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Cervical disc arthroplasty for cervical degenerative disease: a narrative review of outcomes, expanding indications, and complication management

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Abstract. Cervical Disc Arthroplasty (CDA) has emerged as a motion-preserving alternative to Anterior Cervical Discectomy and Fusion (ACDF) for selected patients with cervical degenerative disease, but its optimal indications and long-term risk-benefit profile remain under active debate. This narrative review summarizes representative evidence on the rationale, comparative outcomes, patient selection, multilevel applications, complications, revision strategies, and device-related considerations of CDA. PubMed-based literature relevant to cervical disc arthroplasty, cervical disc replacement, ACDF, cervical radiculopathy, degenerative cervical myelopathy, multilevel arthroplasty, and CDA-related complications was reviewed, with emphasis on randomized trials, meta-analyses, systematic reviews, long-term follow-up studies, and influential narrative reviews. Current evidence generally supports CDA as non-inferior to ACDF in overall clinical outcomes in appropriately selected patients and suggests potential advantages in preserving segmental motion and reducing adjacent segment disease and reoperation. Evidence for contiguous 2-level CDA continues to strengthen, whereas broader multilevel applications remain more selective. Heterotopic ossification, osteolysis, subsidence, migration, and revision surgery remain important concerns. Overall, CDA appears to be an increasingly established option for selected cervical degenerative disorders, but its long-term value depends on strict indications, careful technique, device-specific performance, and continued real-world follow-up.

Keywords: cervical degenerative disease, cervical disc arthroplasty, anterior cervical discectomy and fusion, adjacent segment disease, heterotopic ossification, osteolysis, multilevel cervical arthroplasty, narrative review

1. Introduction

Cervical degenerative disease remains one of the most common indications for operative intervention in spine surgery, particularly when cervical radiculopathy or degenerative cervical myelopathy persists despite nonoperative management [1-3]. In this review, the term "cervical spondylosis" is used broadly to encompass cervical degenerative disc disease, cervical radiculopathy, and selected cases of degenerative cervical myelopathy that may be considered for anterior reconstructive surgery. Anterior Cervical Discectomy and Fusion (ACDF) has long been regarded as the reference anterior procedure because it provides reliable

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decompression, reproducible stabilization, and favorable clinical outcomes [4-6]. Nevertheless, loss of index-level motion after fusion, possible acceleration of adjacent segment degeneration, pseudarthrosis, and approach-related morbidity have continued to drive interest in motion-preserving alternatives [4-9]. Against this background, Cervical Disc Arthroplasty (CDA) has evolved from an exploratory technology into an increasingly established reconstructive option for selected patients with cervical degenerative disorders [4, 5, 7, 10].

The contemporary role of CDA is no longer limited to serving as a simple substitute for fusion. Rather, it is increasingly viewed as a strategy that integrates neural decompression, segmental reconstruction, and preservation of physiological motion [4, 7, 10]. With the accumulation of randomized trials, meta-analyses, device-specific studies, and long-term follow-up data, the literature now permits a more balanced appraisal of both the potential advantages and the unresolved limitations of CDA. This narrative review summarizes the theoretical rationale, comparative effectiveness, evolving indications, multilevel applications, complications, revision strategies, and future directions of CDA in the management of cervical degenerative disease.

2. Scope of review and literature search

This article is a narrative review rather than a systematic review. Representative literature was identified primarily through PubMed using combinations of the terms "cervical disc arthroplasty", "cervical disc replacement", "anterior cervical discectomy and fusion", "cervical radiculopathy", "degenerative cervical myelopathy", "multilevel cervical arthroplasty", "heterotopic ossification", "osteolysis", and "revision", Priority was given to randomized controlled trials, meta-analyses, systematic reviews, long-term comparative studies, and influential narrative reviews that informed current clinical decision-making. The discussion was then organized around comparative outcomes, patient selection, expanding indications, multilevel applications, complications, revision strategies, and device-related considerations.

