the market. Laboratory studies have demonstrated that porous PEEK increases osteoblastic differentiation of cells in vitro and improves osseointegration in vivo compared to both smooth and titanium-coated PEEK. These results have been ascribed to improved mechanical bone locking by the implant's porous spatial surface.[8] A wide variety of plating systems are available. The placement of early devices was associated with piercing the posterior cortex of the vertebral body (bicortical fixation). Contemporary cervical plating systems are designed for uni-cortical placement to avoid posterior bicortical penetration of the cervical vertebra so that neural structures are not injured. New third-generation systems represent dynamic semi-constrained plates designed to prevent stress shielding. Ideally, plates should be available in narrow and wider varieties and they should provide for small increments in plate length. Screws should ideally be marketed in variable lengths and offer variable placement angulation capability, there should be rescue screws matching the corresponding standard screw in length, and the screws should be easy to place with a reliable locking mechanism.[14–15]

Dysphagia

While the most common complication of ACDF is dysphagia, its mechanism is not fully elucidated, with hypotheses including damage to the esophagus, soft tissue edema, hematoma, and adhesions/scarring around the plate.[16] Most papers indicate a statistically lower rate of dysphagia following non-plated ACDF, with 1 report even showing a link (positive correlation) between cervical plate thickness and dysphagia.[17] Additionally, another study found improvement in the symptoms of dysphagia following the removal of a cervical plate and release of plating-induced adhesions. It reported on a series of 31 patients who had their anterior plates surgically removed due to persistent dysphagia following ACDF. There were extensive adhesions around the periphery of the cervical plate that attached the esophagus to the prevertebral fascia and anterior cervical spine. Surgery brought about a significant improvement to mild or no dysphagia in 27 patients.[18] A few high-quality systematic reviews and meta-analyses have confirmed that standalone cages are superior to cage + plate systems in reducing the risk of dysphagia.[19–22] The duration of dysphagia symptoms was also longer with plated compared to non-plated cages.[23] In multiple-level procedures, cervical plating requires more extensive surgical access and is associated with more soft tissue injury that may affect clinical status. Another important aspect of cervical plating surgery is the possibility of complications such as loosening or breakage of the screws stabilizing the plate, or plate dislocation. Of further importance is the fact that the use of cervical plates increases the cost of the procedure.[24–28] If a revision procedure is necessary for a patient with a standalone cage, there is obviously no need to remove a previously placed plate, and so the duration of the surgery may be shorter with less blood loss, less retraction of the surrounding tissues, and a reduced risk of postoperative dysphagia.

Adjacent segment disease (ASD)

A significant aspect of surgery for cervical disc disease is the risk of ASD. Biomechanically, the abolition of mobility within a disc space should lead to the adjacent motion segments below and above the operated segment partly taking over the mobility of the non-mobile segment. Adjacent segment disease is the product of several factors – an accumulated result of natural degeneration and biomechanical changes following fusion within the original motion segment operated on, such as ROM changes of the adjacent segments, changes in the sagittal profile of the spine, and increased intradiscal pressures in the adjacent discs.[29] Symptomatic ASD is the most common underlying cause of revision surgery following ACDF, in up to as many as 47% of patients.[30] The possibility of symptomatic ASD occurrence is higher after single-level fusion than multilevel one, especially if the non-fused segments belong to levels C4–C6. Artificial disc replacement has gained increasing enthusiasm as a motion-sparing alternative to fusion. Nevertheless, despite conducting multiple clinical trials and follow-up studies, the reduction of ASD has not been evidenced when artificial disc replacements are performed instead of fusion. Most of the available published reports indicate a lower risk of ASD with standalone cages than following cage + plate procedures.[16,19,21–23,31–37]

Subsidence and intervertebral disc height (IDH)

