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Open Spinal Fusion versus Minimally Invasive Spine Surgery: A Literature Review

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Abstract

Background: Spinal fusion remains a foundational intervention for degenerative disc disease, spondylolisthesis, and scoliosis. While open spinal fusion (OSF) has been the gold standard for decades, minimally invasive spine surgery (MISS) has gained prominence for its reduced perioperative burden and potential to enhance recovery. A comprehensive comparison of these techniques is necessary to evaluate their relative efficacy, safety, and adaptability across patient populations.

Objectives: To critically compare open spinal fusion and MISS techniques from 2014 to 2024 in terms of clinical outcomes, surgical innovations, patient-specific factors, and economic viability, focusing on quantitative metrics such as fusion success, complication rates, revision frequency, operative parameters, and quality-of-life indices.

Methodology: A systematic review of peer-reviewed literature (2014–2024) was conducted across PubMed, Scopus, and Web of Science using predefined MeSH terms and Boolean logic. Inclusion criteria required comparative studies (RCTs, meta-analyses, systematic reviews) involving ≥50 patients with degenerative disc disease, spondylolisthesis, or scoliosis. Outcome variables included fusion rates, Visual Analog Scale (VAS) pain scores, Oswestry Disability Index (ODI), operative time, blood loss, complications, length of stay (LOS), and revision surgery rates.

Results: MISS demonstrated significantly lower complication rates (5%–10%) compared to OSF (20%–30%) ($p < 0.05$), with reduced blood loss (100–200 mL vs. 400–600 mL), shorter LOS (2–3 vs. 5–7 days), and faster ambulation (up to 3.5 days earlier). Fusion rates were comparable across techniques: 80.5%–98% for MISS and 91.1%–98% for OSF ($p > 0.05$). MISS reduced opioid use by 30%, and in obese patients (BMI > 30), complication rates fell from 15% (OSF) to 6% (MISS, $p < 0.01$). Revision surgery rates were halved in MISS (14% vs. 28%, $p = 0.001$), although early learning curve risks were noted (OR 2.59, $p = 0.003$). In scoliosis, MISS achieved equivalent Cobb angle correction (≈70%) with 50% less blood loss. Quality-of-life outcomes (ODI, EQ-5D, VAS) converged by 2–5 years across all conditions ($p > 0.05$).

Conclusion: MISS provides equivalent long-term efficacy to OSF in spinal fusion while conferring significant perioperative advantages, reduced revision rates, and enhanced recovery—particularly in paediatric, elderly, and obese populations. Despite initial technical challenges and reliance on advanced technology, its integration of endoscopic, robotic, and awake techniques positions MISS as a leading strategy for modern spinal care. Further long-term, condition-specific RCTs are warranted to optimize patient stratification and refine adoption.

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Keywords: Minimally Invasive Surgical Procedures; Spinal Fusion; Spondylolisthesis; Patient Outcome Assessment; Quality of Life; Robotics; Revision Surgery.

Introduction

The field of spinal surgery has witnessed a profound transformation over the past decade, driven by advancements in techniques and a growing emphasis on optimizing patient outcomes, operational efficiency, and economic viability [1]. At the heart of this evolution lies the comparison between open spinal fusion - a long-established standard; and minimally invasive spine surgery (MISS) - an innovative approach gaining traction for its potential to redefine surgical care. This literature review explores the clinical applications, historical context, and technical distinctions between these two methodologies. This review drew on a wealth of contemporary research to illuminate their respective impacts on modern spinal surgery.

Open spinal fusion has served as the cornerstone for treating complex spinal conditions such as lumbar spondylolisthesis and degenerative disc disease [2,3]. This approach, characterized by extensive soft tissue dissection and large incisions, has been a reliable method for achieving spinal stability. Its invasiveness often translates to significant intraoperative blood loss, prolonged anaesthesia times, and extended hospital stays—factors that have prompted scrutiny as patient-centric care gains prominence. Whereas, minimally invasive spine surgery emerged as a response to these challenges, leveraging smaller incisions, specialized instrumentation, and advanced imaging to minimize tissue disruption. Guo and colleagues, in their 2022 analysis highlighted how MISS significantly reduces blood loss and shortens recovery periods compared to traditional open methods [4]. This set the stage for a paradigm shift in surgical practice. Eseonu and team also in 2022 emphasized this by noting MISS's ability to curtail hospital stays [5]. This again emphasized its growing relevance in addressing spinal disorders.

Clinical Applications and Historical Development: Open spinal fusion's dominance traces back decades, rooted in its proven efficacy for conditions requiring robust structural correction. The technique involves exposing the spine through a large incision, enabling direct visualization and manipulation of spinal anatomy—a necessity for complex cases like severe scoliosis or multilevel fusions. Yet, this comes at a cost: Hartmann and peers - in their 2022 observational study - documented how patients undergoing open procedures experience heightened postoperative pain and extended recovery timelines requiring prolonged rehabilitation [6].

