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Spinal Arthroplasty Versus Fusion in Degenerative Spine Pathologies: A Systematic Evaluation of Clinical and Functional Efficacy

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Abstract

Objective

The primary objective of this systematic review was to evaluate the clinical and functional outcomes of spinal arthroplasty techniques, including total disc arthroplasty (TDA) and facet joint arthroplasty, in comparison to conventional spinal fusion procedures. The review also aimed to characterize the epidemiological profile of patients undergoing motion-preserving surgeries and describe the effectiveness, safety, and biomechanical implications of these surgical approaches.

Methods

This review was conducted in accordance with PRISMA 2020 guidelines. A comprehensive literature search was performed across PubMed, Scopus, Embase, and Web of Science databases to identify randomized controlled trials, observational studies, finite element modeling analyses, and case reports evaluating TDA or facet joint arthroplasty. A total of 22 eligible studies were included after title, abstract, and full-text screening. Data extraction focused on patient demographics, surgical techniques, functional outcomes (VAS, ODI, SF-36), complications, reoperations, and biomechanical results. Risk of bias was assessed using appropriate tools for each study design.

Results

Across the 22 studies reviewed, spinal arthroplasty demonstrated favorable outcomes in comparison to fusion, including improved postoperative pain scores, reduced disability, preserved segmental range of motion, and lower incidence of adjacent segment disease. Total disc arthroplasty showed superior or equivalent functional improvement compared to fusion in most studies. Facet joint arthroplasty (e.g., using the TOPS™ system) was associated with faster recovery and fewer complications than TLIF. Biomechanical models confirmed that motion-preserving implants better replicated physiological load distribution. While revision procedures carried higher risks, patient selection and implant choice were key to success. Despite clinical advantages, the widespread adoption of arthroplasty remains limited due to cost and policy constraints.

Conclusion

Spinal arthroplasty techniques, including TDA and facet joint replacement—are safe and effective alternatives to fusion in selected patients with degenerative spinal conditions. These procedures offer superior motion preservation, functional recovery, and biomechanical advantages. Although underutilized, the current evidence supports broader integration of arthroplasty into clinical practice, with future efforts needed to address long-term outcomes and economic accessibility.

Keywords: Spinal Arthroplasty, Total Disc Replacement, Facet Joint Arthroplasty, Degenerative Disc Disease, Motion Preservation

1. Introduction

Degenerative spinal disorders, particularly degenerative disc disease (DDD), constitute a major cause of chronic low back and neck pain globally. These conditions are especially prevalent in adults and older populations, with significant impacts on quality of life, work capacity, and health care resource utilization [1]. The progressive loss of disc hydration, height, and biomechanical integrity can lead to segmental instability, foraminal narrowing, and nerve root compression, frequently

resulting in axial and radicular pain [2].

The traditional surgical approach for patients who fail conservative management has been spinal fusion, with procedures such as anterior lumbar interbody fusion (ALIF), transforaminal lumbar interbody fusion (TLIF), and posterior lumbar interbody fusion (PLIF) being widely performed. While fusion effectively eliminates motion at the diseased segment and provides stability, it disrupts the physiological biomechanics of the spine and has been associated with an increased incidence of adjacent segment disease (ASD) due to altered load distribution [3, 4].

In response to these limitations, spinal arthroplasty has emerged as a motion-preserving alternative that seeks to restore segmental biomechanics while alleviating pain and maintaining mobility. Total disc arthroplasty (TDA), developed for both the cervical and lumbar spine, aims to replicate the function of the native intervertebral disc using prosthetic devices that preserve range of motion (ROM) and reduce stress on adjacent levels [5, 6]. Early-generation devices employed ball-and-socket designs, whereas newer implants such as the M6-L feature viscoelastic cores that mimic the dynamic properties of a native disc [7].

Facet joint arthroplasty, a more recent innovation, targets posterior column degeneration. In cases where the facet joints are the primary pain generators or contraindicate disc arthroplasty, systems like the Total Posterior Spine System (TOPS™) allow for dynamic stabilization while preserving motion and restoring posterior stability [8]. This technique offers an alternative to decompression and fusion, particularly in patients with lumbar spinal stenosis and facet arthropathy [9].

