Randomized Controlled Trial

Comparative Effectiveness of Nucleoplasty and Intradiscal Ozone Therapy for Lumbar Disc Herniation: A Double-Blind, Randomized, Controlled Trial

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Background: Lumbar disc herniation (LDH) is responsible for more than 60% of chronic low back and leg pain. Although some patients respond to conservative treatment, a considerable proportion require surgical or minimally invasive interventions. The demand for minimally invasive procedures has increased; these procedures have high success rates in appropriately selected patients.

Objective: To compare the clinical outcomes of intradiscal ozone therapy and percutaneous lumbar nucleoplasty in patients with LDH.

Study Design: Prospective, double-blind, randomized controlled trial.

Setting: A tertiary care center.

Methods: Ninety patients with low back pain due to lumbar disc herniation were assigned to intradiscal ozone therapy (Group I) or percutaneous lumbar nucleoplasty (Group II). Pain was assessed using the Visual Analog Scale (VAS), disability using the Oswestry Disability Index (ODI), and quality of life using the Short Form-36 (SF-36) at baseline, and at postprocedure months one and 12. All procedures were performed under sterile conditions with C-arm fluoroscopy.

Results: Significant postprocedure improvements in pain, disability, and quality of life were observed in both groups. Both groups had statistically significant decreases in VAS and ODI scores at the postprocedure one-month and 12-month follow-ups ($P < 0.001$). However, when the postprocedure one-month scores were compared, it was evident that Group II had lower VAS and ODI scores than Group I; this difference is statistically significant ($P < 0.001$). This difference was maintained at 12 months and became more pronounced, with a greater improvement favoring Group II, particularly in the VAS scores ($P < 0.001$). While both methods are effective in the short term, nucleoplasty yields better long-term results than intradiscal ozone therapy (12 months). This finding supports the idea that nucleoplasty may have a longer-lasting effect on pain control and functional improvement.

Limitations: The main limitations of our study are the limited number of patients and the short follow-up time.

Conclusion: Our study compared the efficacy of percutaneous lumbar nucleoplasty and intradiscal ozone therapy. Both procedures were efficacious in reducing patients' pain and improving their quality of life. However, percutaneous lumbar nucleoplasty had superior long-term outcomes compared to intradiscal ozone therapy.

Key words: Low back pain, intradiscal ozone, nucleoplasty, lumbar disc herniation, lumbar disc degeneration

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Lumbar discogenic pain has been identified as the underlying cause in more than 60% of patients who have chronic low back pain and lower extremity pain (1). A review published (2) reported that the lifetime prevalence of low back pain was 38.9%, and a separate study on lumbosacral radiculopathy found the prevalence to be 3%–5% (3). Although the specific cause of pain has not been established in 60%–80% of patients, disc degeneration is considered to be responsible for 5%–15% (4). Degenerative discs have been identified to be the leading causative factor for lumbar discogenic pain. Lumbar discogenic pain has been defined as either a disorder of the nucleus pulposus, rupture of the annulus fibrosus, or injury to the vertebral endplates (5).

There are several treatment options available for lumbar discogenic pain resulting from degenerative discs. Minimally invasive methods have been shown to be effective at preventing or delaying open surgery for patients who do not respond to standard conservative treatments for low back pain due to degenerative disc-induced lumbar disc herniation (LDH). A range of methods have been developed for reducing disc volume, including intradiscal laser decompression, thermal lesions with radiofrequency, and chemonucleolysis with ozone. The popularity of these methods, which reduce the volume of the nucleus pulposus and the pressure on surrounding tissues, has increased significantly (6). The use of ozone in medicine is due to its recognized anti-inflammatory, analgesic, and antiseptic properties. Ozone treatment has been shown to alleviate low back pain caused by LDH by reducing inflammation surrounding the nerve root, thereby decreasing disc volume (7). Ozone reduces the a herniated disc's volume by breaking down proteoglycans in the nucleus pulposus, neutralizing the negative charge of sulfate side chains, and reducing water retention (8,9). Previous studies have shown that ozone therapy can be used prior to surgery for patients who do not respond to conservative treatment or in circumstances where surgery is not a viable option (10-12).