Minimally invasive techniques represent a relatively recent innovation - with widespread adoption accelerating in the early 21st century. Goldstein and associates, in their 2014 work, link this rise to the aging population's increasing prevalence of degenerative spine conditions [7]. This ramped up the demand for less traumatic interventions. MISS encompasses procedures like transforaminal lumbar interbody fusion (TLIF) - which Danison and colleagues in 2017 praised for achieving comparable fusion success to open surgery while minimizing collateral damage [8]. The historical shift from open to minimally invasive methods reflects not just technological progress but a broader reorientation toward patient outcomes, as evidenced by Weiss and team's 2019 findings of reduced complication rates with MISS [9].

Technical Differences and Surgical Approaches: The technical divergence between open spinal fusion and MISS is stark. Open surgery relies on extensive muscle retraction and bone removal, often requiring general anaesthesia and significant operative time. This approach, while effective for visualization, amplifies risks like infection and blood loss—drawbacks Guo and colleagues in 2022 quantify in their comparative studies. MISS employs smaller incisions - typically less than an inch – and guided by fluoroscopy or navigation systems. Choi and team, in their 2022 analysis, emphasized how robotic-assisted MISS enhances precision [10]. This is in line with outcomes of open techniques while preserving the benefits of reduced invasiveness.

Recent innovations further distinguish MISS. Garg and associates in 2020 as well as Rangnekar and peers in 2022 - explore awake spinal fusion - a technique using local anaesthesia to expedite mobilization and minimize postoperative discomfort [11,12]. This advancement exemplifies MISS's trajectory toward maximizing efficiency and patient satisfaction/ This was a trend which Good et al. in 2022 tied to the integration of cutting-edge navigation technologies [13].

Clinical Outcomes and Patient Recovery: Patient outcomes form the crux of this comparison. Open spinal fusion, while effective for fusion success, often yields higher complication rates—Weiss and team in 2019 noted increased infection risks and prolonged pain [9]. MISS, conversely, offers a compelling alternative: Hartmann and colleagues in 2022 demonstrate that patients undergoing minimally invasive TLIF report lower postoperative pain and faster discharges, a finding echoed by Guo and peers in the same year [4] Vora and associates in 2018 add that MISS reduces narcotic reliance post-surgery, a critical advantage amid heightened scrutiny of opioid use [14].

Recovery metrics further favour MISS. Studies by Pholprajug and team in 2023 and Hinojosa-González and colleagues in 2022 stressed the importance of customized approaches to patient-specific factors—such as age or comorbidities—where MISS consistently outperformed in reducing rehabilitation time [15,16] Su and peers in 2022

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highlighted its applicability in vulnerable populations - like osteoporotic elderly patients - where open surgery's risks are amplified [17].

Economic Implications: Beyond clinical outcomes, economic considerations shape the discourse. Eseonu and team in 2022 conducted a systematic review revealing that MISS lowered overall healthcare costs by mitigating complications and shortening hospital stays [5] This was a stark contrast to the resource-intensive nature of open fusion. This cost-effectiveness aligns with the rising demand for spinal interventions - as Goldstein and associates in 2014 predicted [7]. This positioned MISS as a sustainable solution in an era of constrained healthcare budgets.

Advantages, Limitations, and Future Directions: MISS's advantages included reduced trauma, faster recovery and lower costs; but are subject to a few limitations. Its reliance on advanced technology and surgeon expertise poses a learning curve. This was a challenge that Choi and colleagues in 2022 acknowledged [10]. Open fusion is more invasive but remains indispensable for complex deformities - where direct access is critical. Looking ahead - research gaps persist; long-term outcomes and quality-of-life metrics remain under-explored. Su and team in 2022 suggested this as well and pointed to the need for longitudinal studies to solidify MISS's superiority [17].

The past decade's evidence - from Guo and Hartmann in 2022 [4,6] to Weiss in 2019 [9] - indicated a shift in spinal surgery. As technology like robotics and awake techniques continues to evolve - MISS is expected to dominate and to offer a balanced approach to clinical efficacy. This review assessed that - while both methods retain relevance - the trajectory favours minimally invasive strategies as the future of spinal care.

Methodology

Search Strategy and Evidence Collection: This literature review systematically evaluates open spinal fusion versus minimally invasive spine surgery (MISS) from 2014 to 2024, synthesizing evidence on clinical outcomes, surgical techniques, and patient-specific factors. The search targeted peer-reviewed studies on degenerative disc disease, spondylolisthesis, and scoliosis, prioritizing high-quality designs—randomized controlled trials (RCTs), meta-analyses, and systematic reviews. Key metrics included fusion success, complication rates, recovery times, operative durations, quality of life, revision rates, and cost-effectiveness, reflecting clinical, operational, and economic priorities outlined in the Introduction.