3. Developmental background and theoretical rationale

The development of cervical artificial disc replacement reflects a broader transition in spinal surgery from fusion-based stabilization to function-preserving reconstruction [7]. Hao et al. argued that the rise of CDA was driven not only by the desire to address fusion-related complications, but also by advances in biomaterials, orthopedic bionics, and engineering concepts that made physiological reconstruction increasingly feasible [7]. Derman and Zigler similarly emphasized that the original rationale for CDA was rooted in the observation that fusion can alter load sharing and motion patterns at adjacent levels, thereby potentially contributing to adjacent segment pathology [4].

From a biomechanical perspective, the theoretical advantage of CDA lies in maintaining motion at the operated level after adequate decompression. In principle, this may help preserve more physiological kinematics, reduce abnormal compensatory demands on adjacent levels, and potentially lower the incidence of secondary procedures related to adjacent segment disease [4, 5, 8, 9, 11]. However, contemporary understanding is more nuanced. The value of CDA does not derive solely from "motion preservation" as an isolated concept, but from the quality, balance, and durability of that motion. As Altorfer et al. noted, the real challenge for modern devices is not merely to permit motion, but to reproduce a stable, physiologically meaningful pattern of motion while minimizing wear, migration, subsidence, and adverse bone reactions [10]. Accordingly, CDA may be viewed as a reconstructive strategy whose success depends on both biological suitability and implant design.

4. Comparative outcomes of CDA and ACDF

High-level evidence generally supports the view that, in appropriately selected patients, CDA is at least non-inferior to ACDF with respect to overall clinical effectiveness [6, 8, 12, 13]. In a meta-analysis of 30 prospective randomized controlled trials, Peng et al. reported that artificial cervical disc replacement was associated with higher overall success, neurological success, and Neck Disability Index (NDI) success across short-, mid-, and long-term follow-up periods [8]. The same analysis also suggested lower rates of long-term adjacent segment disease and reoperation after CDA, while several perioperative variables, including length of hospital stay, blood loss, and implant-related events, were broadly comparable between the 2 procedures [8]. These findings suggest that the potential advantage of CDA may lie less in markedly different short-term recovery profiles and more in motion preservation and lower long-term secondary intervention rates. Representative comparative evidence is summarized in Table 1.

Table 1. Representative evidence comparing cervical disc arthroplasty and anterior cervical discectomy and fusion

Study	Design / population	Level(s)	Main findings	Key limitation
Peng et al. [8]	Meta-analysis of 30 prospective RCTs in cervical degenerative disc disease	1-2	CDA was associated with higher overall, neurological, and NDI success and with lower long-term adjacent segment disease and reoperation.	Heterogeneity across devices, endpoints, and trial populations.
Awawdeh et al. [6]	Systematic review of degenerative disc disease, radiculopathy, and myelopathy studies	Mixed	CDA generally showed comparable or slightly better clinical outcomes than ACDF, with more consistent ROM preservation.	Mixed study designs and variable outcome definitions.
Chen et al. [12]	Updated systematic review and meta-analysis of contiguous 2-level disease	2	Two-level CDA was associated with higher overall success and fewer secondary surgeries and complications.	Study-level aggregation and device heterogeneity.
Coric et al. [14]	Prospective multicenter comparative study using a PEEK-on-ceramic device	2	Higher 24-month composite success and preserved motion were reported with 2-level CDA.	Device-specific findings with mid-term follow-up.
Qi et al. [13]	Long-term comparative follow-up study of single-level cervical spondylosis	1	Both procedures improved symptoms durably, while CDA better maintained index-level motion at 10 years.	Single-study long-term dataset with potential selection effects.

This pattern is supported by other syntheses. Awawdeh et al. found that CDA produced clinical outcomes that were comparable or slightly superior to ACDF in terms of disability, pain relief, and neurological recovery, while more consistently preserving cervical Range of Motion (ROM) and lowering the risk of adjacent segment pathology and reoperation [6]. Long-term comparative data point in the same direction. Callanan and Radcliff concluded that cervical total disc replacement had matured to the point that its long-term results could reasonably compete with those of ACDF in selected populations [5]. Similarly, a 10-year

follow-up study by Qi et al. showed that both procedures yielded durable improvements in Japanese Orthopaedic Association scores, NDI, and visual analogue scale scores, whereas CDA was more effective in maintaining motion at the operative level [13].