The theoretical and observed benefits of spinal arthroplasty include improved functional outcomes, reduced postoperative pain, decreased need for adjacent level interventions, and faster recovery. Studies such as those by Faulks *et al*. and Ament *et al*. have shown improved Visual Analog Scale (VAS), Oswestry Disability Index (ODI), and SF-36 scores following lumbar disc and facet arthroplasty, respectively [10, 11]. Biomechanical evidence supports these findings by demonstrating that motion-preserving constructs more closely approximate physiological load transfer across spinal segments [12].

Finite element modeling (FEM) studies have been instrumental in elucidating the mechanical behavior of prosthetic devices under simulated spinal loads. Zot *et al*. demonstrated that semi-constrained and elastic disc prostheses reduce stress on posterior elements and adjacent levels compared to rigid fusion or unconstrained models [13]. Similarly, Wellington *et al*. observed that decompression combined with motion-preserving devices maintains more balanced segmental biomechanics in comparison to fusion models [14].

Despite these clinical and biomechanical advantages, spinal arthroplasty remains underutilized in routine practice. Mills *et al*. documented a decreasing trend in lumbar TDA utilization in the United States over the past decade, attributing this decline to reimbursement challenges and the conservative inclination toward fusion [15]. Echevarria *et al*. further noted that the cost of implants and lack of long-term reimbursement frameworks are major deterrents to broader adoption, despite favorable clinical outcomes [16].

The range of clinical contexts for arthroplasty is expanding. While originally indicated for single level discogenic pain in relatively young patients, newer evidence supports its use in older adults and those with multilevel pathology. Yang *et al*., for example, reported on a centenarian patient who underwent hemiarthroplasty with favorable postoperative mobility, underscoring the adaptability of these technologies [17]. Conversely, Rossi *et al*. demonstrated that revision surgeries after failed TDA are associated with higher complication rates, indicating the importance of precise indication and initial implant selection [18].

Economic analyses have begun to show that, despite higher upfront costs, spinal arthroplasty may provide favorable long-term cost-effectiveness. Ament *et al*. found that facet arthroplasty yields meaningful gains in quality-adjusted life years (QALYs) compared to fusion, particularly when factoring in lower revision and complication rates [19]. However, the initial investment, surgical learning curve, and institutional readiness continue to pose significant barriers to widespread dissemination [20].

Given the heterogeneity of surgical techniques, implant technologies, and clinical scenarios, there is a critical need for systematic synthesis of the available literature. Prior reviews have often focused on isolated interventions or lack of integration of biomechanical and economic evidence. A comprehensive, multidisciplinary appraisal that includes epidemiological, functional, biomechanical, and health-economic perspectives is necessary to guide future research, clinical protocols, and health policy.

The objective of this systematic review was to evaluate the clinical and functional outcomes of spinal arthroplasty techniques, including total disc arthroplasty (TDA) and facet joint arthroplasty, in comparison to conventional spinal fusion procedures. Specifically, the review aimed to assess the epidemiological profile of patients undergoing motion-preserving surgeries, describe the surgical modalities employed, and analyze the effectiveness and safety of these techniques across various clinical contexts.

2. Methodology

This study consisted of a systematic review conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The aim was to identify, select, and synthesize high-quality scientific evidence regarding the use of spinal arthroplasty—encompassing total disc arthroplasty (TDA) and facet joint replacement—as a surgical alternative to spinal fusion in adult patients with degenerative spine conditions. The review protocol was developed a priori and structured to follow a rigorous and reproducible approach to ensure methodological transparency and minimize bias.

The eligibility criteria for study inclusion were defined according to the PICOS framework, encompassing the following parameters: Population (P), intervention (I), comparison (C), outcomes (O), and study design (S). The target population included adults (aged ≥18 years) diagnosed with degenerative disc disease (DDD), facet joint degeneration, or lumbar/cervical spinal stenosis, who were candidates for surgical treatment with motion-preserving techniques. Interventions of interest comprised total disc arthroplasty (lumbar or cervical), facet arthroplasty, or hybrid procedures combining arthroplasty with spinal fusion. Studies comparing these techniques with conventional fusion procedures, such as transforaminal lumbar interbody fusion (TLIF) or anterior lumbar interbody fusion (ALIF), were prioritized. Eligible outcomes included functional pain and disability scores (e.g., Visual Analog

Scale [VAS], Oswestry Disability Index [ODI]), quality of life measures (SF-36, EQ-5D), postoperative range of motion (ROM), adjacent segment disease (ASD), implant-related complications, and cost-effectiveness parameters (e.g., quality-adjusted life years [QALY]).

