Comparative Clinical and Radiological Outcomes of Cervical Disc Arthroplasty at Higher Versus Lower Cervical Regions

Nikhil Sai[1], William A. Green[2], Joshua Mathew[2], Gregorio Baek[2], Yulia Lee[2], Yasmine Eichbaum[2], Morgan Hitchner[2], Jonathan Dalton[2], Alan Hilibrand[2], Alexander Vaccaro[2], Christopher Kepler[2], Gregory Schroeder[2]

[1]Philadelphia College of Osteopathic Medicine, Philadelphia, PA, [2]Rothman Orthopaedic Institute, Philadelphia, PA

ns3741@pcom.edu

Disclosures: N. Sai (N), W. Green (N), J. Mathew (N), G. Baek (N), Y. Lee (N), Y. Eichbaum (N), M. Hitchner (N), J. Dalton (N), A. Hilibrand: 4; Paradigm Spine. 7A; BioMet, CTL America. A. Vaccaro: 3B; Curiteva, Medcura, Stryker, Globus, Spinal Elements, Accelus, Wheel House Medical, Ferring Pharmaceutical. 4; Accelus, Advanced Spinal Intellectual Properties, Atlas Spine, Avaz Surgical, AVKN Patient Driven Care, Cytonics, Deep Health, Dimension Orthotics LLC, Electrocore, Flagship Surgical, FlowPharma, Rothman Institute and Related Properties, Globus, Harvard MedTech, Innovative Surgical Design, Jushi (Haywood), Orthobullets, Parvizi Surgical Innovation, Progressive Spinal Technologies, Sentryx, Stout Medical, See All AI, ViewFi Health. 7B; Stryker, Globus, Medtronic, Atlas Spine, Alphatec Spine, SpineWave, Spinal Elements, Curiteva, Elsevier, Jaypee, Stout Medical, Taylor Francis/Hodder and Stoughton, Wolters Kluwer, Wheel House Medical, Thieme. 8; Committee for National Spine Health Foundation (NSHF), Sentryx, and Accelus. G.D. Schroeder: 3B; Advance Medical, Bioventus, Surgalign. 5; Cerapedics, DePuy, Johnson & Johnson, Medtronic Sofamor Danek. 8; Wolters Kluwer, Lippincott Williams & Wilkins. 9; AOSpine, Cervical Spine Research Society. C. Kepler: 4; Altus. 5; Regeneration Technologies Inc, NIH, Cervical Spine Research Society. 7A; Inion, Curetiva. 8; Clinical Spine Surgery.

INTRODUCTION: Cervical disc arthroplasty (CDA) has been identified as a promising off-label substitute for anterior cervical discectomy and fusion (ACDF) for the maintenance of motion at the C5–6 and C6–7 levels. In contrast, the cervical level of C3–4 has unique anatomical and biomechanical features, such as decreased disc height, decreased segmental mobility, inwardly directed facets, and proximity to the vertebral artery, which increase the concern about the safety and efficacy of using CDA off-label at this particular level. The purpose of this systematic review and meta-analysis is to compare and assess the clinical and radiological results of CDA at the C3–4 level with those at the inferior cervical levels of C5–6 and C6–7, with regard to segmental range of motion (ROM), heterotopic ossification (HO), pain relief, and functional recovery.

METHODS: A PRISMA-compliant systematic review was conducted using PubMed, Embase, Web of Science, and Cochrane Library databases (January 2005 to June 2025). Inclusion criteria comprised clinical studies with ≥12 months follow-up reporting level-specific outcomes of CDA at C3–4, C5–6, or C6–7. Primary endpoints included segmental ROM, Neck Disability Index (NDI), Visual Analog Scale (VAS) for neck pain, and HO incidence. Secondary outcomes encompassed Japanese Orthopaedic Association (JOA) scores, adjacent segment degeneration (ASD), and reoperation rates. Pooled data were analyzed via random-effects meta-analytic models. Subgroup and sensitivity analyses were also conducted. Study quality was evaluated using the Newcastle–Ottawa Scale and Cochrane Risk of Bias 2.0 tools.

