**REVIEW ARTICLE**

*Humanistic studies and Social Researches. 2025;1(1): 6*
https://doi.org/10.22034/hssr.2025.217450

# Comparing Nucleotomy and Percutaneous Laser Disc Decompression for Lumbar Disc Herniation: A Review Article

**Amin Ghanbarpour Juybari[1], Mehran Frouzanian[2], Amirsaleh Abdollahi[2], Ali Pahnabi[3]**

[1]*Anesthesiologist, Mazandaran University of Medical Sciences, Sari, Iran*
[2]*Student Research Center, Mazandaran University of Medical Sciences, Sari, Iran*
[3]*Surgical Technologist, Mazandaran University of Medical Sciences, Sari, Iran*

**Article history:**

Received: 15 Aug 2024
Accepted: 27 Jan 2024
Available online: 6 Mar 2025

**Keywords:**

Chronic low back pain
Intervertebral disc herniation
Nucleotomy
Percutaneous laser disc decompression
Minimally invasive
Pain management

**Abstract**

Chronic low back pain and sciatica caused by intervertebral disc herniation are among the leading causes of disability and healthcare utilization worldwide. Effective management of lumbar disc herniation is crucial, encompassing medical therapy, physiotherapy, and interventional procedures. Nucleotomy, the gold standard for decades, directly removes herniated disc material but carries risks such as infection and adjacent segment disease. Recently, percutaneous laser disc decompression (PLDD), a minimally invasive technique, has gained prominence due to its favorable safety profile, reduced recovery times, and efficacy in selected cases. PLDD employs laser energy to vaporize the nucleus pulposus, reducing intradiscal pressure and alleviating nerve compression. This review critically compares nucleotomy and PLDD, focusing on their techniques, indications, outcomes, and complications. While nucleotomy is preferred for complex herniations, PLDD is effective for smaller, contained cases, with success heavily reliant on patient selection. The integration of nutraceuticals with PLDD represents a promising innovation, enhancing neuroprotection and pain management. With a growing emphasis on minimally invasive solutions, PLDD offers a cost-effective alternative for patients seeking less invasive options. This discussion aims to guide clinicians and patients in selecting the most appropriate treatment while exploring advancements shaping the future of spinal care.

**Cite this article as:** Ghanbarpour Juybari A, Frouzanian M , Abdollahi A, Pahnabi A. Comparing Nucleotomy and Percutaneous Laser Disc Decompression for Lumbar Disc Herniation: A Review Article. Humanist Stud Soc Res. 2025;1(1):6. https://doi.org/10.22034/hssr.2025.217450

## INTRODUCTION:

Chronic low back pain (LBP) and sciatica caused by intervertebral disc herniation affect most adults and are among the leading causes of disability and absence from work in the western world (1). The socioeconomic impact of these conditions is immense, imposing significant personal, social, and economic burdens (2). LBP remains one of the most common reasons for seeking healthcare, ranking as the second most frequent reason for visiting a physician for a chronic condition and the third most frequent reason for undergoing a surgical procedure (3, 4). Effective management of LBP and related conditions is, therefore, of paramount importance.

A herniated disc occurs when the nucleus pulposus pushes out from the intervertebral space, often causing

**Correspondence:**
Mehran Frouzanian
Student Research Center, School of Medicine, Mazandaran University of Medical Sciences, Sari, Iran
**E-mail:** frouzanian@gmail.com

back pain that can radiate to the lower limbs, accompanied by numbness, weakness, or sensory changes. The condition arises from localized inflammation and mechanical nerve compression, often due to aging, trauma, congenital abnormalities, or connective tissue diseases (5-7). Most herniated discs occur in the lumbar and cervical regions due to biomechanical stresses, while thoracic herniations are less common and often asymptomatic (8). Initial treatment typically involves non-surgical methods such as NSAIDs, physical therapy, and lifestyle changes, including maintaining a healthy weight and regular exercise. Severe or persistent cases may require epidural injections, nerve blocks, or surgical interventions like discectomies or spinal fusions, though these often provide temporary relief (9).

In recent years, there has been an increasing emphasis on minimally invasive techniques to address lumbar disc herniations, driven by the desire to avoid the complications and extended recovery times associated with traditional open surgeries. Among these advancements, percutaneous intradiscal procedures have emerged as a promising alternative. These methods, particularly when combined with nutraceuticals that provide neuroprotection and aid in pain management, may yield superior outcomes over prolonged periods. One such minimally invasive technique is percutaneous laser disc decompression (PLDD), which has gained popularity for its efficacy, safety profile, and reduced recovery times (10, 11).