Nucleoplasty employs coblation technology to ablate and coagulate tissue within the intervertebral disc. This technique uses significantly lower radiofrequency energy than conventional systems. By generating a low-temperature plasma field (55 °C–80 °C) made up of ionized particles, it breaks the molecular bonds in the disc tissue, thereby forming small channels. As a result, a portion of the nucleus pulposus is coagulated, which lowers the intradiscal pressure (13). This pressure reduction also lessens the load on the annulus fibrosus and the adjacent nerve root, thereby helping to minimize damage to pain-transmitting C fibers. The effectiveness of coblation nucleoplasty for low back pain, with or without lower extremity pain secondary to contained lumbar disc herniation, has been demonstrated by numerous clinical studies, with few complications reported (14-16).

The aim of our prospective study was to investigate and compare the efficacy and safety of intradiscal ozone therapy and nucleoplasty for LDH pain in a randomized controlled trial.

Methods

Patients

Our study was conducted from January 2023 through April 2024 with 100 patients who completed a 12-month follow-up period. The study was completed with the data of 90 patients. Ethics committee approval was obtained for the study, and patients were informed about the study both verbally and in writing.

The prospective randomized, controlled, double-blind study included 100 patients between 18 and 75 years old who had low back pain. While 6 patients did not attend for a baseline examination, 4 patients were excluded from the study upon request; the final analyses were performed with data from 90 patients.

Inclusion criteria were: patients with a diagnosis of LDH due to degenerative disc disease via anamnesis; clinical examination and imaging findings indicative of low back and leg pain; persistent pain for at least 3 months that was unresponsive to conservative treatments; and an absence of prior spinal surgery. Furthermore, no interventional pain treatment had been performed within the previous 6 months. Patients also needed a pain score greater than 4 on the Visual Analog Scale (VAS) and disc protrusion at L4–L5 or L5–S1 confirmed by magnetic resonance imaging.

Exclusion criteria included patients with a systemic infection or uncontrolled systemic diseases such as hemorrhagic diathesis, a history of lumbar surgery, glucose-6-phosphate dehydrogenase (G6PD) deficiency, pregnancy, progressive motor deficits, and calcified discs. Those who refused to participate in the study were excluded.

Patients were randomized into 2 groups. Group I received intradiscal ozone treatment, while Group II received percutaneous lumbar nucleoplasty treatment. Randomization was performed using the sealed-enve-

lope method. The patients were evaluated at 3 different times: preprocedure and postprocedure months one and 12. The evaluations looked at the patients' pain, functionality, and quality of life. Pain was assessed using the Visual Analog Scale (VAS), functionality using the Oswestry Disability Index (ODI), and quality of life using the Short Form 36 Health Survey questionnaire. The primary outcome was pain intensity; secondary outcomes were disability and quality of life scores. The physicians who conducted the evaluations and the patients were blinded to the treatment groups.

Procedure

Povidone iodine was used for sterilization in all procedures and patients' vital signs were monitored throughout their procedure. Imaging was performed using C-arm fluoroscopy. The patient was positioned prone and the lumbar lordosis was flattened by placing a pillow under the abdomen. Injection site cleaning was in accordance with asepsis and antisepsis guidelines. Once the fluoroscopy-related level had been determined, the disc was approached from the ipsilateral side with a 22G, 20-cm spinal needle using fluoroscopic anteroposterior views and a posterolateral approach (Figs. 1A, 1B). Needle placement was confirmed with radiopaque contrast medium into the center of the disc (Figs. 1C, 1D). Turkozone Blue S was used as the ozone generator; 5 mL of an O_2-O_3 mixture containing 40 µg/mL of O_3 was injected intradiscally in Group I patients.

For patients in Group II, under fluoroscopic guidance a Flextrode cannula disposable electrodes, with 13 mm tips and 20 gauge, and 15 cm/17 gauge cannulae - Boston Scientific was advanced into the nucleus pulposus, followed by an injection electrode needle. The active tip of the catheter was positioned centrally within the disc or at the site of symptomatic degeneration (Figs. 2A, 2B). Controlled plasma-mediated ablation was then initiated, using bipolar radiofrequency energy to generated with Radio Frequency G4 Generator a low-temperature ionized plasma field. This field disrupted molecular bonds within the disc tissue while maintaining a relatively low thermal profile. Intradiscal temperatures were steadily elevated in stages, commencing at 55°C and rising to 80°C, with each stage lasting 2 minutes. In the final stage, a temperature of 80°C was applied for 4 minutes (Fig. 2C). When the procedure ended, patients were monitored for one hour before being discharged. They were advised to rest for 3 days and were given amoxicillin-clavulanic acid (1,000 mg) to be taken twice daily for 5 days.

Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics 24.0 for Windows (IBM Corporation). Descriptive statistics are expressed as number and percentage for categories, and as mean (SD), and minimum–maximum for continuous variables. Independent variables between the groups were compared using the Student t test when the numerical variables were normally distributed, or the Mann–Whitney U-test when the data were not normally distributed. Dependent variables in more than 2 groups were analyzed using repeated measures analysis of variance when the numerical variables were normally distributed, and Friedman analysis when they were not. A subgroup analysis was performed using the Wilcoxon test and interpreted using Bonferroni correction for nonparametric tests. A $P < 0.05$ was considered statistically significant.

Results

The mean (SD) age of Group I (n = 52) was 49.08 (10.5) years, while that of Group II (n = 48) was 38.71 (11.8) years. No statistically significant difference was found in terms of age ($P = 0.236$). There were no statistically significant differences between the 2 groups in terms of gender distribution, height, weight, body mass index, and pain duration ($P > 0.05$) (Table 1).

Both treatment methods resulted in significant improvement for treating chronic back and leg pain. Both groups had statistically significant decreases in VAS and ODI scores at postprocedure months one and 12 compared to their preprocedure scores ($P < 0.001$). This demonstrated that both intradiscal ozone therapy and percutaneous lumbar nucleoplasty were effective in reducing pain and functional impairment. However, when comparing the results of postprocedure month one, we found that Group II had lower VAS and ODI scores than Group I; this difference was statistically significant ($P < 0.001$). In the at postprocedure month 12, this difference was maintained, and even became more pronounced, with a more significant improvement favoring Group II, particularly in VAS scores ($P < 0.001$).

Group I had a statistically significant decrease in both VAS and ODI scores when comparing their preproduce scores to their postprocedure months one and 12 scores ($P < 0.001$). However, the change between months one and 12 was not statistically significant for either measure (VAS, $P = 0.078$; ODI, $P = 0.112$). Group 2 had a statistically significant improvement in both VAS and ODI scores when comparing their preproduce