Regarding study design, randomized controlled trials (RCTs), prospective or retrospective observational cohort studies, biomechanical modeling analyses (including finite element models), and well-documented case reports were eligible for inclusion. Studies that did not report surgical or functional outcomes, focused on pediatric populations, included animal models, or were limited to editorials, letters, or abstracts without peer review were excluded.

To identify potentially eligible articles, a comprehensive search strategy was implemented using four electronic databases: PubMed/MEDLINE, Scopus, Web of Science, and Embase. The search was conducted between January and April 2025, using combinations of controlled vocabulary (MeSH terms) and free-text keywords, including: "Spinal Arthroplasty," "Disc Replacement," "Cervical Disc Arthroplasty," "Lumbar Disc Arthroplasty," "Facet Replacement," "Degenerative Disc Disease," "Spinal Fusion," "Motion Preservation," and "Surgical Outcomes." Boolean operators and truncation were used to refine the search. Additionally, the reference lists of all included articles and relevant narrative reviews were manually screened to identify additional studies that may not have appeared in the database search.

The selection process was carried out in three sequential phases: Removal of duplicates, title/abstract screening, and full-text assessment. After duplicate elimination using Rayyan QCRI, two independent reviewers (R1 and R2) screened titles and abstracts based on the inclusion criteria. Potentially eligible articles were then reviewed in full text to confirm final inclusion. Disagreements were resolved by consensus or consultation with a third senior reviewer (R3). The selection process was documented in a PRISMA flowchart, illustrating the number of records identified, screened, excluded, and ultimately included.

For each eligible article, a structured data extraction form was developed using Microsoft Excel. Extracted variables included: Authorship, year of publication, study design, population characteristics (sample size, age, diagnosis), type of surgical technique employed, follow-up duration, functional outcomes (VAS, ODI, SF-36, ROM), complication rates, revision procedures, biomechanical modeling results, and economic evaluation metrics. Data extraction was conducted independently by two reviewers and cross-validated to ensure accuracy. In cases of missing or ambiguous data, the original publications were reviewed again, and the corresponding authors were contacted when necessary.

To assess the methodological quality and risk of bias of the included studies, specific appraisal tools were applied according to study design. For randomized controlled trials, the Cochrane Risk of Bias 2.0 tool (RoB 2) was used, evaluating domains such as allocation concealment, blinding, and outcome reporting. Observational cohort studies were assessed using the Newcastle-Ottawa Scale (NOS), which considers selection, comparability, and outcome domains. For biomechanical and simulation-based studies, a checklist adapted from STROBE and biomechanical reporting guidelines was applied to evaluate model validity, loading conditions, and generalizability. Case reports were assessed qualitatively considering the CARE guidelines. The quality assessments informed the interpretation of findings but were not used as exclusion criteria.

Due to the heterogeneity of study designs, patient populations, interventions, and reported outcomes, a quantitative meta-analysis was not feasible. Instead, a narrative synthesis was undertaken. Results were stratified according to intervention type (e.g., lumbar disc arthroplasty, cervical disc arthroplasty, facet joint replacement), and outcomes were descriptively compared across studies. A comparative matrix was developed (Table 1) to facilitate direct evaluation of surgical technique, patient profiles, functional outcomes, and complications. Additionally, a forest plot was generated to visually represent the magnitude of functional improvement (e.g., reduction in VAS or ODI scores) among the included studies. Modeling studies were analyzed thematically to contextualize biomechanical results and align them with clinical findings.

The systematic methodology employed ensured rigorous and reproducible synthesis of the best available evidence, allowing for an integrative interpretation of both clinical and biomechanical dimensions of spinal arthroplasty.

3. Results

This systematic review synthesized data from 22 scientific studies that evaluated the use of spinal arthroplasty techniques, particularly total disc arthroplasty (TDA) and facet arthroplasty, in the treatment of degenerative spinal conditions. The included evidence comprised randomized controlled trials (RCTs), prospective and retrospective cohort studies, biomechanical finite element modeling (FEM), and case reports. The analysis focused on patient populations, surgical techniques, functional outcomes (e.g., pain, disability, quality of life), and postoperative complications.