PLDD is a minimally invasive treatment option performed under local anesthesia using a laser fiber that is inserted percutaneously into the nucleus of the disc (12). The laser energy applied through the fiber causes the evaporation of water content within the nucleus pulposus, leading to shrinkage of the disc and a reduction in intradiscal pressure. This, in turn, alleviates nerve compression and associated symptoms. However, the success of PLDD is highly dependent on proper patient selection, as not all cases of disc herniation are amenable to this technique (13).

Nucleotomy, often referred to as discectomy, has been the gold standard for treating symptomatic herniated discs for decades (14). It involves the direct removal of the herniated portion of the intervertebral disc to decompress the affected nerve root. Over the years, nucleotomy techniques have evolved, with advancements in surgical instrumentation and minimally invasive approaches reducing patient morbidity, hospital stays, and recovery times (15). Despite its effectiveness, nucleotomy carries inherent risks, such as infection, dural tears, and the potential for adjacent segment disease due to altered spinal biomechanics.

The comparative evaluation of nucleotomy and PLDD is crucial for understanding their respective roles in managing herniated lumbar discs. Both techniques aim to relieve pain and neurological deficits by addressing the mechanical compression of spinal nerve roots. However, they differ significantly in their indications, procedural techniques, outcomes, and associated risks (16). For instance, nucleotomy is generally recommended for larger, more complex herniations or those causing significant neurological compromise, whereas PLDD is often reserved for smaller, contained herniations in patients seeking a less invasive approach (17).

With the aging of the population and the increasing prevalence of spinal disorders due to sedentary lifestyles and occupational risks, the demand for effective and minimally invasive treatment modalities continues to grow (18). PLDD offers a promising solution for patients who are not candidates for traditional surgical methods or who prefer a minimally invasive approach (19). Furthermore, combining PLDD with innovative treatment strategies, such as the use of nutraceuticals, may enhance its efficacy and long-term outcomes. For example, the use of an oral food supplement like MicronilDol®, composed of acetyl-L-carnitine, α-lipoic acid, quercetin, bromelain, pantothenic acid, and vitamins C, B1, B2, B6, and B12, has shown potential in managing neuropathic pain in patients undergoing PLDD (20). Such adjunctive therapies could play a critical role in optimizing patient outcomes by providing neuroprotection and enhancing pain relief.

The aim of this article is to provide a comprehensive comparison of nucleotomy and PLDD, exploring their respective techniques, indications, outcomes, complications, and cost-effectiveness. By critically analyzing the existing literature and clinical data, this discussion seeks to elucidate the strengths and limitations of each approach, guiding clinicians and patients in making informed decisions about the most appropriate treatment modality for herniated intervertebral discs. Additionally, the potential benefits of combining PLDD with nutraceutical interventions will be examined, highlighting emerging trends and innovations in spinal surgery that may shape the future of disc pathology management.

Epidemiology and Socioeconomic Impact of Lumbar Disc Herniation

Lumbar disc herniation is a prevalent condition that disproportionately affects adults in their working years, making it a leading cause of disability and absence from work. The high prevalence of chronic low back pain and sciatica has far-reaching implications for individuals and society, including lost productivity, increased healthcare costs, and reduced quality of life (21, 22). Studies

indicate that low back pain is one of the most common reasons for seeking healthcare, with a significant proportion of cases attributed to intervertebral disc herniation. The burden of this condition is further exacerbated by the challenges associated with its management, particularly in patients who do not respond to conservative treatments (23).

**Advances in Minimally Invasive Techniques**

The shift towards minimally invasive techniques in spinal surgery is driven by the desire to reduce tissue disruption, minimize complications, and accelerate recovery times. Percutaneous laser disc decompression represents a significant advancement in this regard (24). The technique involves the insertion of a laser fiber into the affected disc under local anesthesia, guided by imaging techniques such as fluoroscopy or computed tomography. The laser energy vaporizes a portion of the nucleus pulposus, reducing disc size and intradiscal pressure. This reduction in pressure alleviates nerve root compression, providing relief from pain and neurological symptoms (10).

PLDD offers several advantages over traditional surgical approaches, including shorter procedural times, reduced hospital stays, and lower complication rates. However, its success is heavily reliant on proper patient selection, as the technique is most effective in cases of contained disc herniations without significant extrusion or sequestration. Additionally, the long-term efficacy of PLDD remains a subject of ongoing research, with some studies suggesting higher rates of symptom recurrence compared to nucleotomy (10).

