

Review

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[Halil Bulut](#)^{*}, Kursat Guner^{*}, Omer Polat, Peter Derman

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Review

Minimally Invasive Lumbar Discectomy: Mapping the Landscape of Techniques and Outcomes through Bibliometric Analysis of Current Meta-Analyses

Halil Bulut ^{1,*}, Kursat Guner ^{2,*}, Omer Polat ² and Peter Derman ³

¹ Houston Methodist, Institute for Technology, Innovation & Education, Houston, TX, USA

² Orthopedics and Traumatology Department, Ümraniye Training and Research Hospital, Istanbul, TR

³ Department of Orthopedic Spine, Texas Back Institute - Dallas, Dallas, TX, USA

* Correspondence: halilibrahim.bulut@ogr.iuc.edu.tr (H.B.); kursat-guner@hotmail.com (K.G.)

Abstract: Introduction: Lumbar radiculopathy, frequently triggered by disc herniations, affects around one in 50 young adults, leading to significant impacts on quality of life. When conservative treatments fail to alleviate symptoms, surgical intervention such as discectomy is often pursued. Technological advancements have led to various minimally invasive techniques, promising improved outcomes. Our aim was to compare clinical outcomes of different techniques. **Methods:** We conducted a systematic search in PubMed using "lumbar disc hernia" and the meta-analysis filter. Inclusion criteria comprised meta-analyses focusing on lumbar disc herniation treatments, published in English. A rigorous selection process adhering to PRISMA guidelines ensured high-quality evidence extraction. **Results:** From 28,171 initial records, 31 meta-analyses involving 87,852 patients were included. Heterogeneity across the literature presented challenges, notably in study populations, surgical techniques, and research designs. Among the techniques evaluated, full-endoscopic lumbar discectomy (FELD) emerged as superior in various perioperative parameters, including Visual Analog Scale (VAS) scores, Oswestry Disability Index (ODI), operation time, and complications. Conversely, automated percutaneous discectomy (AUTD) consistently exhibited poorer outcomes, suggesting limited effectiveness compared to other techniques. **Conclusion:** Despite advancements, the heterogeneity observed in the literature underscores the need for standardized approaches in minimally invasive spinal surgery research. FELD stands out as a preferred technique, offering favorable outcomes across multiple parameters. Conversely, techniques like AUTD raise concerns regarding efficacy. Future research should aim for uniformity in methodologies to facilitate accurate comparisons and guide clinical decision-making.

Keywords: lumbar disc herniation; discectomy; full-endoscopic lumbar discectomy (FELD); automated percutaneous discectomy (AUTD); Microendoscopic Discectomy (MED)

Introduction

Lumbar radiculopathy, often caused by disc herniations, affects approximately one in 50 young adults(1). The resulting symptoms can significantly impact an individual's quality of life, necessitating effective treatment strategies. If symptoms remain sufficiently limiting despite conservative measures, surgical intervention in the form of discectomy is often considered. More than half a million discectomies are conducted each year in only USA, making it the most prevalent spine surgery. This widespread procedure, like many others, continues to benefit from technological advancements and innovations, enhancing its effectiveness and outcomes (3).

Minimally invasive discectomy, introduced in the mid-1980s, revolutionized discectomy procedures, which had been successfully performed since the early 1900s. Today, there are several advanced techniques for minimally invasive disc treatments, including tubular microdiscectomy, micro endoscopic discectomy, and full endoscopic discectomy. These modern methods offer

numerous benefits, such as reduced recovery times, minimized scarring, and enhanced precision, significantly improving patient outcomes (4).

In this meta-review, our primary objective is to systematically evaluate the existing meta-analyses on these treatment procedures. By doing so, we aim to compile and analyze the findings in the relevant literature, providing clearer and more comprehensive insights into the effectiveness and safety of these procedures.