Implant subsidence after ACDF is a widely known, undesirable effect that should be prevented. Reduced disc space height may lead to foraminal stenosis. A review of implant subsidence data in the available literature reveals the superiority of cage + plate procedures over the placement of standalone cages regarding the prevention of this undesirable phenomenon. Subsidence can be reduced if the mechanical properties of vertebral endplates are retained to the greatest extent possible during the surgery. From a pathophysiological angle, some of the endplates need to be removed so that bone union can occur, but injury to endplates facilitates subsequent sinking of the cage into the vertebral bodies. Cage subsidence occurs more often when endplates are removed. Implant subsidence has been defined in several ways. Two definitions see it as the immersion length of the cage (in millimeters) beyond the borders of the adjacent endplates or as the percentage reduction in interbody space height. The decreased interbody space height may produce foraminal stenosis. The risk of cage subsidence is higher in the presence of a smaller anteroposterior cage diameter, more posterior placement of the cage in relation to the vertebral body, and a smaller cage surface area resulting in endplate coverage.[38] There is a significant relationship between subsidence and a coefficient representing the ratio of the implant surface area to the surface area of bone of the adjacent vertebral bodies: Subsidence is significantly less frequent for coefficient values ≥0.37.[39] Cage subsidence may adversely affect spinal biomechanics and alignment, be the cause of segmental kyphosis and contribute to ASD. Additional anterior plate fixation is recommended when endplates are removed.[40]

Cervical alignment

The normal lordotic alignment of the cervical spine is crucial for ensuring good motion and function of the cervical spine. Alignment in the sagittal plane is important for the distribution of stress across fixation devices. Loss of cervical lordosis theoretically increases the risk of ASD as a kyphotic alignment of the cervical segment accelerates degenerative changes in that segment by augmenting biomechanical stress on the anterior portion of the vertebral bodies of adjacent segments.[41] The most marked alterations in lordosis and intervertebral space height are seen immediately after surgery, with baseline values subsequently usually decreasing gradually over time, but postoperative values at 12 or 24 months are still better than baseline. The curvature of the cervical segment is shaped by a range of factors, such as muscle tone distribution in the neck and the shoulder girdle or the shape of the thoracic and lumbosacral segments. The curvatures of individual spinal segments influence each other. Cervical spine surgery introduces slight modifications to the pre-surgical anatomic relations. Efforts are always made to restore the near-anatomical relationships; however, it is important to note that complete restoration of physiological cervical alignment cannot be guaranteed, and the anatomical changes visible in immediate postoperative radiographs may not be permanent. The preservation of better parameters of cervical alignment following cage + plate procedures is particularly visible after multiple-level surgery, while following single-level surgery, differences between the groups are less evident, or, in some reports, no significant differences are noted.[20,22,23,42–44]

Appropriate rehabilitation appears quite important for maintaining normal spinal curvatures. A meta-analysis by Cheung et al. indicates that cage + plate procedures are associated with better postoperative radiographic appearances, with near-normal values of indices of cervical lordosis and disc space height and lower rates of implant subsidence.[45] Another meta-analysis/systematic review by Liu et al. provided slightly diverging data regarding disc space height as it failed to find a statistically significant difference in disc space height between pre-operative, immediate postoperative and last-follow-up radiographs in patients with non-plated (standalone) compared to plated cages. At the same time, the authors confirmed better preservation of cervical alignment following cage + plate procedures.[23]