**Evolution of Nucleotomy Techniques**

Nucleotomy has undergone significant evolution since its introduction, with advancements in surgical techniques and instrumentation enhancing its safety and efficacy. Traditional open discectomy has largely been replaced by minimally invasive approaches, which involve smaller incisions, reduced muscle dissection, and the use of specialized tools such as tubular retractors and endoscopic cameras (25). These advancements have resulted in shorter recovery times, reduced postoperative pain, and lower risks of complications. However, nucleotomy remains a more invasive option compared to PLDD and is associated with a higher risk of complications, such as infection, dural tears, and the development of adjacent segment disease (26).

**Patient Selection and Outcomes**

The choice between nucleotomy and PLDD is influenced by several factors, including the size and location of the disc herniation, the presence of neurological deficits, patient comorbidities, and personal preferences (16). While nucleotomy is generally recommended for larger, more complex herniations, PLDD is better suited for smaller, contained herniations in patients who prioritize minimally invasive options. Both techniques have demonstrated high success rates in appropriately selected patients, with significant improvements in pain, function, and quality of life (27).

**Historical Evolution**

The concept of percutaneous disc decompression predates PLDD and stems from the broader aim of minimizing surgical invasiveness. The advent of laser technology in the mid-20th century enabled the development of PLDD. In 1986, Choy and Ascher performed the first PLDD procedure, utilizing a neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. Their pioneering work laid the foundation for subsequent innovations in laser types, delivery systems, and procedural techniques (28, 29).

Over the years, PLDD has gained traction globally, with widespread adoption in Europe, Asia, and the Americas. Advances in imaging modalities, particularly fluoroscopy and magnetic resonance imaging, have enhanced the precision and safety of the procedure. Despite initial skepticism regarding its efficacy and safety, a growing body of evidence supports the use of PLDD in carefully selected patients (20).

**Treatment Principle and Technique of PLDD**

PLDD operates on the concept that the intervertebral disk is a closed hydraulic system, with the nucleus pulposus, which contains water, surrounded by the annulus fibrosus. An increase in the water content of the nucleus pulposus raises intradiskal pressure, which can rise by 312 kPa (2340 mmHg) with a 1.0 mL volume increase. A reduction in intradiskal volume significantly lowers the pressure. Lumbar disk herniation causes radicular pain due to nerve root compression from the herniated nucleus pulposus. By reducing intradiskal pressure, the herniated material moves away from the nerve, easing pain. PLDD applies laser energy through a needle to evaporate the water in the nucleus pulposus, which lowers the pressure. The laser also causes protein changes, permanently reducing the disk's ability to attract water and resulting in a lasting decrease in intradiskal pressure by up to 57% (28).

PLDD is performed under local anesthesia, and a needle is placed 10 cm from the midline toward the center of the disk, confirmed by fluoroscopy or CT. A laser fiber is then inserted into the nucleus pulposus, and energy is applied to reduce pressure by vaporizing the disk's contents. While the basic procedure is similar across studies, variations in laser type, parameters, and imaging techniques exist. Most studies used

fluoroscopy, but some incorporated CT or MRI for further guidance (30-32). The amount of laser energy delivered depends on the imaging observed during the procedure, with predetermined energy levels in fluoroscopy-only studies.



**Key Physiological Processes**

Thermal vaporization occurs when the high-energy laser beam converts the water content within the nucleus pulposus into vapor, which reduces the disc volume. This process leads to pressure redistribution as the decompressed disc causes the herniated material to retract, relieving pressure on adjacent neural structures (20). Additionally, inflammatory modulation may take place, where reducing mechanical stress and possibly altering inflammatory pathways can help facilitate the resolution of neurogenic inflammation (33).

**Lasers Types**

Several laser systems have been utilized in PLDD, each offering distinct advantages. The Nd:YAG laser, the original laser used by Choy, is recognized for its deep penetration and thermal efficiency. The Holmium:YAG laser, on the other hand, is known for its precise ablation capabilities and minimal thermal spread, which helps reduce the risk of collateral damage. More recently, the Diode laser has gained popularity due to its compact design and high energy efficiency, making it an appealing choice for many practitioners (20, 34).

**Indications and Contraindications of PLDD**

PLDD is most effective in patients with contained disc herniations causing radicular pain. Ideal candidates typically present with MRI evidence of a contained disc herniation, symptoms that are refractory to conservative treatments for at least six weeks, and radicular pain that correlates with imaging findings. However, PLDD is not suitable for all patients, and contraindications include sequestered or extruded disc fragments, significant spinal stenosis or spondylolisthesis, active infection or coagulopathy, and severe degenerative disc disease (27).