Data Sources and Keywords: Searches were conducted across PubMed, Scopus, and Web of Science, leveraging their comprehensive coverage of medical literature. Keywords and MeSH terms included: "open spinal fusion" "minimally invasive spine surgery" "MISS" "TLIF" "degenerative disc disease" "spondylolisthesis" "scoliosis" "fusion success" "complications" "recovery time" "operative duration" "quality of life" "revision surgery" and "cost-effectiveness" Boolean operators (e.g., AND, OR) refined queries - such as "open spinal fusion AND minimally invasive AND (complications OR recovery)" Filters restricted results to English-language publications from January 1, 2014, to April 3, 2025 (current date) to capture a decade of advancements.

Inclusion and Exclusion Criteria: Studies were selected based on rigorous criteria (Table 1). Inclusion required: (1) direct comparison of open and MISS techniques, (2) sample sizes ≥50 patients for statistical power (per Eseonu et al., 2022) (3) focus on specified conditions, and (4) quantitative outcome data. Excluded were case reports, editorials, non-comparative studies, and those with <50 participants or pre-2014 publication. This ensured reliability and relevance, mirroring standards in Goldstein et al. (2014) for aging population trends [5,7].

Evidence Selection and Yield: Initial searches yielded ~300 articles, narrowed to 25 core studies after screening titles, abstracts, and full texts for compliance with criteria. Examples include Imada et al. (2017) on MISS versus open TLIF, Liu et al. (2024) on lumbar fusion meta-analysis. Gaps persisted —e.g., limited degenerative disc disease data - but the dataset spans diverse populations (e.g., elderly in Soh & Lee, 2019; paediatric in Sarwahi et al., 2021) [18–21] and techniques (e.g., endoscopic TLIF in Zhou et al., 2023). Cost-effectiveness insights from Eseonu et al. (2022) and Navarro et al. (2018) complemented clinical findings [5,22].

Analytical Approach: Data were synthesized narratively and quantitatively, with statistical trends (e.g., p-values, percentages) extracted to compare approaches. This methodology ensures an evidence-driven review, balancing clinical rigor with real-world applicability, while acknowledging areas for future research.

Table 1: Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Study Design	RCTs, meta-analyses, systematic reviews	Case reports, editorials, non-comparative
Sample Size	≥50 patients	<50 patients
Conditions	Degenerative disc disease, spondylolisthesis, scoliosis	Other spinal conditions
Publication Date	2014–2024	Pre-2014
Outcomes	Quantitative (e.g., fusion rates, complications)	Qualitative only
Language	English	Non-English

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Results

Initial Comparative Findings

Clinical Outcomes: Evidence spanning 2014–2024 reveals distinct clinical outcome profiles for open spinal fusion and minimally invasive spine surgery (MISS). Fusion success, a primary endpoint, demonstrates equivalence across techniques, yet MISS consistently reduces complications and accelerates recovery. Hammad et al. (2019), in a systematic review, compared minimally invasive transforaminal lumbar interbody fusion (MITLIF) to open TLIF (OTLIF) and reported fusion rates exceeding 90% for both [23]. However - MITLIF patients experienced lower postoperative pain (VAS scores reduced by 1–2 points, $p < 0.05$) and faster discharge (2–3 days vs. 5–7 days for open). Complication rates further support MISS as Hammad et al. noted 5%–10% for MITLIF versus 20%–30% for OTLIF [23]. This included infection rates of 1%–2% versus 5%–7% ($p < 0.05$). Park et al. (2018) via a meta-analysis of RCTs and cohorts also corroborated this - finding a 50% reduction in postoperative infections (2% vs. 4%, $p < 0.01$) and 30% lower opioid use in MISS patients; attributed to reduced tissue trauma [24]. Recovery times reflected this advantage and averaged 4–6 weeks for MISS versus 8–12 weeks for open surgery.

Surgical Techniques: MISS's operational benefits stem from refined techniques. Hu et al. (2023) in a systematic review quantified shorter operative durations for MITLIF (120–150 minutes) compared to OTLIF (180–210 minutes) [25]. This was driven by smaller incisions and less dissection. Blood loss is similarly reduced, averaging 100–200 mL for MISS versus 400–600 mL for open procedures—a critical factor for high-risk cohorts. Yang et al. (2022) highlighted a caveat: MISS operative times can extend to 180 minutes in complex cases or early adoption phases [26]. This indicated a learning curve which is navigated by experience and robotic assistance - which Hu et al. credit for a 20% further blood loss reduction.25 Navarro et al. (2018) tie these efficiencies to economic gains, with MISS reducing hospital stays (2–3 days vs. 5–7 days) and costs by 20%–30% for single-level fusions.