Methods

Search Strategy and Databases

To identify relevant meta-analyses on lumbar disc treatments, we conducted a comprehensive search in PubMed. The search strategy involved using the keywords "lumbar disc hernia" combined with the meta-analysis filter. This approach ensured that we captured all pertinent studies that systematically reviewed and synthesized data on treatment options for lumbar disc herniation. By focusing on meta-analyses, we aimed to gather high-level evidence that provides robust conclusions about the effectiveness and safety of various treatment procedures.

By adhering to the PRISMA guidelines (4), we ensured a rigorous and transparent methodology, enhancing the reliability and validity of our meta-review findings.

Inclusion and Exclusion Criteria

For this meta-review, we included studies that met the following criteria:

- Type of Study: Only meta-analyses were considered.
- Focus: Studies addressing treatment options for lumbar disc herniation.
- Language: Articles published in English.

We excluded studies that:

- Were not meta-analyses.
- Did not focus on lumbar disc herniation treatments.
- Were published in languages other than English.

Study Selection and Data Extraction Process

The study selection process involved several steps:

1. Initial Search: Conducted using PubMed with the keywords "lumbar disc hernia" and the meta-analysis filter.

2. Screening: Titles and abstracts were screened to identify potentially relevant studies.

3. Full-Text Review: Full texts of the selected studies were reviewed to confirm their eligibility based on the inclusion and exclusion criteria.

4. Data Extraction: Relevant data from the included studies were systematically extracted. This included information on study design, patient populations, treatment methods, outcomes, and key findings.

By adhering to this rigorous selection and extraction process, we ensured that our meta-review is comprehensive and based on high-quality evidence.

Nomenclature for Minimally Invasive Techniques;

In this meta-review, we classified lumbar discectomy procedures based on their endoscopic nature and anatomical approach, consistent with the current classifications in the literature (5). The methods and nomenclature used in this study focus specifically on lumbar discectomy procedures.

Full-Endoscopic Lumbar Discectomy (FELD):

- **Transforaminal Endoscopic Lumbar Discectomy (TELD):** A minimally invasive procedure performed through the transforaminal approach to access and remove the herniated disc material.
- **Interlaminar Endoscopic Lumbar Discectomy (IELD):** A technique that involves an interlaminar approach, providing direct access to the disc through the natural space between the vertebrae.

- **Extraforaminal Endoscopic Lumbar Discectomy (EELD):** An approach that targets the extraforaminal space, particularly useful for treating foraminal and extraforaminal disc herniations.
- Endoscopy-Assisted Surgery:**
- **Microendoscopic Discectomy (MED):** A less invasive procedure that uses a microscope and small tubular retractors to remove herniated disc material through a small incision.
 - **Unilateral Biportal Endoscopic (UBE):** A more advanced endoscopic technique involving two small incisions to provide a better visualization of the surgical site, allowing for precise removal of herniated disc material.

By following this nomenclature, we systematically reviewed the available meta-analyses to provide a structured comparison of these lumbar discectomy techniques, focusing on their clinical effectiveness, safety profiles, and perioperative outcomes.

Results

Overview of Included Studies

Records were initially identified from the MEDLINE database, totaling 28,171 entries. Before screening, 27,806 records were removed due to being unrelated article types. Following screening, 365 records were assessed, resulting in the exclusion of 312 records. Subsequently, 52 reports were sought for retrieval, all of which were successfully retrieved. These reports were then assessed for eligibility, with all 52 being included in the review. Finally, after thorough evaluation, 30 studies were deemed suitable for inclusion in the review process.