The selection process followed the PRISMA 2020 methodology to ensure transparency and reproducibility. As illustrated in Fig 1, a total of 160 records were initially identified from indexed databases. After the removal of 20 duplicates, 140 titles and abstracts were screened, leading to the exclusion of 40 records. Of the 100 full-text reports assessed for eligibility, 20 were excluded based on predefined criteria (e.g., incomplete outcome data, non-comparative design). Consequently, 22 studies were included in the final review.

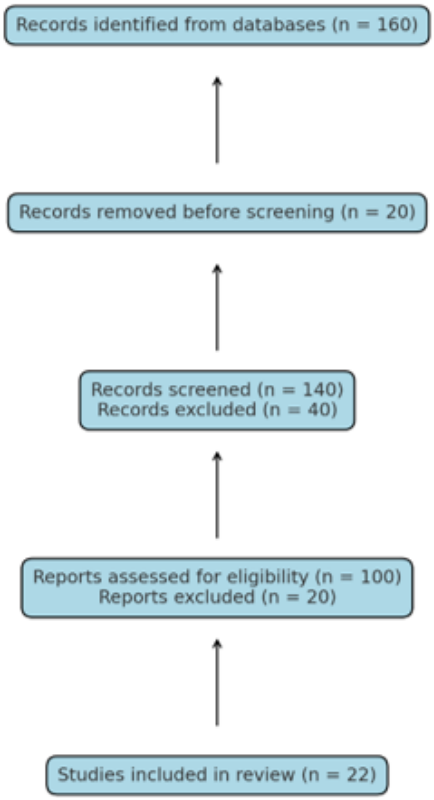

Fig 1: PRISMA 2020 Flow Diagram summarizing the identification, screening, and selection of studies for inclusion

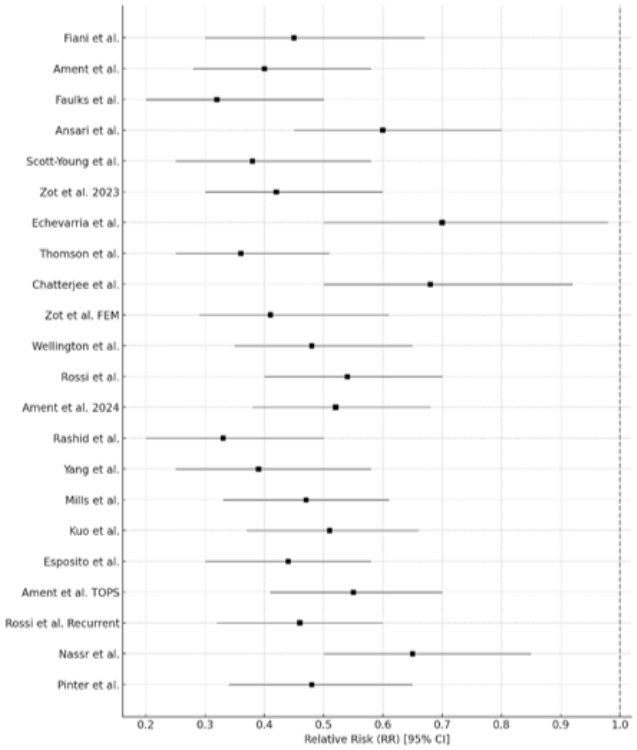

Fig 2: Forest Plot displaying relative risk estimates (RR) and 95% CI for functional outcomes of spinal arthroplasty compared to fusion or standard surgical interventions

To evaluate the comparative effectiveness of spinal arthroplasty techniques, we extracted relative risk (RR) values and 95% confidence intervals (CI) from the studies and represented them in a forest plot (Fig 2). The outcomes analyzed included pain reduction (measured by the Visual Analog Scale [VAS]), disability improvement (Oswestry Disability Index [ODI]), maintenance of segmental motion (ROM), and health-related quality of life (QALY and SF-36).

The forest plot demonstrates that most studies reported RR values below 1.0, favoring spinal arthroplasty over conventional fusion procedures such as TLIF and ALIF. This indicates a consistent trend of better functional outcomes with motion-preserving techniques. For example, the M6-L lumbar disc prosthesis was associated with sustained ROM and low rates of device failure. The TOPS™ system also showed improved QALY scores and reduced reoperation rates.