Patient-Specific Factors: Patient demographics displayed MISS's adaptability. Alhammoud et al. (2021), in a meta-analysis of minimally invasive scoliosis surgery - reported equivalent Cobb angle corrections (50°–60°) to open methods but with 50% less blood loss (200 mL vs. 400 mL) and lower complication rates (8% vs. 18%, $p < 0.05$) in adolescents [27]. For elderly patients, Park et al. (2018) confirmed reduced morbidity, with recovery times halved [24]. Obesity amplifies MISS's edge: Park et al. (2024) demonstrated complication rates dropping to 6% versus 15% for open surgery in patients with BMI > 30 ($p < 0.01$) [28]. This was due to fewer wound issues. Hammad et al. (2019) suggested broader applicability for comorbidities like diabetes [23].

Statistical Trends: MISS's advantages are also backed by statistical significance. Complication rates range 5%–10% for MISS versus 20%–30% for open surgery (Hammad et al., 2019; Park et al., 2018), with p-values < 0.05 in meta-analyses [23] Pain reduction (VAS drops of 1.5–2.5 points) and recovery savings (2–4 weeks) are similarly significant (Alhammoud et al., 2021) [27]. Technological advances like robotics enhance these trends – even though data gaps persist for degenerative disc disease and spondylolisthesis specificity.

Extended Comparative Findings

Quality of Life and Long-Term Outcomes: Beyond immediate outcomes, quality of life (QoL) and durability metrics reveal nuanced comparisons. Heemskerk et al. (2021), in a meta-analysis of 16 studies (1,321 patients), found no significant differences in 2-year patient-reported outcomes (PROs) between MIS-TLIF and open TLIF—Oswestry Disability Index (ODI), VAS pain, and EQ-5D scores improved equivalently ($p > 0.05$) [29]. Fusion rates were 80.5% for MISS versus 91.1% for open ($p = 0.29$), with reoperation rates at 3.0% versus 2.4% ($p = 0.50$). Zhao et al. (2019), in an RCT (91 patients) with 5-year follow-up, reported near-identical fusion success (98% for both) and adjacent-level reoperation rates (4.3% vs. 6.7%, $p = 0.63$), though MISS showed early pain relief (VAS lower at 7 days, $p < 0.05$).30 These findings affirmed MISS's long-term parity with open surgery for degenerative conditions.

Revision Surgery Rates: Revision rates offer insight into durability and technique maturity. Ramanathan et al. (2023), analyzing 2,130 patients over 5 years, found a cumulative reoperation rate of 14% for MISS versus 28% for open surgery ($p = 0.001$). They suggested MISS's tissue-sparing approach halves long-term reintervention needs [31]. Conversely, Qu et al. (2015), in a meta-analysis of 14 studies, noted a higher revision risk with MISS (OR 2.59, $p = 0.003$), linked to early learning curve issues like screw malposition. Fusion rates remained equivalent (~95%, $p > 0.05$). They indicated that surgeon experience is pivotal—mature MISS programs mirror or outperform open surgery [32].

Advanced Surgical Techniques: Emerging MISS techniques, like percutaneous endoscopic TLIF (PE-TLIF), extend invasiveness reductions. Zhou et al. (2023), in a meta-analysis of 8 studies (487 patients), compared PE-TLIF to MIS-TLIF, finding equivalent ODI and leg pain relief ($p > 0.05$) but superior back pain reduction with PE-TLIF ($p < 0.05$); lower blood loss and faster ambulation ($p < 0.05$) [33]. Downsides include longer operative times and higher fluoroscopy exposure ($p < 0.05$). Goldstein et al. (2016), in a meta-analysis (1,662 patients), reinforce MISS's perioperative edge: 260 mL less blood loss, 2.9-day shorter LOS, and 3.5-day faster ambulation (all $p < 0.001$), with no increase in surgical complications (~11% both) [34].

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Condition-Specific Outcomes

Degenerative Disc Disease and Spondylolisthesis: For degenerative disc disease (DDD) and spondylolisthesis, MISS matches open surgery long-term. Lu et al. (2017), in a meta-analysis of 10 studies (602 patients, Grade I–II spondylolisthesis), reported equivalent ODI and VAS improvements ($p > 0.05$) ; MISS reducing blood loss by 331 mL ($p < 0.0001$) and LOS by 1.7 days ($p = 0.008$) [35]. Zhao et al. (2019) confirm this for single-level DDD, with 5-year PROs equalizing after early MISS advantages [30]. Open surgery may edge out in operative speed (19 minutes shorter, $p = 0.04$) as per Lu et al.'s prospective subset [35].

Scoliosis: Scoliosis outcomes vary by population. Sarwahi et al. (2021) in a multicentre study of 485 adolescent idiopathic scoliosis (AIS) patients, found MISS achieved 70% Cobb angle correction (50° to 15°, $p = 0.46$ vs. open) [36]. ; 55% less blood loss (360 mL vs. 790 mL, $p < 0.001$) and shorter LOS (4.6 vs. 6.0 days, $p < 0.001$). Kyphosis improved with MISS (+5° vs. -8°, $p < 0.001$). For adult degenerative scoliosis (ADS), Shao et al. (2024), in a meta-analysis (1,527 patients), noted open surgery's superior lumbar lordosis gain ($p = 0.04$), but MISS offered lower blood loss and complications ($p < 0.0001$), with equivalent Cobb correction and PROs ($p > 0.05$) [37].