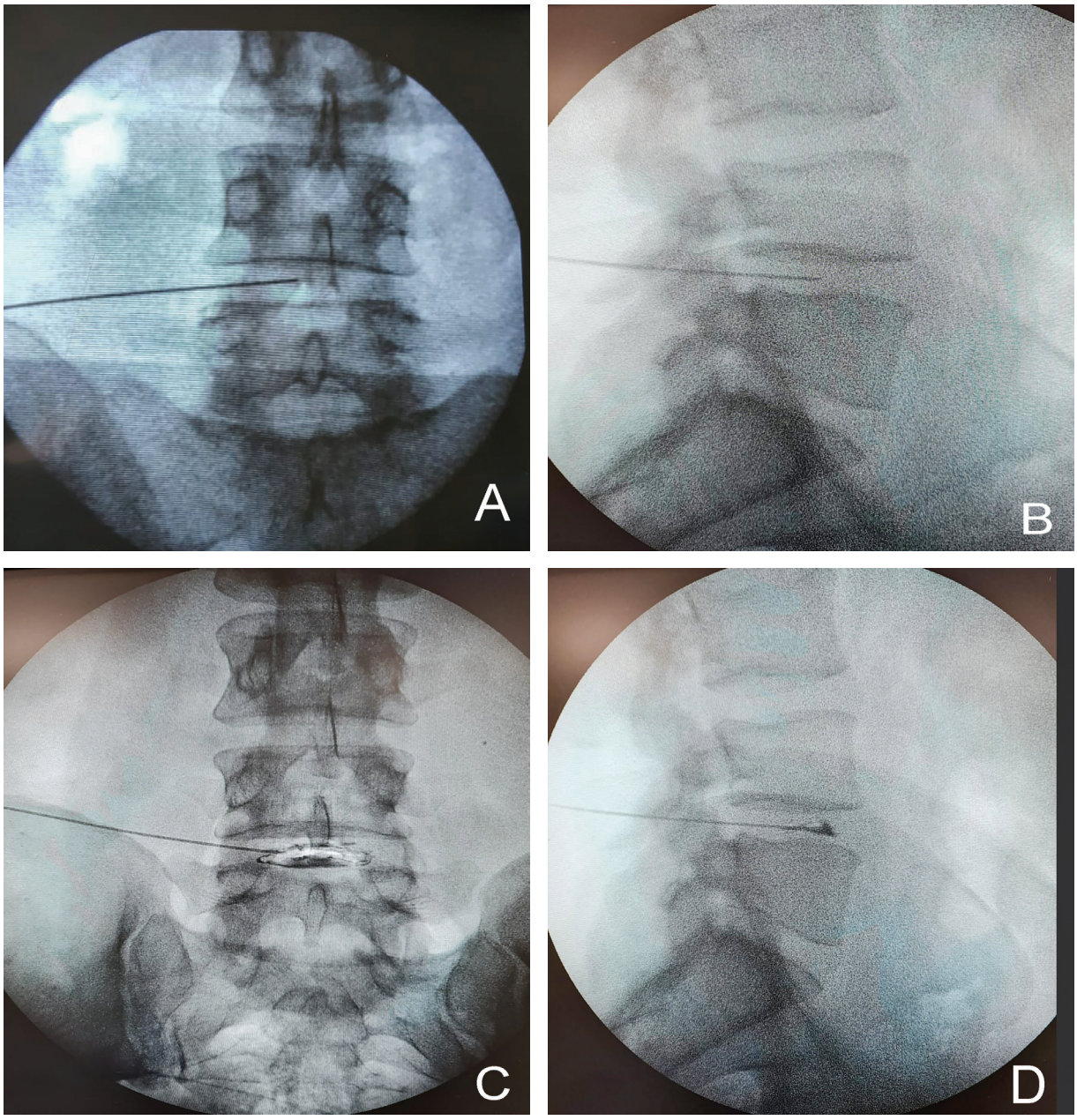


Fig 1. *Fluoroscopic images of the spinal needle placed in the L4-L5 interdiscal space during intradiscal ozone therapy. A) anterior, B) lateral, C) post contrast anterior, D) post contrast lateral*

scores to their postprocedure months one and 12 scores ($P < 0.001$). The change between months one and 12 was statistically significant for VAS ($P = 0.042$), while it remained at borderline significance for ODI ($P = 0.057$) (Table 3). While both methods were effective in the short term, percutaneous lumbar nucleoplasty yielded better results than intradiscal ozone therapy in the long term (12 months). This finding supports the notion that nucleoplasty may provide a more lasting effect on pain control and functional improvement (Table 2).

Baseline quality-of-life parameters showed no significant difference between groups. Although significant improvements were seen for many subscales in postprocedure assessments compared to preprocedure