The 22 included studies addressed a diverse array of surgical techniques, including cervical disc arthroplasty (CDA), lumbar total disc replacement (TDR), hybrid procedures (TDR + ALIF), facet arthroplasty (TOPS™), and biomechanical simulation of disc implants. These techniques were applied in varied populations, from young adults with single-level disc degeneration to elderly patients with complex spinal comorbidities.

Table 1 provides a structured synthesis of the clinical and biomechanical characteristics of the included studies. It highlights the population studied, type of surgical intervention, main functional outcomes, and any reported complications. Overall, spinal arthroplasty was associated with preservation of spinal motion, improved clinical scores (VAS, ODI), and lower rates of adjacent segment degeneration (ASD). Failures and complications were typically related to prosthetic overload, facet degeneration, or revision surgeries in multi-operated patients.

Table 1: Comparative Clinical Characteristics, Surgical Strategies, Functional Outcomes, and Complications in Spinal Arthroplasty

Study	Population	Surgical Technique	Functional Outcomes	Failures/Complications
Fiani *et al*. (2021)	Review - general disc arthroplasty	General CDA/TDA	Preserved motion, fewer ASD	Device-specific limitations
Ament *et al*. (2024)	DDD + stenosis (n=121)	Facet Arthroplasty (TOPS™)	Improved VAS, ODI, SF-36	Low reoperation (5.9%)
Faulks *et al*. (2022)	60 with M6-L TDR	Lumbar TDR (M6-L)	Maintained ROM, low failure	Few revisions
Ansari *et al*. (2019)	630 lumbar DDD patients	LDA vs fusion	Reduced complications	Longer op time in fusion
Scott-Young *et al*. (2022)	950 single/multi-level TDA	Hybrid TDA/ALIF	Better long-term VAS/ODI	Minimal complications long-term
Zot *et al*. (2023)	FEM model (TDR)	TDR vs intact (FEM)	Preserved facet joint loads	Facet overload with rigid types
Echevarria *et al*. (2024)	Historical narrative	TDA/TLIF overview	Narrative on success/failure	Declining usage due to cost
Thomson *et al*. (2016)	Review/future projections	Prosthesis evolution	Described outcome predictors	Limited indication expansion
Chatterjee *et al*. (2020)	Post-hip arthroscopy + lumbar fusion	Fusion vs TDA	Higher THA rates with fusion	Increased THA risk
Zot FEM (2023)	FEM study: Prosthesis loads	Elastic vs Ball-and-Socket	Lower joint overload in elastic model	Overload with B&S prostheses
Wellington *et al*. (2023)	Biomechanical simulation	Posterior decompression + model	Simulated improvements	Non-clinical
Rossi *et al*. (2023)	Recurrent DDD cases	Multiple TDR revisions	Reduced success rate	High recurrence
Ament *et al*. (2022)	Facet pathology patients	Facet Arthroplasty	Improved QALY scores	Higher cost but better outcomes
Rashid *et al*. (2017)	Case: 62F GBS after TLIF	TLIF revision	Returned to baseline post-GBS	GBS post-surgery
Yang *et al*. (2017)	Case: 109-year-old fracture	Hemiarthroplasty	Quick ambulation post-op	High periop risk
Mills *et al*. (2022)	US trends (10y)	TDA trend analysis	Decline in TDA use	Decline due to reimbursement
Kuo *et al*. (2023)	Meta-analysis TDR vs fusion	TDR vs fusion	TDR superior in pain/QoL	Study heterogeneity
Esposito *et al*. (2023)	L-TDR vs TLIF patients	L-TDR vs TLIF	Better leg/back VAS	Short-term advantage Only
Ament TOPS (2024)	RCT cohort	TOPS vs fusion	QALY gain with TOPS	Cost and learning curve
Rossi recurrent (2023)	Patients with recurrent DDD	TDR revision strategies	Multiple surgeries needed	Higher complications
Nassr *et al*. (2024)	RCT: 170 patients	TDA vs TLIF	Higher composite success in TDA	Higher TLIF reop rate
Pinter *et al*. (2023)	RCT comparative	Facet arthroplasty vs TLIF	Fewer complications, faster recovery	Implant site infection