Patient-Specific Factors: Pediatric AIS patients benefit from MISS's reduced morbidity (Sarwahi et al., 2021), while elderly ADS patients leverage its lower complication profile (Shao et al., 2024). Ramanathan et al. (2023) suggest MISS's reoperation advantage persists despite higher diabetes rates in older cohorts. Smoking's impact on fusion failure lacks direct study here, but MISS's tissue preservation may mitigate risks compared to open surgery's extensive exposure [31,36].

Statistical Trends and Technological Influence: MISS's edge is statistically robust: reoperation reductions (14% vs. 28%, $p = 0.001$; Ramanathan et al., 2023) and perioperative gains (e.g., 61% lower medical complications, RR 0.39, $p = 0.001$; Goldstein et al., 2016) highlight its maturity. Endoscopic and navigation technologies (Zhou et al., 2023) amplify these trends, though learning curves temper early adoption (Qu et al., 2015) [31,32,34].

Discussion

Interpretation of Clinical Outcomes and Quality of Life: The comparative analysis of open spinal fusion and minimally invasive spine surgery (MISS) over 2014–2024 reveals a compelling shift toward less invasive approaches, driven by clinical and patient-centered outcomes. Fusion success, a hallmark of efficacy, remains comparable across techniques, with Hammad et al. (2019) and Zhao et al. (2019) reporting rates exceeding 90% and 98%, respectively, for both methods in degenerative conditions. However, MISS consistently outperforms in reducing immediate postoperative burdens—pain scores drop by 1–2 VAS points (Hammad et al., 2019), infections halve from 4% to 2% (Park et al., 2018), and hospital stays shorten by 2–4 days (Goldstein et al., 2016). These perioperative advantages align with Guo et al.'s (2022) emphasis on MISS's tissue-sparing benefits, suggesting a reorientation of surgical priorities from structural correction alone to holistic recovery [4,7,23,24,30,34].

Long-term quality of life (QoL) metrics, however, temper this enthusiasm. Heemskerk et al. (2021) found no significant 2-year differences in ODI, VAS, or EQ-5D scores between MIS-TLIF and open TLIF, a parity echoed at 5 years by Zhao et al. (2019). This equivalence challenges MISS's perceived superiority, indicating that while early recovery accelerates, functional outcomes converge over time. Hartmann et al. (2022) and Weiss et al. (2019) suggest open surgery's higher complication rates (20%–30% vs. 5%–10%) may offset its durability in complex cases, yet the lack of sustained QoL divergence calls for deeper investigation into patient-reported outcome measures (PROMs) beyond 5 years [6,9,30].

Advantages and Limitations of Surgical Techniques: Surgical technique advancements underscore MISS's operational edge. Hu et al. (2023) and Goldstein et al. (2016) quantify reductions in operative time (120–150 vs. 180–210 minutes) and blood loss (100–200 mL vs. 400–600 mL), bolstered by robotic precision and endoscopic innovations like PE-TLIF (Zhou et al., 2023). These efficiencies, coupled with Navarro et al.'s (2018) 20%–30% cost savings, position MISS as a scalable solution, as predicted by Goldstein et al. (2014) amid rising spinal intervention demand. Choi et al. (2022) and Good et al. (2022) highlight robotics and navigation as catalysts, aligning outcomes with open surgery while minimizing invasiveness [7,10,13,22,25].

Table 2: Extended Comparative Outcomes (2014–2024)

Study	Condition	Key Metrics (MISS vs. Open)
Heemskerk (2021)[29]	DDD/Spondylolisthesis	ODI/VAS equal ($p > 0.05$); Fusion: 80.5% vs. 91.1% ($p = 0.29$)
Ramanathan (2023)[31]	DDD	Reoperation: 14% vs. 28% ($p = 0.001$)
Zhou (2023)[33]	DDD	PE-TLIF vs. MIS-TLIF: Less blood loss, faster LOS ($p < 0.05$)
Sarwahi (2021)[36]	AIS	Cobb: 70% both ($p = 0.46$); Blood loss: 360 vs. 790 mL ($p < 0.001$)
Shao (2024)[37]	ADS	Lordosis gain higher in open ($p = 0.04$); Complications lower in MISS ($p < 0.0001$)

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Yet, limitations persist. Yang et al. (2022) and Qu et al. (2015) note MISS's learning curve, with operative times extending to 180 minutes and early revision risks rising (OR 2.59), respectively, due to technical demands like screw placement. Zhou et al. (2023) add that PE-TLIF's fluoroscopy exposure and longer durations offset some benefits, particularly in resource-limited settings. Open surgery, despite its invasiveness, retains an edge in complex deformities—Shao et al. (2024) report superior lumbar lordosis gains in adult degenerative scoliosis (ADS)—suggesting its indispensability where direct visualization is paramount, per Choi et al. (2022) [10,26,32,33,37].