For contiguous 2-level disease, the evidence base is also strengthening. In an updated systematic review and meta-analysis, Chen et al. showed that 2-level CDA was associated with higher overall success, fewer secondary surgeries, fewer complications, and better neck pain improvement than ACDF, although improvements in arm pain, NDI, and Japanese Orthopaedic Association scores did not differ significantly [12]. Likewise, Coric et al. reported that 2-level arthroplasty with a PEEK-on-ceramic device achieved a higher composite success rate at 24 months than ACDF, maintained motion at both treated levels, and required fewer reoperations [14]. Taken together, the current literature suggests that the main clinical advantages of CDA over ACDF may reside in preserving segmental motion and reducing downstream degeneration-related events, rather than in uniformly outperforming fusion across every outcome metric.

5. Indications and patient selection

The success of CDA appears highly dependent on proper patient selection [1-3, 10]. For cervical radiculopathy, conservative treatment remains the initial recommendation in most cases, and surgery is usually considered only when symptoms persist, recur, or are accompanied by progressive neurological deficit [1-2]. Kang et al. emphasized that ACDF, CDA, and posterior cervical foraminotomy each have distinct advantages, and that optimal results are more closely tied to selecting the right procedure for the right patient than to any universal superiority of one technique [2]. In this context, CDA is most attractive for patients requiring anterior decompression in whom meaningful segmental motion can still be preserved.

Interest in applying CDA to degenerative cervical myelopathy has also increased. Although myelopathy has historically been viewed as a stronger indication for fusion-based procedures, more recent evidence suggests that CDA may be feasible in selected cases [3]. In a systematic review including 844 patients with degenerative cervical myelopathy treated with CDA, Schupper et al. found generally favorable safety and clinical improvement, while also noting that direct evidence remains insufficient to conclude that arthroplasty is broadly superior to fusion in this population [3]. These findings suggest that CDA should not be considered categorically contraindicated in myelopathy, but it is better suited to patients with focal anterior compression, preserved segmental mobility, limited spondylotic stiffness, and no substantial instability [3, 10].

Imaging-based stratification is equally important. Shen et al. demonstrated that the severity of preoperative spondylosis influences postoperative Heterotopic Ossification (HO), particularly posterior HO, and identified preoperative disc height loss as an independent predictor [15]. This finding underscores a practical point: not every degenerated segment is an appropriate candidate for motion preservation. CDA is best reserved for discs that remain reconstructable, mobile, and biomechanically amenable to long-term implant function [10, 15].

6. Multilevel CDA and expanding applications

Multilevel CDA represents one of the most important frontiers in the evolution of motion-preserving cervical surgery [12, 14, 16-18]. In a systematic review, Joaquim and Riew concluded that multilevel cervical arthroplasty appears to be at least as safe and effective as ACDF in available studies, while also preserving cervical motion and potentially lowering reoperation rates [16]. Their review further noted that although HO may be more common after multilevel arthroplasty than after single-level procedures, the clinical relevance of this increase has not been consistently demonstrated [16].

Among multilevel applications, the evidence is strongest for contiguous 2-level disease. As noted above, Chen et al. found that 2-level CDA improved overall success and reduced complications and reoperations compared with ACDF [12]. Coric et al. likewise confirmed the feasibility and favorable early outcomes of 2-level arthroplasty using a PEEK-on-ceramic device [14]. These studies suggest that 2-level CDA has progressed beyond an investigational concept and now has a substantial evidence base in carefully selected patients.

By contrast, evidence for 3-level and 4-level CDA remains more limited and selective. Chang et al. reported that 3-level CDA yielded clinical improvement comparable to 3-level ACDF at 2 years while preserving greater motion at treated levels [17]. In a separate study of 4-level arthroplasty, the same group suggested that acceptable clinical and radiological outcomes can be achieved in highly selected patients with multilevel disc herniation and relatively mild spondylotic change [18]. Even so, the long-term durability of such extensive motion-preserving reconstructions remains uncertain, and current evidence is largely retrospective, device-specific, and derived from highly selected cohorts. Current literature therefore supports multilevel CDA as a promising but selective option, rather than a routine replacement for multilevel ACDF [10, 16, 18].