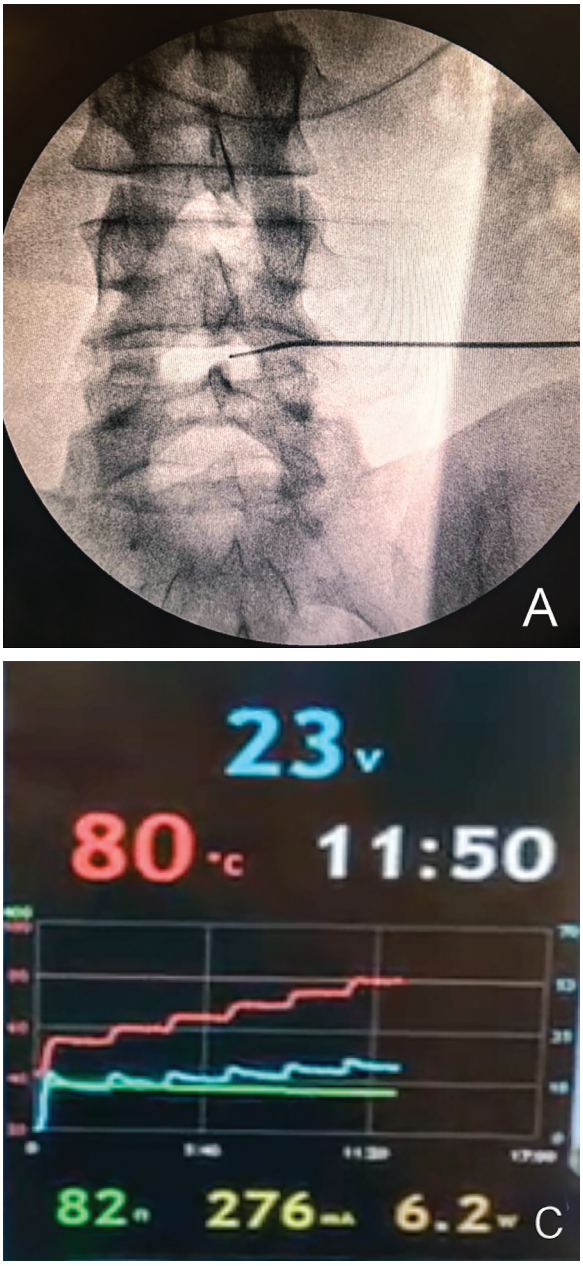


Fig 2. *Fluoroscopic images of the Coblation catheter placed in the L4-L5 interdiscal space during intradiscal nucleoplasty therapy. A) anterior, B) lateral, C) time and temperature graph on the monitor*

assessments, there was no statistically significant difference between groups. However, nucleoplasty has been shown to be more effective in improving quality of life in the long term (Table 4).

Discussion

Percutaneous lumbar nucleoplasty and intradiscal ozone therapy have been increasingly applied in recent years for chronic discogenic low back pain (7,14,15,17-19). In nucleoplasty, the nucleus pulposus is coagulated more safely to achieve mechanical decompression. Intradiscal pressure is decreased as a result of coagulation. The reduction in pressure also results in a reduction in the load on the annulus fibrosus and the adjacent nerve root, thereby helping to minimize damage to pain-transmitting C fibers (14).

Table 1. *Demographic characteristics of the study groups.*

	Group I (n = 52)		Group II (n = 48)		*P* Value
Gender n (%)					
Women	32 (61.5%)		23 (47.9%)		
Men	20 (38.5%)		25 (52.1%)		
Mean (SD)		**Min. – Max.**	**Mean (SD)**	**Min. – Max.**	
Age, yrs	49.08 (10.5)	27.00-74.00	38.71 (11.79)	18.00-65.00	0.236
Height, cm	168.06 (8.0)	152.00-185.00	171.40 (7.86)	152.00-192.00	0.569
Weight, kg	74.96 (12.3)	54.00-94.00	78.52 (9.35)	59.00-101.00	0.753
BMI	26.57 (4.3)	18.47-37.65	26.86 (3.87)	20.09-39.45	0.498
Preprocedure Pain Duration (months)	33.75 (29.5)	2-121	18.17 (14.29)	2-60	0.332

BMI: body mass index, kg/m^2

Table 2. *Changes in pain and disability scores between groups.*

		Group I (Mean (SD)	Group II (Mean (SD)	*P* Value
VAS	Preprocedure	7.68 (1.15)	7.85 (1.08)	0.443
	Postprocedure month one	5.53 (1.80)	4.19 (1.55)	< 0.001
	Postprocedure month 12	4.91 (1.50)	3.44 (174)	< 0.001
	P value	< 0.001	< 0.001	
ODI	Preprocedure	24.35 (8.52)	20.28 (9.09)	0.023
	Postprocedure month one	17.31 (7.49)	13.77 (6.67)	< 0.001
	Postprocedure month 12	15.39 (6.33)	12.99 (6.24)	< 0.001
	P value	< 0.001	< 0.001	

VAS: Visual Analog Scale; ODI: Oswestry Disability Index

Intradiscal ozone therapy involves interrupting the inflammatory prostaglandin cascade, preventing tissue hypoxia by increasing O_2 concentration, repairing damaged discs by activating fibroblastic cells, and most importantly, preventing water retention and reducing disc volume by decreasing mechanical compression (17,20). Intradiscal ozone therapy has been proven to be effective in treating LDH-induced back and leg pain in many studies(8,17,20). However, a recent meta-analysis (4) has highlighted the need for further investigation due to methodological shortcomings in previous studies that examined its efficacy.