Patient-Specific Factors and Condition-Specific Insights: Patient demographics and spinal conditions further delineate the approaches' applicability. For adolescents with idiopathic scoliosis (AIS), Sarwahi et al. (2021) and Alhammoud et al. (2021) demonstrate MISS's equivalence in Cobb correction (70% and 50°–60°, respectively) with 50%–55% less blood loss, reducing morbidity in younger cohorts. Elderly patients, particularly with ADS or comorbidities, benefit similarly—Shao et al. (2024) and Park et al. (2018) note lower complications (e.g., 6% vs. 15% in obese patients; Park et al., 2024) and halved recovery times. Su et al. (2022) and Hammad et al. (2019) extend this to osteoporotic or diabetic populations, where MISS's lower stress profile mitigates risks [17,27,36,37].

Condition-specific outcomes reveal trade-offs. In degenerative disc disease (DDD) and spondylolisthesis, Lu et al. (2017) and Zhao et al. (2019) affirm MISS's long-term parity in PROMs, with perioperative gains (331 mL less blood loss, 1.7-day shorter LOS) outweighing open surgery's slight speed advantage (19 minutes; Lu et al., 2017). Scoliosis, however, splits: AIS favours MISS, while ADS leans toward open surgery for lordosis correction (Shao et al., 2024). Smoking's impact remains underexplored, though Ramanathan et al.'s (2023) reoperation reduction (14% vs. 28%) hints at MISS's resilience across comorbidities [30,31,35].

Economic and Practical Implications: Economic viability amplifies MISS's appeal. Eseonu et al. (2022) and Navarro et al. (2018) document reduced healthcare costs via shorter stays and fewer complications, aligning with Goldstein et al.'s (2014) forecast of sustainable interventions. This contrasts with open surgery's resource intensity, per Guo et al. (2022), yet MISS's reliance on advanced technology—robotic systems, fluoroscopy—poses adoption barriers in rural or underfunded settings, a gap Yang et al. (2022) and Choi et al. (2022) acknowledge [7,26].

Research Gaps and Future Directions: Despite robust evidence, gaps persist. Long-term QoL beyond 5 years remains understudied—Su et al. (2022) and Heemskerk et al. (2021) call for longitudinal PROMs to validate MISS's trajectory. Degenerative disc disease data is sparse beyond single-level cases and spondylolisthesis lacks multi-level focus (Lu et al., 2017) [17,29,35].

Smoking's fusion impact, speculated by Ramanathan et al. (2023), warrants direct comparison, as does MISS's efficacy in rural populations, where technology access lags (ChatGPT speculation). Pholprajug et al. (2023) and Hinojosa-González et al. (2022) emphasize tailoring to patient factors, yet personalized outcome predictors remain nascent [15,16,31].

Future research should prioritize: (1) RCTs with 10-year follow-ups for QoL and revision rates, building on Ramanathan et al. (2023); (2) multi-level DDD and spondylolisthesis studies; (3) smoking and comorbidity-specific trials; and (4) cost-effectiveness analyses in diverse healthcare systems. Innovations like awake MISS (Garg et al., 2020; Rangnekar et al., 2022) and endoscopic techniques (Zhou et al., 2023) merit broader validation to cement MISS's dominance [11,12,33].

Synthesis and Trajectory: The decade's evidence spanning Guo et al. (2022), Weiss et al. (2019), and Ramanathan et al. (2023) emphasized MISS's ascent, balancing efficacy, recovery, and cost. Open surgery endures for complex corrections, but MISS's technological evolution (Good et al., 2022) and patient-centric gains (Vora et al., 2018) signal its future primacy. Bridging existing research gaps is expected to further strengthen this shift [4,9,13,14,31].

Conclusion

Over the past decade - minimally invasive spine surgery (MISS) has re-defined spinal fusion by offering a strong and patient-centred alternative to traditional open spinal fusion (OSF). This literature review observed that MISS achieved equivalent fusion success and long-term functional outcomes across degenerative disc disease, spondylolisthesis and scoliosis while providing distinct perioperative advantages. MISS delivered (A) reduced blood loss (by 200–400 mL) (B) shorter operative times in experienced hands (C) lower complication rates (5%–10% vs. 20%–30%) (D) significantly faster recoveries. This translated into improved early mobility and reduced opioid reliance.

MISS's superiority is especially pronounced in vulnerable populations. In adolescents, it achieves comparable deformity correction with 50% less blood loss and fewer complications. In elderly and obese patients, MISS lowers morbidity and halved re-operation rates (14% vs. 28%) with earlier discharges. Technological advances such as endoscopic TLIF, robotic navigation, and awake spine surgery have further enhanced MISS precision and broadened its applicability. These innovations also mitigate the early learning curve that once posed a barrier to widespread adoption.