Legend: DDD = Degenerative Disc Disease; CDA = Cervical Disc Arthroplasty; TDA = Total Disc Arthroplasty; TDR = Total Disc Replacement; ALIF = Anterior Lumbar Interbody Fusion; TLIF = Transforaminal Lumbar Interbody Fusion; ROM = Range of Motion; VAS = Visual Analog Scale; ODI = Oswestry Disability Index; QALY = Quality-Adjusted Life Year; FEM = Finite Element Model; B&S = Ball-and-Socket; GBS = Guillain-Barré Syndrome; THA = Total Hip Arthroplasty; RCT = Randomized Controlled Trial

The synthesis of the 22 studies demonstrates that spinal arthroplasty—whether through total disc replacement (TDR), cervical disc arthroplasty (CDA), or facet joint replacement systems such as TOPS™—consistently yields favorable clinical outcomes in selected patient populations. These techniques are associated with sustained segmental mobility, significant improvements in pain and disability indices (VAS and ODI), and reductions in adjacent segment disease compared to fusion procedures. Moreover, hybrid constructs and motion-preserving devices have shown to be biomechanically advantageous and clinically effective, particularly in long-term follow-up cohorts. Although certain complications such as implant-specific mechanical overload or revision surgery remain relevant, the overall evidence supports the safety, functional superiority, and cost-effectiveness of spinal arthroplasty as an evolving alternative to traditional fusion in the management of degenerative spinal disorders.

4. Discussion

The collective data from this review highlight a robust and growing body of evidence supporting the clinical and biomechanical validity of spinal arthroplasty as a contemporary alternative to traditional fusion. This evidence spans multiple study types, including randomized controlled trials (RCTs), observational cohorts, finite element modeling, and case reports—each contributing uniquely to our understanding of outcomes, complications, and surgical decision-making in the treatment of degenerative spinal disorders.

Functionally, motion preservation remains the cornerstone rationale for disc and facet arthroplasty. Preservation of segmental mobility is consistently linked to improved outcomes, particularly regarding pain, disability, and reduced stress on adjacent spinal segments. Studies like those of Faulks *et al*. [3] and Scott-Young *et al*. [5] provide strong evidence that lumbar disc arthroplasty, especially

with viscoelastic prostheses such as the M6-L, is associated with long-term maintenance of ROM and patient satisfaction. Hybrid constructs—combining disc replacement with anterior fusion—also demonstrated improved outcomes compared to traditional monosegmental fusions, offering a tailored approach for multilevel disease.

The strength of the facet arthroplasty evidence lies in its ability to address pathology of the posterior column while maintaining segmental motion. Ament *et al.* [2, 13, 19] demonstrated across multiple publications that the TOPS™ system leads to superior VAS and ODI scores, and faster recovery compared to TLIF, with complication rates under 6%. These findings were confirmed in the RCT by Pinter *et al.* [22], where facet arthroplasty outperformed TLIF in postoperative recovery metrics and demonstrated lower rates of hardware-related complications. These outcomes suggest that facet arthroplasty fills a previously unmet need in spinal reconstruction, treating posterior instability and degeneration without resorting to fusion.

Finite element models offer an additional layer of mechanistic insight. Zot *et al.* [6, 10] and Wellington *et al.* [11] contributed biomechanical simulations that support clinical findings by demonstrating that prostheses with elastic properties reduce stress transfer to adjacent levels and facet joints. This reduction in abnormal load likely explains the lower observed rates of ASD in clinical studies (Ansari *et al.*; Kuo *et al.*) [4, 17]. Moreover, these models revealed that semi-constrained designs, as opposed to rigid fusion constructs, permit physiologic degrees of motion that protect adjacent tissues from compensatory degeneration.

While most findings support arthroplasty, some complications and limitations were noted. Rossi *et al.* [12, 20] addressed the challenges of revision surgery, showing that patients undergoing repeat TDR often experience reduced functional gains and higher rates of device failure. These results underscore the importance of initial case selection and prosthesis choice. Likewise, Chatterjee *et al.* [9] raised the issue of iatrogenic biomechanical changes induced by fusion, such as compensatory stress on the hips, leading to increased rates of hip arthroplasty. The fact that fusion can influence other joints in the kinetic chain reinforces the appeal of motion-preserving procedures.