Study Characteristics

The research encompassed a total of 31 studies (6-36), which included six network meta-analyses and 25 meta-analyses, involving a cumulative total of 85,546 patients. Among these studies, the breakdown of the different minimally invasive techniques examined is as follows: 13 studies focused on full-endoscopic lumbar discectomy (FELD), 10 on microendoscopic discectomy (MED), seven on tubular discectomy (TD), nine on open discectomy (OD), 13 on open microdiscectomy (OMD), four on percutaneous laser disc decompression (PLDD), two on unilateral biportal endoscopic decompression (UBED), two on interlaminar endoscopic lumbar discectomy (IELD), two on transforaminal endoscopic lumbar discectomy (TELD), two on automated percutaneous lumbar discectomy (AUTD). these studies provide a comprehensive analysis of the efficacy, safety, and perioperative outcomes of various minimally invasive spinal surgery techniques. The meta-analyses and network meta-analyses offer robust comparisons, highlighting the relative advantages and limitations of each technique concerning visual analog scale (VAS) scores, Oswestry Disability Index (ODI), complications, operative time, and length of hospital stay (LOS). (figure 1 and Table 1)

Table 1. included studies.

Author (reference number)	Year	Type	Comparison	Studies (n)	Patients	Follow up	Outcome	Key findings
Ding (6)	2018	Meta analysis	TELD vs. FD	17	1390	Perioperati ve	Vas, Comp., Opt. time, LOS and ODI	TELD>FD VAS, ODI,LOS and opt time.
Wang (7)	2019	Meta analysis	TMD vs. OMD	4	610	Perioperati ve	VAS, SF36,ODI	Similar
Wang (8)	2014	Meta analysis	ILMI vs. OMD	7	1012	Perioperati ve	Grade,VAS, LOS,Opt.tim e	ILMI>OM D

								Similar (ODI and VAS)
Qin (9)	2024	Network Analysis	OD, MD TD, FELD, CN PLDD, MED	50	5702	Perioperative	VAS, ODI, Opt time and Comp.	FELD and MED better in VAS and ODI.
Huang (10)	2020	Meta analysis	IELD vs TELD	13	974	Perioperative	VAS and ODI	Similar
He (11)	2024	Meta analysis	UBED Vs UPFED	9	745	Perioperative	Vas, Comp., Opt. time, LOS and ODI	Only los and opt time different (UPFED better)
Cong (12)	2016	Meta analysis	ED vs OD	9	1092	Perioperative	Comp. and opt time	ED>OD in LOS, others similar
Yin (13)	2020	Meta analysis	TELD vs. IELD	15	1156	Perioperative	Comp.	similar
Zhang (14)	2018	Meta analysis	TED vs. OMD	9	1527	Perioperative	Vas, Comp., Opt. time, and LOS	TED better in only LOS
Ma (15)	2022	Meta analysis	FELD vs. UBED	6	281	Perioperative	Vas, Comp., Opt. time, and LOS	similar
Xu (16)	2020	Meta analysis	FELD vs. MED	9	984	Perioperative	Comp., ODI and VAS	FELD>MED
Wei (17)	2021	Network Analysis	OMD, MED, FELD, PD, TD	22	2529	Perioperative	Comp.	FELD better
Yang (18)	2022	Meta analysis	FELD vs OMD	19	1918	Perioperative	Comp.	FELD better
He (19)	2024	Meta analysis	UBED vs. FELD	12	1175	Perioperative	Opt time, VAS, ODI and LOS	FELD better only in LOS and Opt time
Zhang (20)	2023	Meta analysis	TD vs. OD	4	523	Perioperative	Opt time, VAS, ODI and LOS	TD better in only ODI
Kamper (21)	2014	Meta analysis	ILMI vs. MD TFMI vs. MD	29	4472	Perioperative	Opt time and LOS	ILMI reduces LOS
He (22)	2016	Meta analysis	MED vs. OMD	5	501	Perioperative	Opt time, VAS, ODI and LOS	MED reduces LOS
Ruan (22)	2016	Meta analysis	FELD vs. OMD	7	1389	Perioperative	Opt time, VAS, ODI and LOS	FELD reduces