Yet, open fusion retains a critical role in managing complex

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deformities requiring aggressive correction, particularly in adult degenerative scoliosis where it yields superior sagittal realignment. Long-term patient-reported outcomes between MISS and OSF converged after 2–5 years. This emphasizes that procedural success must be measured not only by early recovery but also by sustained quality of life.

MISS offers a scalable and cost-effective solution. Its trajectory signals a shift from maximal exposure to maximal precision. As surgical technologies mature and long-term data evolve, MISS is poised to become the dominant paradigm in spinal fusion; it offers a balance of durability, safety and patient-focused recovery beyond traditional open techniques.

References

1. Lewandrowski KU, Soriano-Sánchez JA, Zhang X, et al. Regional variations in acceptance, and utilization of minimally invasive spinal surgery techniques among spine surgeons: Results of a global survey. Journal of Spine Surgery 6 (2020).

2. Sharif S, Shaikh Y, Bajamal AH, et al. Fusion Surgery for Lumbar Spinal Stenosis: WFNS Spine Committee Recommendations. World Neurosurg X 7 (2020).

3. Försth P, Ólafsson G, Carlsson T, et al. A Randomized, Controlled Trial of Fusion Surgery for Lumbar Spinal Stenosis. New England Journal of Medicine. 15 (2016): 374.

4. Guo H, Song Y, Weng R, et al. Comparison of Clinical Outcomes and Complications Between Endoscopic and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Lumbar Degenerative Diseases: A Systematic Review and Meta-Analysis. Global Spine J 13 (2022): 1394-1404.

5. Eseonu K, Oduoza U, Monem MA, et al. Systematic Review of Cost-Effectiveness Analyses Comparing Open and Minimally Invasive Lumbar Spinal Surgery. The International Journal of Spine Surgery 16 (2022): 612-624.

6. Hartmann S, Lång A, Lener S, et al. Minimally Invasive Versus Open Transforaminal Lumbar Interbody Fusion: A Prospective, Controlled Observational Study of Short-Term Outcome. Neurosurg Rev 45 (2022): 3417-3426.

7. Goldstein CL, Macwan K, Sundararajan K, et al. Comparative Outcomes of Minimally Invasive Surgery for Posterior Lumbar Fusion: A Systematic Review. Clin Orthop Relat Res 472 (2014): 1727-1737.

8. Danison A, Lee DJ, Panchal RR. Temporary Stabilization of Unstable Spine Fractures. Curr Rev Musculoskelet Med 10 (2017): 199-206.

9. Weiss H, García RM, Hopkins B, et al. A Systematic Review of Complications Following Minimally Invasive Spine Surgery Including Transforaminal Lumbar Interbody Fusion. Curr Rev Musculoskelet Med 12 (2019): 328-339.

10. Choi JY, Park S, Kim H, et al. Recent Updates on Minimally Invasive Spine Surgery: Techniques, Technologies, and Indications. Asian Spine J 16 (2022): 1013-1021.

11. Garg B, Ahuja K, Sharan AD. Awake Spinal Fusion. J Clin Orthop Trauma 11 (2020): 749-752.

12. Rangnekar A, Anand MK, Goparaju P, et al. Awake Spinal Fusion: A Retrospective Analysis of Minimal Invasive Single Level Transforaminal Lumbar Interbody Fusion Done Under Spinal Anaesthesia in 150 Cases. Int J Res Orthop 8 (2022): 649.

13. Good CR, Orosz L, Lehman RA, et al. Minimally Invasive Posterior Facet Decortication and Fusion Using Navigated Robotic Guidance: Feasibility and Workflow Optimization. Neurospine 19 (2022): 773-779.

14. Vora D, Kinnard M, Falk D, et al. A Comparison of Narcotic Usage and Length of Post-Operative Hospital Stay in Open Versus Minimally Invasive Lumbar Interbody Fusion With Percutaneous Pedicle Screws. Journal of Spine Surgery 4 (2018): 516-521.

15. Pholprajug P, Kotheeranurak V, Liu Y, et al. The Endoscopic Lumbar Interbody Fusion: A Narrative Review, and Future Perspective. Neurospine 20 (2023): 1224-1245.

16. Hinojosa-González DE, Roblesgil-Medrano A, Villarreal-Espinosa JB, et al. Minimally Invasive Versus Open Surgery for Spinal Metastasis: A Systematic Review and Meta-Analysis. Asian Spine J. 16 (2022): 583-597.

17. Su H, Ko HJ, Su Y, et al. Prevention of Compression Fracture in Osteoporosis Patients Under Minimally Invasive Trans-Foraminal Lumbar Interbody Fusion With Assistance of Bone-Mounted Robotic System in Two-Level Degenerative Lumbar Disease. Medicina (B Aires) 58 (2022): 688.

18. Imada AO, Huynh TR, Drazin D. Minimally Invasive Versus Open Laminectomy/Discectomy, Transforaminal Lumbar, and Posterior Lumbar Interbody Fusions: A Systematic Review. Cureus. (2017).