RESULTS SECTION: Twelve studies comprising 1,242 patients met the inclusion criteria. Segment-specific ROM was statistically comparable between C3–4 (6.55°) and lower levels (C5–6: 7.68°, C6–7: 6.59°), with mean differences of −1.13° (95% CI: −4.10 to 1.84) and −0.04° (95% CI: −3.53 to 3.45), respectively—both non-significant. Pooled analysis demonstrated consistent postoperative pain relief (VAS improvement: −4.61, 95% CI: −5.29 to −3.92) and functional recovery (NDI improvement: −28.11, 95% CI: −38.04 to −18.18) across all levels. A non-significant trend toward higher HO incidence was noted at C3–4 (+15.7%, 95% CI: −3.84% to +35.24%). No significant differences in reoperation or complication rates were observed between upper and lower segments. Study heterogeneity was low ($I^2 < 30\%$), and fixed-effect models confirmed result robustness.

DISCUSSION: Cervical disc arthroplasty (CDA) at the C3–4 level, despite its unique anatomical challenges and inherently reduced mobility, demonstrates motion preservation and clinical outcomes comparable to those seen at C5–6 and C6–7. While the incidence of HO appears numerically higher in the upper cervical segment, this difference does not achieve statistical significance, and its clinical relevance remains uncertain. Functional and radiographic results appear consistently favorable across various prosthesis designs and surgical techniques, provided that patient selection and implant choice are appropriate. Nonetheless, the proximity of the vertebral artery and the distinct orientation of the facet joints at C3–4 demand careful preoperative planning and precise surgical technique. Notably, most current prostheses were originally developed for mid-cervical applications and may require further adaptation to address the specific anatomical constraints of C3–4. To further clarify indications and optimize outcomes at this underrepresented level, future prospective studies with level-specific analyses and extended follow-up are necessary.

SIGNIFICANCE/CLINICAL RELEVANCE: This study shows that performing cervical disc arthroplasty at the technically demanding C3–4 level results in clinical and radiographic outcomes on par with procedures done at lower cervical segments. These results support including C3–4 in motion-preserving surgical plans, broadening the available options for managing multilevel cervical pathology.

IMAGES AND TABLES:

Comparasion	Mean Difference	95% Confidence Interval	Std. Deviation of Diff	Interpretation
ROM C3-C4 vs. C5-C6	−1.13°	−4.10 to +1.84°	1.51	No significant difference in ROM
ROM C3-4 vs. C6-C7	−0.04°	−3.53 to +3.45°	1.78	Equivalence in ROM
HO Rate C3-C4 vs C5-C6	+15.70%	−3.84% to +35.24%	12.00	Trend toward higher HO at C3–4, but not statistically significant
Vas Neck (Pre vs Post)	−4.61 points	−5.29 to −3.92	0.35	Significant pain reduction
NDI (Pre vs Post)	−28.11 points	−38.04 to −18.18	5.07	Major improvement in function

Table 1. Summary of Quantitative Findings of CDA C3-C4 vs C5-6/6-7.

Study ID	Author	Year	Design	Sample Size	C3–4 ROM (°)	C5–6 ROM (°)	C6–7 ROM (°)
Chang PY et	Chang PY	2016	Retrospecti	88	8.18	8.45	
Chang H-K e	Chang H-K	2024	Case Series	17	4.1	8.2	
Radcliff et a	Radcliff	2016	RCT	225	9	9	9
Huppert et	Huppert	2011	Prospective	231		6.4	6.4
Tu et al., 2C	Tu	2012	Retrospecti	33	1.3	1.3	1.3
Malham et	Malham	2014	Prospective	24		7.9	7.4
Reinas et al	Reinas	2020	Retrospecti	32	7.8		
Gornet et a	Gornet	2019	RCT (IDE)	209		8.6	7.3
Lanman et	Lanman	2017	RCT (IDE)	209			
Shen et al.,	Shen	2021	Retrospecti	138	7.06	9.12	
Hui et al., 2	Hui	2020	Systematic	5861			

Table 2: Comparing Range of Motion in Cervical Vertebrae Across Published Studies

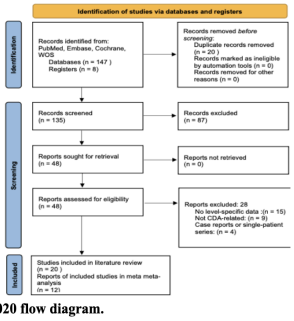

Figure 1. PRISMA 2020 flow diagram.