								LOS and opt time
Kim (24)	2018	Meta analysis	FELD vs. OMD	7	1254	Perioperative	Opt time, VAS, ODI and LOS	FELD better all points
Gadjradj (25)	2021	Meta analysis	TELD v. OMD	14	1465	Perioperative	VAS	Similar
Rickers (26)	2021	Network Analysis	Cons, OD, MD TD,AUTD,PE D AFrep,OD_ds	32	4877	Perioperative	VAS and ODI	AUTD worst, PED slightly better
Rasouli (27)	2014	Meta analysis	MED vs. OD	11	1172	Perioperative	VAS and ODI	OD slightly better
Feng (28)	2017	Network Analysis	FELD, OMD, OD ,MED , PLDD,CN,AUTD	29	3146	Perioperative	VAS, ODI Comp.	FELD best AUTD worst
Bai (29)	2021	Meta analysis	FELD vs. other techniques	14	2528	Perioperative	Vas, Comp., ODI and LOS	FELD better
Li (30)	2018	Meta Analysis	TMD vs OMD	10	801	Perioperative	Vas, Comp., ODI and LOS	Similar
Chen (31)	2019	Network Analysis	PLDD,MED, FELD, OMD	18	2273	Perioperative	comp	FELD slightly better
Yu (32)	2019	Meta Analysis	TELD vs MED	8	805	perioperative	Vas, Comp., ODI and LOS	TELD>MED
Chen (33)	2020	Network Analysis	OMD, MED, FELD, PLDD	37	6912	perioperative	Comp.	FELD better
Phan (34)	2017	Meta Analysis	ED, MED, OD	23	28487	perioperative	Vas, Comp., ODI and LOS	Similar
Shi (35)	2018	Meta Analysis	FELD vs MED	18	2161	perioperative	ODI,Vas, Comp., Opt. time, and LOS	FELD better
Qin (36)	2018	Meta Analysis	FELD vs OMD	9	1585	perioperative	Comp., LOS, and opt time	FELD reduces LOS

- VAS: Visual Analog Scale - Comp: Complications - ODI: Oswestry Disability Index - LOS: Length of Stay - Opt Time: Operation Time- TELD: transforaminal endoscopic lumbar discectomy- FD: Fenestration Discectomy - TMD: Tubular Microdiscectomy - ILMI: Interlaminar Minimally Invasive Discectomy - OMD: Open Microdiscectomy - TD: Tubular Discectomy - FELD: full-endoscopic lumbar discectomy - CN: Chemonucleolysis - PLDD: Percutaneous Laser Disc Decompression -- OD: Open Discectomy - AUTD: Percutaneous Discectomy (automated, laser, thermal coblation, or nucleoplasty) - Afrep: Annulus Fibrosus Repair (including Xclose, Barricaid, and cryopreserved amniotic membrane) - MED: Microendoscopic Discectomy - Cons: Conservative Treatment- IELD:interlaminar endoscopic lumbar discectomy.

Figure 1. PRISMA Diagram.

Comparison of Techniques

The comparative analyses elucidate the superior performance of FELD in several key aspects when pitted against other techniques. Qin's (2024) extensive network analysis, spanning 50 studies with 5702 patients, highlighted FELD's remarkable efficacy compared to MED, showcasing superior outcomes in terms of Visual Analog Scale (VAS), Oswestry Disability Index (ODI), operation time, and complications. Similarly, He's (2024) meta-analysis comparing UBED to FELD found that while both techniques were comparable in most outcomes, FELD demonstrated an advantage in terms of LOS and operation time. Moreover, several meta-analyses underscored FELD's superiority over OMD. Ruan's (2016) study involving 1389 patients and Kim's (2018) analysis with 1254 patients both emphasized FELD's ability to reduce both LOS and operation time while maintaining favorable outcomes in VAS scores and ODI. Shi (2018) further corroborated these findings, indicating that FELD outperformed MED across various perioperative parameters, including LOS, VAS scores, complications, and operation time. Furthermore, Feng's (2017) network meta-analysis, incorporating 29 studies and 3146 patients, concluded that FELD emerged as the superior technique among a diverse range of options, including OMD, OD, MED, PLDD, and others. Additionally, Chen's (2020) network meta-analysis involving 6912 patients provided further evidence of FELD's superiority, particularly in terms of complications. Overall, the collective evidence from these studies underscores FELD as a preferred technique due to its consistently superior outcomes across various perioperative parameters, reaffirming its position as a cornerstone in minimally invasive spinal surgery.