19. Liu J, Zheng H, Chan C. Clinical Effectiveness and Biochemical Impacts of Minimally Invasive Versus Open Transforaminal Lumbar Interbody Fusion: A Meta-Analysis. Medical Research 6 (2024): 15-39.

20. Soh JW, Lee JC. Minimally Invasive Lateral Lumbar Interbody Fusion: Indications, Outcomes and

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DOI:10.26502/fjsrs0086

Complications. The Journal of the Korean Orthopaedic Association. 54 (2019): 203.

21. Bazin L, Ansorge A, Vendeuvre T, Cochard B, Tabard-Fougère A, Vazquez O, et al. Minimally Invasive Surgery for Posterior Spinal Instrumentation and Fusion in Adolescent Idiopathic Scoliosis: Current Status and Future Application. Children 10 (2023): 1882.

22. Navarro SM, Frankel WC, Haeberle HS, et al. Fixed and Variable Relationship Models to Define the Volume-Value Relationship in Spinal Fusion Surgery: A Macroeconomic Analysis Using Evidence-Based Thresholds. Neurospine 15 (2018): 249-260.

23. Hammad A, Wirries A, Ardeshiri A, et al. Open Versus Minimally Invasive TLIF: Literature Review and Meta-Analysis. J Orthop Surg Res (2019).

24. Park Y, Seok SO, Lee S, et al. Minimally Invasive Lumbar Spinal Fusion Is More Effective Than Open Fusion: A Meta-Analysis. Yonsei Med J 59 (2018): 524.

25. Hu X, Yan L, Jin X, et al. Endoscopic Lumbar Interbody Fusion, Minimally Invasive Transforaminal Lumbar Interbody Fusion, and Open Transforaminal Lumbar Interbody Fusion for the Treatment of Lumbar Degenerative Diseases: A Systematic Review and Network Meta-Analysis. Global Spine J 14 (2023): 295–305.

26. Yang H, Jia X, Hai Y. Posterior Minimally Invasive Scoliosis Surgery Versus the Standard Posterior Approach for the Management of Adolescent Idiopathic Scoliosis: An Updated Meta-Analysis. J Orthop Surg Res 17 (2022).

27. Alhammoud A, Alborno Y, Baco AM, et al. Minimally Invasive Scoliosis Surgery Is a Feasible Option for Management of Idiopathic Scoliosis and Has Equivalent Outcomes to Open Surgery: A Meta-Analysis. Global Spine J 12 (2021): 483-492.

28. Park SM, Kim HJ, Yeom JS. Is Minimally Invasive Surgery a Game Changer in Spinal Surgery? Asian Spine J 18 (2024): 743-752.

29. Heemskerk JL, Akinduro O, Clifton W, Quiñones-Hinojosa A, Abode-Iyamah KO. Long-term clinical outcome of minimally invasive versus open single-level transforaminal lumbar interbody fusion for degenerative lumbar diseases: a meta-analysis. The Spine Journal. 2021;21(12): 2049-2065.

30. Zhao H, Gao H, Zhou C, et al. A randomized controlled trial with ≥5 years of follow-up comparing minimally invasive and open transforaminal lumbar interbody fusion in disc herniation at single level. Exp Ther Med 17 (2019): 3614-3620.

31. Ramanathan S, Rapp A, Perez-Cruet M, et al. Long-term reoperation rates after open versus minimally invasive spine surgery for degenerative lumbar disease: five-year follow-up of 2130 patients. World Neurosurg 171 (2023): e126-e136.

32. Qu J tao, Tang Y, Wang M, et al. Comparison of MIS vs. open PLIF/TLIF with regard to clinical improvement, fusion rate, and incidence of major complication: a meta-analysis. European Spine Journal 24 (2015): 1058-1065.

33. Zhou Y, Pan Z, Yang H, et al. Percutaneous endoscopic versus minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative diseases: a meta-analysis. Videosurgery and Other Miniinvasive Techniques. 18 (2023): 100-112.

34. Goldstein CL, Macwan K, Sundararajan K, et al. Perioperative outcomes and adverse events of minimally invasive versus open posterior lumbar fusion: meta-analysis and systematic review. J Neurosurg Spine 24 (2016): 416-427.

35. Lu VM, Kerezoudis P, Gilder HE, et al. Minimally invasive surgery versus open surgery spinal fusion for spondylolisthesis: a systematic review and meta-analysis. Spine (Phila Pa 1976) 42 (2017): E177–E185.

36. Sarwahi V, Galina JM, Hasan S, et al. Minimally invasive versus standard surgery in idiopathic scoliosis patients: a comparative study. Spine (Phila Pa 1976) 46 (2021): 1326–1335.

37. Shao Z, Liang H, Li S, et al. Comparison of open surgery versus minimally invasive surgery in nonsevere adult degenerative scoliosis: a systematic review and meta-analysis. Spine (Phila Pa 1976). 49 (2024): E210–E220.

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