A recent systematic review also demonstrated reasonable evidence for nucleoplasty for treating pain caused by limited disc herniation (7). Nucleoplasty can provide adequate relief in appropriately selected patients with disc herniation who do not also have significant complications or morbidity (21). The authors aimed to achieve percutaneous disc decompression using nucleoplasty by ablating the nucleus pulposus tissue and reducing intradiscal pressure with radiofrequency energy via patented coblation technology (22,23). Most studies have reported a success rate greater than 50%, with 67.7% of patients achieving substantial pain relief (≥ 50% improvement in VAS scores) at the final follow-up (22-25).

In our study, we compared the effect of intradiscal ozone therapy with nucleoplasty on clinical outcomes. The mean VAS scores, our primary outcome measure, showed no statistically significant difference between groups at postprocedure month one's assessment. However, we observed that percutaneous lumbar nucleoplasty yielded better results in the long term. Similarly, the proportion of patients showing a 50% or greater reduction in pain, calculated based on the VAS, also showed a statistically significant difference in favor of nucleoplasty, with more patients achieving ≥ 50% improvement. We believe we achieved these results by evaluating treatment success based on changes in pain. However, we did not evaluate other factors that could affect patients' pain, especially chronic pain, such as sociocultural environment, pain beliefs, pain behaviors, and psychological factors. Therefore, we may not have obtained a clinically significant response. We believe that further studies evaluating these variables will contribute to the literature.

In this study, we assessed disability and quality of life, as well as pain intensity. Significant improvements in disability scores, as measured by the ODI, were observed in both groups. Although significant improvement was seen in both groups one month after the procedure, at postprocedure month 12 Group II had more meaningful results. Similarly, in terms of quality-of-life parameters, more meaningful results were obtained in Group II in the long term. Disability was also evaluated using ODI as it had been in previously published studies. Similar to our study, these studies also reported that intradiscal ozone and intradiscal nucleoplasty treatments had positive effects on disability (22,26,27) . Furthermore, our study found that both treatments had a positive effect on quality of life. To our knowledge, no other studies have compared intradiscal ozone and

percutaneous lumbar nucleoplasty treatments. Our study is therefore of great importance in this regard.

Our study's design aimed to compare the positive effects of intradiscal ozone and percutaneous lumbar nucleoplasty treatments on pain, disability, and functional outcomes rather than evaluating their efficacy. Indeed, success rates of up to 60% (as assessed by the VAS) were observed at postprocedure month 12. These rates are consistent with those reported in the literature. However, as the primary aim of this study was not to evaluate efficacy, a placebo group was not included as a control.

Finally, our study has some limitations. The most important of these were the limited number of patients and the follow-up period being limited to 12 months. Another important limitation is that this study only compares 2 methods and evaluates their results. For this reason, it was not necessary to include a control group. Having a control group in a study would facilitate more rigorous evaluations of these 2 methods independently. The strength of our study is that it is the first study to compare these 2 treatment methods in patients with low back pain caused by LDH. Furthermore, evaluating the effect of these treatments on patients' quality of life was also a strength of our study.

Table 3. *Within-group analysis of VAS and ODI scores.*

		VAS	ODI
		***P* Value**	***P* Value**
Group I	Preprocedure vs postprocedure month one	< 0.001	< 0.001
	Preprocedure vs postprocedure month 12	< 0.001	< 0.001
	Postprocedure month one vs postprocedure month 12	0.078	0.112
Group II	Preprocedure vs postprocedure month one	< 0.001	< 0.001
	Preprocedure vs postprocedure month 12	< 0.001	< 0.001
	Postprocedure month one vs postprocedure month 12	0.042	0.057