While the focus is often on identifying the best techniques in minimally invasive spinal surgery, it's equally crucial to acknowledge those with less favorable outcomes. Among the array of techniques assessed in the literature, some have been associated with poorer results in terms of various perioperative parameters.

One such technique highlighted in the studies is AUTD. Rickers (2021) conducted a network analysis across 32 studies involving 4877 patients, where AUTD emerged as one of the least favorable techniques. The analysis revealed that patients undergoing AUTD experienced worse outcomes compared to other techniques, particularly in terms of VAS scores and ODI. Furthermore, Feng's (2017) network meta-analysis involving 29 studies and 3146 patients highlighted AUTD as one of the worst-performing techniques. While FELD emerged as the best technique in terms of outcomes, AUTD consistently demonstrated poorer results, indicating its limited effectiveness compared to other minimally invasive approaches.

Similarly, Rasouli's (2014) meta-analysis comparing MED to OD across 11 studies involving 1172 patients indicated that OD slightly outperformed MED in terms of VAS and ODI outcomes. While MED is considered minimally invasive, this finding suggests that it may not always yield the most optimal results compared to traditional open techniques.

Additionally, Gadraj's (2021) meta-analysis TELD to OD across 14 studies involving 1465 patients reported no significant differences between the two techniques in terms of VAS scores. Although TELD is minimally invasive, the lack of superiority in outcomes compared to OMD raises questions about its efficacy in certain cases.

Discussion

This systematic review provides the most comprehensive overview to date on the surgical treatments for lumbar disc herniations, which have approximately 30,000 articles indexed in MEDLINE. By examining existing meta-analyses and network analyses, this review highlights that the vast majority of meta-analyses demonstrate the superiority of minimally invasive treatments. Additionally, network analyses specifically emphasize the advantages of FELD and notably indicate that AUTD lags other treatments.

A review of the literature reveals that many meta-analyses and systematic reviews focus on various outcome measures, including LOS, ODI, VAS, operation duration, and complications. These studies highlight the critical aspects of patient recovery and treatment efficacy. Notably, there is

significant heterogeneity in studies where different treatment types yield nearly equivalent outcomes (7,10,13,15,25,27,30,34). This variability can be attributed to differences in study design, patient populations, and surgical techniques. In studies where heterogeneity is present, the ambiguity of the results is a statistically expected outcome, reflecting the inherent complexities and variabilities in clinical research (37).

"Less is more" has become a prominent slogan in many surgical disciplines today, including spinal surgery(38). The literature overwhelmingly supports the advantages of endoscopic treatments in terms of cost-effectiveness, patient comfort, and medical outcomes, with only one meta-analysis (27) deviating from this trend (6-26, 28-36). The lone meta-analysis favoring open surgery is dated earlier than the others, possibly reflecting the cumulative learning curve associated with minimally invasive spinal surgery (27). Indeed, contemporary literature highlights the crucial importance of the learning curve in mastering minimally invasive techniques, underscoring its impact on surgical outcomes and overall effectiveness (38-40).

The superiority of FELD in the surgical treatment of lumbar disc herniation is well-supported by recent literature. Six network analysis consistently demonstrate that FELD outperforms other surgical methods (9,17,26,27,31,33). Additionally, seven meta-analyses specifically highlight FELD's advantages over MED and OMD. FELD's superior outcomes can be attributed to several factors (16,20,24,25,31,37,38). First, the minimally invasive nature of FELD leads to reduced tissue damage and quicker recovery times, enhancing patient comfort and satisfaction. Furthermore, FELD has shown a lower incidence of complications and shorter hospital stays compared to traditional methods, contributing to its cost-effectiveness. These benefits are reflected in the consistent findings across multiple meta-analyses and network meta-analysis. However, it is noteworthy that one meta-analysis found FELD to be similar to UBED(15). This suggests that while FELD generally exhibits superior outcomes, UBED may offer comparable benefits in specific cases or patient populations. The similarity between FELD and UBED in this single analysis highlights the need for further comparative studies to delineate the precise contexts in which each technique excels.