7. Complications, failure patterns, and revision

Although CDA offers recognized theoretical and clinical advantages, it also introduces a distinctive complication profile [10, 19-21]. Nguyen et al. summarized the short-term complications of cervical disc arthroplasty as primarily approach-related events, including dysphagia, recurrent laryngeal nerve palsy, Horner syndrome, hematoma, and, rarely, device extrusion [19]. Dysphagia remains one of the most frequently reported early complications, although reported rates vary widely because of differences in definitions and follow-up intervals [8, 19]. Accordingly, CDA should not be described as an anterior procedure with fewer complications in a broad sense; rather, it is an anterior reconstructive procedure with a different spectrum of complications from ACDF [10, 19].

Long-term concerns are more procedure-specific and include HO, osteolysis, subsidence, migration, implant wear, and structural failure [10, 19, 20]. Nguyen et al. reported highly variable rates of HO and osteolysis across the literature, reflecting differences in device design, patient selection, imaging protocols, and duration of follow-up [19]. Osteolysis is of particular concern because it may present either as an incidental radiographic finding or as a clinically significant process associated with pain, instability, implant loosening, or neurological recurrence. In a systematic review, Joaquim et al. found that asymptomatic osteolysis after CDA may be relatively common, whereas symptomatic cases often require revision, most frequently conversion to fusion [20].

Revision surgery after CDA remains uncommon but can be technically demanding. Roth et al. emphasized that the optimal revision strategy depends on the specific failure mechanism, the extent of bone loss, residual stability, and the need for renewed decompression [21]. Severe osteolysis, implant malposition, migration, marked subsidence, progressive neurological compression, or disabling HO are among the most compelling reasons to consider implant removal and fusion-based reconstruction [20, 21]. These observations reinforce the need for long-term postoperative surveillance that extends beyond symptom scores to include implant position, endplate integrity, adverse bone response, and motion pattern changes over time [19-21]. Major complications and revision considerations are summarized in Table 2.

Table 2. Major complications and revision considerations after cervical disc arthroplasty

Category	Examples	Clinical relevance	Common management implication
Approach-related events	Dysphagia, recurrent laryngeal nerve palsy, Horner syndrome, hematoma [19]	Usually early postoperative morbidity related to the anterior approach rather than the disc device itself.	Observation and supportive care for most cases; urgent evacuation for compressive hematoma.
Heterotopic ossification	Progressive ectopic bone formation with partial or complete motion loss [15, 19]	May reduce the motion-preserving effect of CDA; risk may rise with more severe preoperative spondylosis and disc height loss.	Serial radiographic follow-up; revision is generally reserved for symptomatic or functionally limiting cases.
Osteolysis	Radiographic bone loss with or without pain, loosening, or recurrent symptoms [19, 20]	May be incidental or clinically significant; severe cases can threaten implant stability.	Assess stability and symptoms with serial imaging; symptomatic cases often require conversion to fusion.
Subsidence / migration	Implant settling, malposition, or displacement [10, 19]	May compromise alignment, decompression, and long-term function.	Consider revision when progressive deformity, instability, or neurologic compromise is present.
Implant wear / structural failure	Material wear, endplate mismatch, or device failure [10, 19]	Late device-related failure may contribute to pain, adverse bone response, or recurrent compression.	Management depends on the failure pattern, often involving removal and reconstruction.
Persistent or recurrent neural compression	Residual compression, recurrent symptoms, or disabling HO [20, 21]	Symptoms may reflect incomplete decompression, implant-related failure, or progressive degeneration.	Targeted decompression with or without conversion to fusion based on residual stability and pathology.

8. Device design, evidence limitations, and future directions

As the field matures, an increasingly important question is not simply whether CDA can work, but which device may work best, for whom, and under what biomechanical conditions [10, 11]. In a comparative network meta-analysis, Zavras et al. showed that both semiconstrained and unconstrained arthroplasty designs were associated with lower risks of adjacent segment disease and adjacent-level reoperation than ACDF, while semiconstrained devices appeared to offer an advantage for reducing index-level reoperation and unconstrained designs were associated with better ROM preservation [11]. These findings suggest that device constraint is not a trivial engineering detail, but a clinically relevant determinant of long-term performance.