VAS: Visual Analog Scale; ODI: Oswestry Disability Index

Table 4. *Changes in quality-of-life scores based on the Short Form 36 (SF-36).*

		Group I Mean (SD)	Group II Mean (SD)	*P* Value
Physical Function	Preprocedure	24.3 (8.5)	20.2 (9.1)	0.070
	Postprocedure month one	17.3 (7.5)	16.1 (6.8)	0.281
	Postprocedure month 12	15.4 (6.3)	12.0 (6.1)	0.012
	P	< 0.001	< 0.001	
Social Function	Preprocedure	52.6 (15.3)	53.1 (14.9)	0.884
	Postprocedure month one	58.9 (16.1)	59.4 (15.7)	0.911
	Postprocedure month 12	54.8 (15.2)	61.7 (16.3)	0.037
	P	0.118	0.004	
Mental Health	Preprocedure	58.2 (12.9)	57.6 (13.4)	0.792
	Postprocedure month one	56.1 (13.5)	58.4 (12.7)	0.482
	Postprocedure month 12	55.9 (13.8)	62.2 (13.1)	0.029
	P	0.241	0.006	
Vitality	Preprocedure	54.2 (14.8)	53.7 (15.2)	0.871
	Postprocedure month one	52.3 (14.9)	54.1 (14.6)	0.552
	Postprocedure month 12	51.6 (15.2)	59.3 (14.8)	0.018
	P	0.334	0.009	
Pain	Preprocedure	7.68 (1.15)	7.85 (1.08)	0.443
	Postprocedure month one	5.53 (1.80)	4.91 (1.55)	0.091
	Postprocedure month 12	4.91 (1.50)	3.44 (1.74)	0.003
	P	< 0.001	< 0.001	
Overall Health	Preprocedure	55.9 (13.1)	54.7 (12.6)	0.689
	Postprocedure month one	53.1 (13.5)	54.9 (13.4)	0.521
	Postprocedure month 12	52.0 (13.8)	60.2 (12.9)	0.021
	P	0.386	0.008	

Conclusion

In this study, we compared the efficacies of percutaneous lumbar nucleoplasty and intradiscal ozone therapy. Both treatments were effective in reducing patients' pain and improving their quality of life. Our findings showed that the long-term outcomes of percutaneous lumbar nucleoplasty were better than those of intradiscal ozone therapy. To our knowledge, this is the first study in the literature to compare these two treatment methods. Moreover, our results were consistent with those reported in the literature. We emphasize the need for studies (including a control group) in the treatment of discogenic low back pain.