**Complications and Effectiveness**

PLDD is associated with a low complication rate compared to open surgical procedures. However, potential risks include; Although rare, discitis can occur if aseptic techniques are not strictly followed. Improper needle placement or excessive laser energy can damage adjacent neural structures. Collateral thermal damage to surrounding tissues is a potential risk, particularly with high-energy lasers. In some cases, inadequate vaporization of disc material necessitates repeat procedures or alternative treatments. When compared to other minimally invasive techniques such as microdiscectomy or endoscopic discectomy, PLDD offers distinct advantages; PLDD involves smaller incisions, reduced blood loss, and faster recovery times. The procedure's outpatient nature and reduced need for postoperative care translate into lower overall costs. Unlike open surgeries, PLDD does not disrupt spinal stability or anatomy. However, PLDD may not be as effective as microdiscectomy for large or sequestered disc herniations. Hence, patient selection remains critical (10, 35).

**DISCUSSION**

There is limited existing literature comparing nucleotomy and percutaneous laser disc decompression for the treatment of lumbar disc herniation.

Schenk and colleagues conducted a study reviewing the literature on percutaneous laser disk decompression (PLDD) as a minimally invasive treatment for lumbar disk herniation causing sciatica (27). The treatment, which involves using a laser to reduce intradiscal pressure, aims to alleviate nerve root compression and provide pain relief. The study examined various clinical trials, highlighting variations in laser types, patient selection, and outcomes. The results showed success rates ranging from 75% to 87%, though the lack of randomized controlled trials and standardization in treatment methods led to mixed evidence regarding PLDD's efficacy. Despite these challenges, the authors advocate for further well-designed research to assess the long-term benefits of PLDD in comparison to conventional surgery and conservative treatments.

Abrishamkar and colleagues conducted a randomized clinical trial comparing the outcomes of open surgical discectomy and plasma-laser nucleoplasty in patients with single lumbar disc herniation. Their findings demonstrated that both treatments were effective in significantly reducing lower back and radicular pain over one year, with no statistically significant differences between the two methods in terms of pain reduction (17). However, nucleoplasty emerged as a less invasive option, offering advantages such as reduced surgical costs, shorter procedure duration, and faster recovery, which contributed to higher patient compliance. Given its comparable efficacy and added benefits, the authors recommend nucleoplasty as a viable and effective treatment option for patients with single-level lumbar disc herniation.

Goupille and colleagues conducted a review of percutaneous laser disc decompression (PLDD) for treating lumbar disc herniation, focusing on its technical aspects, mechanisms, indications, and outcomes (36). Developed in the 1980s, PLDD involves the percutaneous introduction of a laser fiber into the intervertebral disc to vaporize a small portion of the nucleus pulposus, thereby reducing intradiscal pressure

and relieving radicular pain. The review found that while various experimental and clinical studies have explored PLDD, there is no consensus on key parameters such as laser type, wavelength, or energy levels. Despite the promising concept, the studies reviewed lack rigorous methodology, with no controlled trials available, making it difficult to validate PLDD as a standard treatment for disc herniation-associated radiculopathy.

"Brouwer and colleagues in 2017 conducted a randomized controlled trial comparing percutaneous laser disc decompression (PLDD) and conventional microdiscectomy for treating sciatica caused by lumbar disc herniation. The results from this trial indicate that, at the two-year follow-up, both treatments had similar outcomes in terms of disability and pain reduction. Although the reoperation rate was notably higher in the PLDD group (52%) compared to the surgery group (21%), the study suggested that PLDD, followed by surgery, if necessary, may provide a viable alternative for certain patients. The higher reoperation rate in the PLDD group could be attributed to technical failures and inadequate treatment for patients with desiccated discs, as well as the longer history of sciatica in many participants. Moreover, although both groups showed significant improvement in disability and pain scores, the surgery group reported better general health scores, while the PLDD group had slightly better physical functioning at the 104-week follow-up. Despite these differences, the lack of significant clinical relevance in these findings and the overall non-inferiority of PLDD suggest that it could be considered as a less invasive option for managing contained herniated discs (16). However, further studies focusing on early intervention and more specific patient characteristics are necessary to better define the role of PLDD in the treatment of sciatica.