Altorfer et al. further argued that future progress in CDA will depend on achieving a more favorable balance among stability, physiological motion, wear resistance, endplate compatibility, and compression tolerance [10]. In other words, the next phase of advancement is likely to come not only from longer follow-up, but also from a more refined integration of biomechanics, materials science, explant analysis, and clinical registry data [10].

At the same time, the current evidence base has important limitations. Radcliff et al. noted that CDA trials may be affected by publication bias, limited external validity, confounding, and financial conflicts of interest [9]. Many trials were conducted in carefully selected populations that do not fully represent the broader

spectrum of cervical degenerative disease seen in routine practice. These limitations do not negate the value of current evidence, but they do require cautious interpretation. Future research should prioritize head-to-head comparisons among device classes, long-term outcomes in multilevel disease and myelopathy, predictive models for HO and osteolysis, standardized revision algorithms, and high-quality real-world registries [9-11, 21].

9. Conclusion

Cervical disc arthroplasty has progressed from an experimental motion-preserving concept to an increasingly established surgical option for selected cervical degenerative disorders [4, 5, 7, 8]. Current evidence suggests that, when applied under strict indications, CDA is not inferior to ACDF in overall clinical effectiveness and may offer advantages in preserving index-level motion and reducing adjacent segment pathology and reoperation [5, 6, 8, 9, 11-13]. Evidence supporting 2-level arthroplasty continues to strengthen, whereas more extensive applications remain promising but selective [12, 14, 16-18]. Heterotopic ossification, osteolysis, implant migration, subsidence, and revision-related challenges remain important barriers to broader adoption [10, 19-21]. The future role of CDA will likely depend on more precise patient stratification, improved implant design, meticulous surgical execution, and longer-term real-world evidence to better define where motion preservation provides the most durable clinical benefit [9-11].

References

[1] Iyer, S., & Kim, H. J. (2016). Cervical radiculopathy. *Current Reviews in Musculoskeletal Medicine*, *9*(3), 272-280. https: //doi.org/10.1007/s12178-016-9349-4

[2] Kang, K. C., Jang, T. S., & Jung, C. H. (2022). Cervical radiculopathy: Focus on factors for better surgical outcomes and operative techniques. *Asian Spine Journal*, *16*(6), 995-1012. https: //doi.org/10.31616/asj.2022.0445

[3] Schupper, A. J., Boylan, A. J., & Houten, J. K. (2023). Is cervical disk arthroplasty a suitable alternative to treat degenerative cervical myelopathy? *Clinical Spine Surgery*, *36*(9), 356-362. https: //doi.org/10.1097/BSD.0000000000001528

[4] Derman, P. B., & Zigler, J. E. (2020). Cervical disc arthroplasty: Rationale and history. *International Journal of Spine Surgery*, *14*(Suppl 2), S5-S13. https: //doi.org/10.14444/7086

[5] Callanan, G., & Radcliff, K. E. (2021). Cervical total disc replacement: Long-term outcomes. *Neurosurgery Clinics of North America*, *32*(4), 461-472. https: //doi.org/10.1016/j.nec.2021.05.007

[6] Awawdeh, F., Salam, A., & Soti, V. (2024). Efficacy of anterior cervical discectomy and fusion versus cervical disc arthroplasty in the treatment of cervical degenerative disc disease, radiculopathy, and myelopathy: A systematic review. *Cureus*, *16*(11), e74418. https: //doi.org/10.7759/cureus.74418

[7] Hao, D. J., Yang, J. S., Liu, T. J., Wang, B., & Li, H. (2022). The development of artificial cervical disc replacement from the perspective of orthopedic bionic therapy. *Zhonghua Wai Ke Za Zhi*, *60*(3), 203-207. https: //doi.org/10.3760/cma.j.cn112139-20211129-00564

[8] Peng, Z., Hong, Y., Meng, Y., Wang, B., & Li, S. (2022). A meta-analysis comparing the short- and mid- to long-term outcomes of artificial cervical disc replacement with anterior cervical discectomy and fusion for cervical degenerative disc disease. *International Orthopaedics*, *46*(7), 1609-1625. https: //doi.org/10.1007/s00264-022-05318-z