References

1. Yakovlev A, Tamimi MA, Liang H, Eristavi M. Outcomes of percutaneous disc decompression utilizing nucleoplasty for the treatment of chronic discogenic pain. *Pain Physician* 2007; 10:319-328.
2. Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of low back pain. *Arthritis Rheum* 2012; 64:2028-2037.
3. Tarulli AW, Raynor EM. Lumbosacral Radiculopathy. *Neurol Clin* 2007; 25:387-405.
4. Costa T, Linhares D, Ribeiro da Silva M,Neves N. Ozone therapy for low back pain. A systematic review. *Acta Reumatol Port* 2018; 43:172-181.
5. Kallewaard JW, Terheggen MAMB, Groen GJ, et al. 15. Discogenic low back pain. *Pain Pract* 2010; 10:560-579.
6. Lu Y, Guzman JZ, Purmessur D, et al. Nonoperativemanagement of discogenic back pain: A systematic review. *Spine (Phila Pa 1976)* 2014; 39:1314-1324.
7. Magalhaes FNDO, Dotta L, Sasse A, Teixera MJ, Fonoff ET. Ozone therapy as a treatment for low back pain secondary to herniated disc: A systematic review and meta-analysis of randomized controlled trials. *Pain Physician* 2012; 15:E115-E129.
8. Buric J, Rigobello L, Hooper D. Five and ten year follow-up on intradiscal ozone injection for disc herniation. *Int J Spine Surg* 2014; 8:17.
9. Murphy K, Elias G, Steppan J, et al. Percutaneous treatment of herniated lumbar discs with ozone: Investigation of the mechanisms of action. *J Vasc Interv Radiol* 2016; 27:1242-1250.e3.
10. Kılıç M. Lumbar intradiscal ozone chemonucleolysis applied together with the epidural steroid treatment. *Sisli Etfal Hastan Tip Bul* Epub ahead of print 2020. https://sislietfaltip.org/jvi.aspx?un=SETB-55649&volume=#
11. Chang MC, Choo YJ, Denis I, Mares C, Majdalani C, Yang S. Effectiveness of intradiscal ozone injections for treating pain following herniated lumbar disc: A systematic review and meta-analysis. *J Back Musculoskelet Rehabil* 2024;37:1131-1139.
12. Bellelli A, D'Andrea V, Bianco NC, Beomonte Zobel B, Pileri M. The "Ozone-Strasse" sign: A novel CT finding after intradiscal ozone therapy. *J Neuroradiol* 2025; 52:101368.
13. Lee D, Loh E, Kueh C, et al. Radiofrequency-induced intradiscal nucleoplasty chronic low back pain secondary to lumbar disc herniation. *Malays Orthop J* 2013; 7:18-20.
14. Shabat S, David R, Folman Y. Nucleoplasty is effective in reducing both mechanical and radicular low back pain: A prospective study in 87 Patients. *J Spinal Disord Tech* 2012; 25:329-332.
15. Sinan T, Sheikh M, Buric J, et al. Percutaneous coblation nucleoplasty in patients with contained lumbar disc prolapse: 1 year follow-up in a prospective case series. In: Alexandre A, Masini M, Menchetti PPM (eds). *Advances in Minimally Invasive Surgery and Therapy for Spine and Nerves.* Springer, Vienna, 2011, pp 107-112.
16. Liliang P-C, Lu K, Liang C-L, Chen Y-U, Tsai Y-D, Tu Y-K. Nucleoplasty for treating lumbar disk degenerative low back pain: An outcome prediction analysis. *J Pain Res* 2016; 9:893-898.
17. Ercalik T, Kilic M. Efficacy of intradiscal ozone therapy with or without periforaminal steroid injection on lumbar disc herniation: A double-blinded controlled study. *Pain Physician* 2020; 23:477–484.
18. Kılıç M, Erçalık T. The effect of lumbar spinal surgery history on intradiscal O_2-O_3 treatment results in patients with lumbar disc herniation. *Sisli Etfal Hastan Tip Bul*. Epub ahead of print 2018. https://sislietfaltip.org/jvi.aspx?un=SETB-50480
19. Rybaczek M, Prokop K, Sawicki K, et al. Long-term clinical efficacy of the Disc-FX procedure in contained disc herniation: A 7-year follow-up from a single-center cohort study. *J Clin Med* 2025; 14:6378.
20. Giurazza F, Guarnieri G, Murphy KJ, Muto M. Intradiscal O_2-O_3: Rationale, injection technique, short- and long-term outcomes for the treatment of low back pain due to disc herniation. *Can Assoc Radiol J* 2017; 68:171-177.
21. Manchikanti L, Falco FJE, Benyamin RM, et al. An update of the systematic assessment of mechanical lumbar disc decompression with nucleoplasty. *Pain Physician* 2013; 16:SE25-SE54.
22. Cincu R, Lorente F, Gomez J, Eiras J, Agrawal A. One decade follow up after nucleoplasty in the management of degenerative disc disease causing low back pain and radiculopathy. *Asian J Neurosurg* 2015; 10:21-25.
23. Mirzai H, Tekin I, Yaman O, Bursali A. The results of nucleoplasty in patients with lumbar herniated disc: A prospective clinical study of 52 consecutive patients. *Spine J* 2007; 7:88-92.
24. Cohen SP, Williams S, Kurihara C, et al. Nucleoplasty with or without intradiscal electrothermal therapy (IDET) as a treatment for lumbar herniated disc. *J Spinal Disord Tech* 2005; 18:S119-S124.
25. Kumar NS, Shah SM, Tan BWL, Juned S, Yao K. Discogenic axial back pain: Is there a role for nucleoplasty? *Asian Spine J* 2013; 7:314-321.
26. Das G, Ray S, Ishwarari S, Roy M, Ghosh P. Ozone nucleolysis for management of pain and disability in prolapsed lumber intervertebral disc: A prospective cohort study. *Interv Neuroradiol* 2009; 15:330-334.
27. Hashemi M, Poorfarokh M, Mohajerani SA, et al. Injection of intradiscal O_2-O_3 to reduce pain and disability of patients with low back pain due to prolapsed lumbar disk. *Anesth Pain Med* 2014; 4:e19206.