The inferiority of AUTD in the surgical treatment of lumbar disc herniation is highlighted by recent research findings. Two network analyses unequivocally demonstrate that AUTD performs worse than all other surgical methods examined(27,29). The suboptimal outcomes associated with AUTD can be attributed to several factors. First, the automated nature of the procedure may limit the surgeon's ability to precisely target and remove herniated disc material, leading to incomplete decompression and persistent symptoms. Additionally, the mechanical aspects of AUTD may result in greater tissue trauma compared to more controlled, manual techniques, thereby increasing the risk of complications and prolonged recovery times.

These findings align with clinical observations that have noted higher rates of reoperation and less favorable long-term outcomes in patients undergoing AUTD compared to those treated with more advanced minimally invasive methods such as FELD and MED. The meta-regressions provide robust evidence that supports these clinical insights, further solidifying the position of AUTD as a less effective option for lumbar disc herniation.

This study offers several strengths that contribute to its value in the field. Firstly, it provides a comprehensive and systematic synthesis of the existing literature on isolated decompression techniques for lumbar disc herniation, offering a detailed comparison of different approaches. By focusing specifically on decompression, this meta-analysis addresses a critical gap in the literature, providing insights into the efficacy and outcomes of these techniques. Secondly, the inclusion of a large number of studies allows for a broad and diverse analysis, capturing a wide range of clinical scenarios and patient populations. Thirdly, the use of bibliometric analysis adds a sophisticated layer of analysis, enabling indirect comparisons between techniques and offering a more nuanced understanding of their relative effectiveness. Additionally, the study highlights important areas where future research is needed, such as the need for standardized outcome measures and high-quality randomized controlled trials, guiding the direction of subsequent investigations. Overall, this work serves as a valuable resource for clinicians and researchers, offering a robust foundation for evidence-based decision-making in the management of lumbar disc herniation.

This study has several limitations that should be acknowledged. First, the issue of overlapping patient cohorts across multiple meta-analyses poses a significant challenge in accurately determining the cumulative number of patients analyzed. Despite efforts to identify and account for potential overlaps, some degree of redundancy may persist, potentially skewing the overall results. Second, the variability in study quality, particularly the lack of standardized outcome measures and differences in surgical techniques, anatomy, and patient mental/social status, introduces heterogeneity that may affect the generalizability of our findings. Additionally, the limited availability of high-quality randomized controlled trials in this area further complicates the interpretation of our results. While our meta-analysis offers a comprehensive synthesis of existing literature on isolated decompression techniques for lumbar disc herniation, the conclusions drawn should be interpreted with caution due to these inherent limitations. Future studies with standardized methodologies and larger, more diverse patient populations are needed to validate and extend our findings.

Conclusion

In conclusion, while FELD consistently demonstrates efficacy and favorable outcomes, AUTD exhibits inferior results compared to other techniques. Nonetheless, the diverse array of research methodologies emphasizes the urgent need for greater consistency and consensus in this field. The extensive literature on minimally invasive spinal surgery underscores the critical importance of standardized approaches in advancing research and enhancing patient outcomes. Overcoming this challenge demands collaborative efforts to establish uniform protocols for study design, patient selection, and outcome evaluation. By prioritizing methodological rigor and continuous assessment, researchers can bolster the reliability and relevance of their findings, thus guiding clinical decisions and optimizing patient care. As the field progresses, a steadfast commitment to standardization will prove indispensable in fostering innovation, refining surgical practices, and ultimately enhancing the well-being of individuals affected by lumbar disc herniation and related ailments.

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