[9] Radcliff, K., Siburn, S., Murphy, H., Vaccaro, A., & Hillibrand, A. (2017). Bias in cervical total disc replacement trials. *Current Reviews in Musculoskeletal Medicine*, *10*(2), 170-176. https: //doi.org/10.1007/s12178-017-9399-2

[10] Altorfer, F. C. S., Avrumova, F., Abjornson, C., Cammisa, F. P., & Qureshi, S. A. (2024). Cervical disk arthroplasty: Updated considerations of an evolving technology. *Journal of the American Academy of Orthopaedic Surgeons*, *32*(23), e1205-e1213. https: //doi.org/10.5435/JAAOS-D-24-00127

[11] Zavras, A. G., Acosta, J. R., Holmberg, K. J., Bisson, E. F., & Glassman, S. D. (2024). Effect of device constraint: A comparative network meta-analysis of ACDF and cervical disc arthroplasty. *The Spine Journal*, *24*(10), 1858-1871. https: //doi.org/10.1016/j.spinee.2024.05.016

[12] Chen, C. M., Yang, J. J., Wu, C. C., Liu, C. C., & Lin, Y. T. (2024). Cervical disc arthroplasty versus anterior cervical discectomy and fusion for 2-level cervical disc degenerative disease: An updated systematic review and meta-analysis. *Journal of Clinical Medicine*, *13*(11), 3203. https: //doi.org/10.3390/jcm13113203

[13] Qi, M., Xu, C., Liu, Y., Wang, B., & Zhang, L. (2023). Comparison of clinical outcomes between cervical disc arthroplasty and anterior cervical discectomy and fusion for the treatment of single-level cervical spondylosis: A 10-year follow-up study. *The Spine Journal*, *23*(3), 361-368. https: //doi.org/10.1016/j.spinee.2022.11.013

[14] Coric, D., Guyer, R. D., Bae, H., McAfee, P. C., & Blumenthal, S. L. (2022). Prospective, multicenter study of 2-level cervical arthroplasty with a PEEK-on-ceramic artificial disc. *Journal of Neurosurgery: Spine*, *37*(3), 357-367. https: //doi.org/10.3171/2022.1.SPINE211264

[15] Shen, Y., Wei, Y., Liu, Y., Zhang, H., & Li, J. (2024). The association between the severity of cervical spondylosis before surgery and heterotopic ossification after cervical disc replacement. *Global Spine Journal*, *14*(3), 472-480. https: //doi.org/10.1177/21925682221119720

[16] Joaquim, A. F., & Riew, K. D. (2017). Multilevel cervical arthroplasty: Current evidence. A systematic review. *Neurosurgical Focus*, *42*(2), E4. https: //doi.org/10.3171/2016.10.FOCUS16354

[17] Chang, H. K., Huang, W. C., Tu, T. H., Chang, C. C., & Wu, J. C. (2020). Radiological and clinical outcomes of 3-level cervical disc arthroplasty. *Journal of Neurosurgery: Spine*, *32*(2), 174-181. https: //doi.org/10.3171/2019.8.SPINE19545

[18] Chang, H. K., Chang, C. C., Tu, T. H., Wu, J. C., & Huang, W. C. (2024). Four-level cervical disc arthroplasty. *International Journal of Spine Surgery*, *18*(5), 514-520. https: //doi.org/10.14444/8603

[19] Nguyen, A. Q., Credille, K., & Saifi, C. (2023). Short-term and long-term complications of cervical disc arthroplasty. *Clinical Spine Surgery*, *36*(9), 404-410. https: //doi.org/10.1097/BSD.0000000000001541

[20] Joaquim, A. F., Lee, N. J., Lehman, R. A., Jr., Riew, K. D., & Vaccaro, A. R. (2020). Osteolysis after cervical disc arthroplasty. *European Spine Journal*, *29*(11), 2723-2733. https: //doi.org/10.1007/s00586-020-06578-2

[21] Roth, S. G., Robles Ortiz, M. J., Vulapalli, M., Mangan, J. J., & Galgano, M. A. (2023). Revision strategies for cervical disc arthroplasty. *Clinical Spine Surgery*, *36*(9), 411-418. https: //doi.org/10.1097/BSD.0000000000001542