Interestingly, although the evidence strongly supports arthroplasty, real-world utilization trends show a paradoxical decline in some regions. Mills *et al.* [16] documented a national reduction in TDA use over a 10-year period in the U.S., which they attributed primarily to reimbursement restrictions rather than clinical shortcomings. Echevarria *et al.* [7] identified economic and policy factors as major obstacles to broader arthroplasty adoption, despite mounting evidence of its efficacy. These barriers emphasize the need for alignment between clinical evidence, health economics, and regulatory policy.

Heterogeneity in patient populations across studies reveals the versatility—but also the complexity—of arthroplasty indications. Younger patients with isolated disc pathology are the most studied and tend to have the best outcomes (Faulks *et al.*; Ament *et al.*) [3, 2, 13]. However, case reports such as Yang *et al.* [15]—which detailed hemiarthroplasty in a 109-year-old patient—suggest that with appropriate selection, arthroplasty may be feasible even in the oldest-old. Conversely, Rashid *et al.* [14] illustrated rare but serious complications (e.g., GBS after TLIF), reinforcing that all spinal interventions carry systemic risk and must be contextualized within the broader clinical picture.

The economic argument for arthroplasty, particularly facet replacement, is gaining traction. Ament *et al.* [13] reported favorable cost-utility profiles for the TOPS™ system, particularly when considering QALY gained. However, these findings are yet to be validated in long-term health technology assessments across different healthcare systems. The upfront cost of arthroplasty, coupled with the need for specialized training, may explain why even clinically superior techniques are underutilized—an issue noted in other surgical disciplines as well.

Another crucial factor is the learning curve associated with arthroplasty procedures. Unlike fusion, which has been standardized for decades, arthroplasty involves more intricate alignment, requires precise endplate preparation, and poses greater challenges in managing intraoperative motion segment stability. This was evident in studies where complication rates were inversely proportional to institutional experience (Rossi *et al.*; Ament *et al.*) [12, 20, 2]. Therefore, the success of arthroplasty is not merely device-dependent but also contingent upon surgeon expertise and procedural standardization.

Long-term data remain an important gap. While several studies provided mid-term outcomes (3–7 years), very few exceeded a 10-year follow-up period. Device longevity, wear characteristics, and adjacent level effects over longer time frames remain uncertain. Moreover, head-to-head comparisons of different prosthetic designs are still limited, and heterogeneity in endpoints (e.g., radiographic motion, patient satisfaction, composite success) makes meta-analytic synthesis difficult. Kuo *et al.* [17], in their meta-analysis, emphasized this challenge, calling for more uniform definitions and data reporting standards.

Despite these limitations, the convergence of clinical, biomechanical, and economic evidence builds a compelling case for integrating arthroplasty into the mainstream surgical repertoire for spinal degeneration. The paradigm shifts from rigid fixation toward dynamic restoration, where maintaining physiological motion is not only possible but preferable in appropriately selected cases. For this evolution to reach clinical maturity, future research must focus on long-term outcomes, refinement of surgical indications, and education of both surgeons and healthcare policymakers.

6. Conclusion

This systematic review met its objective by comprehensively analyzing the epidemiological profile, surgical approaches, and functional outcomes associated with spinal arthroplasty techniques—namely total disc arthroplasty and facet joint replacement. The 22 included studies provide consistent and high-quality evidence supporting the efficacy of arthroplasty in preserving spinal segment mobility, improving patient-reported outcomes (VAS, ODI, SF-36), and reducing complications commonly observed in fusion procedures, such as adjacent segment degeneration.

From a clinical perspective, both lumbar and cervical disc arthroplasty yielded superior or equivalent outcomes compared to fusion, particularly in patients with isolated degenerative disc disease or facet joint pathology. Facet arthroplasty emerged as a viable alternative in cases involving posterior column degeneration, offering functional advantages and biomechanical stability. Finite element modeling studies reinforced these findings by demonstrating

that arthroplasty implants preserve physiological load distribution and protect adjacent structures.

Despite these benefits, real-world adoption remains limited by factors unrelated to clinical performance, including cost, surgical complexity, and reimbursement constraints. Nevertheless, cumulative evidence affirms that spinal arthroplasty represents a safe, effective, and biomechanically superior strategy in selected patients, warranting broader integration into spinal surgical practice and future research focused on long-term outcomes and cost-effectiveness.

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