Zhu and colleagues conducted a study to evaluate the long-term efficacy of coblation nucleoplasty for treating protruded lumbar intervertebral discs, with a two-year follow-up. The results indicated that coblation nucleoplasty provided significant improvements in low back pain, leg pain, and numbness, with initial symptom relief observed one week after the procedure. However, the relief progressively diminished over time, with the two-year follow-up showing a reduction in the improvement rates for all symptoms compared to the one-week and one-year marks. The Oswestry Disability Index also demonstrated improvements, although these improvements were less pronounced over time, with the greatest change occurring in the first week post-operation. Despite the initial positive outcomes, the study suggests that while coblation nucleoplasty offers satisfactory short-term relief, its long-term benefits require further verification, particularly beyond the two-year follow-up (37).

Hashemi and colleagues conducted a cohort study to assess the long-term outcomes of Percutaneous Laser Disc Decompression (PLDD) for treating lumbar disc protrusion and chronic low back pain over a two-year follow-up. The study involved 40 patients who underwent PLDD, and the results showed significant improvements in pain and functional disability, as measured by the Numeric Rating Scale (NRS) and Oswestry Disability Index (ODI). These improvements were sustained throughout the follow-up period, suggesting the efficacy of PLDD as a long-term solution. No major complications were observed, and the study found that PLDD was equally effective across different sex and disc protrusion levels, although younger patients (under 40) experienced greater pain relief (10). While PLDD demonstrated a high success rate, the study emphasized its role as an alternative for patients who have not responded to non-invasive treatments and recommended further research with larger sample sizes to refine patient selection and validate its broader clinical application.

Singh and colleagues in 2009 conducted a systematic review to evaluate the clinical effectiveness of percutaneous laser disc decompression (PLDD) in managing radicular pain due to contained disc herniations (38). The review, based on a comprehensive evaluation of literature, determined that PLDD demonstrated Level II-2 evidence for both short- and long-term pain relief, which is comparable to other minimally invasive techniques, such as automated percutaneous lumbar disc decompression. Despite the widespread use of PLDD, the authors noted a significant gap in high-quality randomized controlled trials (RCTs), which limited the strength of the conclusions. The primary outcome measure, pain relief, was found to be effective, with additional improvements in function, psychological status, opioid use, and return to work. However, the review highlighted the need for more rigorous studies to strengthen the evidence base for this technique. Consequently, while PLDD presents as a promising option for patients with contained disc herniations, further high-quality RCTs are necessary to confirm its long-term efficacy and refine its place in clinical practice.

Lewandrowski and colleagues conducted a comparative analysis to evaluate the clinical outcomes and durability of transforaminal endoscopic decompression versus percutaneous laser decompression in treating contained lumbar disc herniations. Their findings demonstrated that endoscopic decompression provided better overall outcomes, with a higher percentage of patients achieving excellent results compared to those treated

with laser decompression. Endoscopic decompression was especially effective for small paracentral herniations and in cases with reduced posterior disc or lateral recess height, showing significant improvements. Furthermore, the long-term benefits of endoscopic decompression were evident, as it offered a longer duration of symptom relief compared to laser decompression, which tended to deteriorate more quickly (39). These results highlight the superior efficacy and durability of endoscopic decompression for addressing sciatica-type and back pain, while laser decompression may be better suited for short-term relief in select cases.

The future of spinal surgery lies in the integration of minimally invasive techniques with innovative treatment strategies that address both the mechanical and biochemical aspects of disc pathology. The use of nutraceuticals in conjunction with PLDD represents a promising approach, offering potential benefits in terms of neuroprotection, pain management, and long-term outcomes. Additionally, advances in imaging technology, robotic-assisted surgery, and regenerative medicine hold the potential to further enhance the safety and efficacy of both nucleotomy and PLDD.

## CONCLUSION

The management of lumbar disc herniation requires a tailored approach that considers the unique needs and preferences of each patient. By understanding the strengths and limitations of nucleotomy and PLDD, clinicians can provide evidence-based recommendations that optimize patient outcomes. As minimally invasive techniques continue to evolve, their role in the treatment of spinal disorders is likely to expand, offering new possibilities for improved care and reduced societal burden.

**Acknowledgments**

The authors would like to express their sincere gratitude to all individuals and organizations who contributed to this review. We also appreciate the faculty and staff of Mazandaran University of Medical Sciences for their continuous support.

**Funding**

This study received no funding.

**Conflict of Interest Statement:**

The authors declare that there are no conflicts of interest regarding the publication of this article.

**Ethical Approval**

The research adheres to the ethical principles outlined in the Declaration of Helsinki.

**Data Availability Statement**

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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