Fusion rate

Regarding the possibility of obtaining better fusion, results vary, but most reports indicate the superiority of cage + plate procedures over the implantation of standalone cages, with fusion occurring earlier following cage + plate surgery than after standalone cage implantation.[46–48] Contrarily, Nabhan et al. in their radiographic analysis of fusion progression following plated compared to non-plated single-level cervical fusion did not reveal any statistical differences between both groups. Three-dimensional analysis of segmental motion (left-right, craniocaudal and posterior-anterior) failed to reveal statistical differences at any postoperative follow-up visits. The results obtained using visual analogue scale (VAS) were also not different between the groups.[24] A biomechanical study of cadavers subjected to 2-level ACDF with either a standalone cage or cage + plate performed by Nayak et al. concluded that a standalone cage confers comparable rigidity/stability to cage + plate.[49] Scholz et al. demonstrated no differences in flexion/extension, lateral bending or axial rotation between the standalone cage and cage + plate groups.[50] The most significant difference when comparing the zero-profile and traditional cage and plate structures is that the zero-profile implant has no additional plate attached to the anterior aspect of the vertebral body. Connecting the anterior plate to adjacent vertebrae with straight locking screws provides a strong anterior tension band and very rigid fixation, whereas only intersegmental fixation is obtained using the zero-profile device. We know from biomechanical studies that the self-locking standalone cage provides less cervical spine stiffness than the locking plate in 2- or 3-level instrumentation.[51,52] Gandhi et al. studied, among others, the degree of fusion in cases when surgery was necessary on account of ASD. Their analysis of such procedures did not detect a substantial difference in fusion at the site of previous surgery between patients bearing standalone cages compared to cage + plate systems.[2] An optimal radiographic outcome following ACDF is defined as complete fusion without implant subsidence. However, even with implant subsidence, it is still possible for complete fusion at the implant site to occur later. Even if, initially, there is a disruption of endplate continuity and penetration of the implant towards an adjacent vertebral body, it is still possible for complete fusion to occur around the implant. The use of computed tomography (CT) is a reliable, modern approach to evaluating fusion status. The plate curve reduces the likelihood of loss of global cervical lordosis and the fusion segment angle, while also preventing cage subsidence during the fusion process.[53]

Clinical outcomes

Divergent data are provided in the literature regarding fusion, implant subsidence and cervical alignment, and their direct impact on the patient's clinical status. The success of surgery for cervical disc disease depends mostly on the appropriate decompression of neural structures. This is the main determinant of postoperative clinical improvement measured according to scales capturing changes in pain intensity and quality of life. Subsidence and disruption of the physiological spinal curvatures may contribute to ASD and pain. Some state that complete fusion (arthrodesis) improves the clinical outcome, while others claim that fusion does not correlate with clinical outcomes.[54–57] Karikari et al. reported that the finding of implant subsidence was not directly related to the patient's clinical status or symptoms in most cases.[57] The changes in cervical spine alignment and disc space height are not reflected directly in the quality of life or pain intensity. Surgical outcomes are primarily related to adequate decompression of the spinal cord and nerve roots. The focus for the operating surgeon should be on adequate decompression of neural structures and necessary stabilization, while restoration of ideal physiological cervical alignment should not be attempted as the latter does not contribute decisively or directly to treatment outcomes. Still, it should be borne in mind that when cervical lordosis is restored or maintained, this may reduce the future likelihood of ASD.[58–60]

Key differences between standalone cage compared to cage + plate procedures

Based on the analyzed literature and our own experience of many years in surgery for cervical disc disease, we summarized the most significant differences between standalone cage and cage + plate procedures, and presented the analyzed information in Table 1.

Limitations

Including standalone cages and zero-profile cages, also known as self-anchoring or self-locking cages, in one group, despite some differences between them, is not an ideal solution, but it was done intentionally to systematize comparable treatment methods.

Table 1. Summary of key differences between standalone cage compared to cage + plate procedures

Criterion	Standalone cage	Cage + plate
Fusion	inferior fusion indices	superior fusion indices
	longer time to fusion	shorter time to fusion
Intervertebral disc height	inferior preservation of disc space height achieved	superior preservation of disc space height achieved
Subsidence	greater risk	lower risk
Cervical alignment (multiple-level surgery)	inferior cervical alignment indices	superior cervical alignment indices
cervical alignment (single-level surgery)	similar cervical alignment indices	similar cervical alignment indices
Dysphagia	lower rates of dysphagia	higher rates of dysphagia
	shorter time to resolution of dysphagia	longer time to resolution of dysphagia
Adjacent segment disease	lower risk	higher risk
Surgery duration	shorter	longer
Cost of surgery	lower	higher
Technical difficulty of revision/repeat surgery	less	more
Clinical outcomes (pain, quality of life)	comparable	comparable

Conclusions

An ideal replacement for natural components of the human body does not exist, even though increasingly more refined solutions appear every year. A comparison of the outcomes of standalone cage and cage + plate procedures should separately analyze radiological and clinical outcomes. Both methods have their advantages and disadvantages. Overall, radiological outcomes are slightly better following cage + plate procedures, while clinical outcomes are comparable.

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