Original article

Limited Discectomy for single level lumbar disc herniation: a retrospective study in a tertiary level hospital

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Abstract

Objective: To perform retrospective analysis of 1000 patients who underwent open limited discectomy (OLD) for single level lumbar disc herniation (LDH) and to assess the long- term clinical outcomes.

Methods*:* 745 men and 255 women, with mean age of 38.03 ± 9.14 years (range 19- 55 years) who had primary LDH at L4-5 (n=640), L5-S1 (n=352), and L3-4 (n=8); underwent OLD were reviewed. Records were obtained regarding their demographic data, the side and level of disc herniation, operating time period, intraoperative blood loss, hospital stay, and perioperative complications. VAS score was measured before and after operation, for the assessment of low back pain (LBP) and radicular pain. Comprehensive outcome outcomes were measured postoperatively with the modified Macnab criteria and the Oswestry Disability Index (ODI) score.

Results: The mean follows up was 24.5 (range 24-70) months. Significant improvement of mean VAS score for back and leg pain was achieved. At the two years follow-up, results were excellent in 525 (52.50%), good in 325 (32.50%), fair in 140 (14.00%) and poor in 10 (1.00%). Complications found were reherniation (n=52), discitis (n=19), superficial wound infection (n=7), dural tear (n=7) and foot drop (n=2).

Conclusion: Open limited discectomy following fenestration or laminotomy is a safe and effective procedure and achieved favorable long-term outcome (e.g., low rate of recurrent LBP) and excellent patients' satisfaction.

Keywords: Limited discectomy; Single level; Lumbar disc herniation.

Bangladesh Journal of Medical Science Vol. 21 No. 01 January'22 Page :37-44
DOI: https://doi.org/10.3329/bjms.v21i1.56325

Introduction

Low back pain (LBP) is extremely prevalent, and is the second most common reason for people for pursuing medical help, which is the major cause of disabilities for persons below 45 years of age.[1] The annual incidence is 5% and only 1% of patients will have nerve root symptoms and only 1-3% have LDH.[2, 3, 4] In the absence of an acute, severe and progressive neurological deficit, most of the patients with LDHs and radiculopathy can be successfully treated non-operatively such as analgesic, physiotherapy, spinal manipulation, epidural steroid injections, structured exercise and etc.[5]But, those patients who are failure to response conservative therapies and progressive to neurological deficit, surgical intervention is recommended.[5,6] Treatment

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of primary LDH include aggressive medical management and surgical intervention. Surgical technique includes conventional open discectomy, minimally invasive open discectomy and open discectomy with fusion. The surgical gold of LDH is to remove the prolapsed parts of lumbar intervertebral disc (IVD) that is causes compression on the nerve root. Conventionally, lumbar discectomy implicates extraction of the offending herniated disc fragment either by conservative or aggressive excision of the IVD. Extraction of only herniated portion of the disc fragment with or without little invasion of the disc space implies conservative excision or limited discectomy (LD).[7,8]Whereas repeated invasion of disc space (curettage to remove the loose or fragmented disc from normal disc) along with extraction of offending disc is known as aggressive excision or aggressive discectomy (AD)[9]but still there is no sufficient evidence in the literature that demonstrating LD is superior to AD for LDH. Appropriately selected patients with typical signs and symptoms of nerve root compression and evident of disc prolapse at the relevant level determined by MRI, are the ideal candidates for disc surgery by LD, where only extruded portion of herniation or sequestered disc can be potentially removed without hampering the IVD space. Additionally, there is still debate whether this technique is adequate to prevent relapse of symptoms and provide sufficient relief from pain and discomfort. We reviewed 1000 patients who underwent surgical treatment by open LD otherwise known as fragmentectomy, following fenestration or laminotomy for a single level LDH and to assess their long- term clinical outcomes.

Materials and Methods

After an approval from our Institutional Review Board, we retrospectively evaluated 1000 patients from October 2003 to October 2020. Records of 745 men and 255 women aged 19 to 55 (mean, 38.03) years who underwent LD for a primary LDH at L4-5 (n=640), L5-S1 (n=352) and L3-4 (n=8) were reviewed. Inclusion criteria were: (1) leg pain more than back pain, (2) severe neurological deficit, (3) progressive neurological deficits with radiculopathy, (4) persistent pain hindering his or her daily activities (5) positive root tension sign and MRI finding that correlates anatomically (Fig.1 a, b) and (6) MRI findings for level and side matching the clinical symptoms. Excluded were: (1) spinal instability, (2) cauda equina syndrome, (3) preceding history of lumbar spine surgery or recurrent LDH, and (4) spinal pathology other than LDH. Records of the disc herniation (level and side), time period of operation, intra operative blood loss, hospital stay, and complications were obtained. VAS score was measured before and after operation, for the assessment of back pain and radicular pain. The modified Macnab criteria[10] (Table 1)and the ODI score were used to assess the clinical outcome.

Table 1: Modified Macnab criteria[10]

Results	Criteria
Excellent	No pain; no restriction of mobility; return to work and original level of activity
Good	Occasional non-radicular pain; return to modified work
Fair	Some improved functional capacity; still handicapped and unemployed
Poor	Continued objective symptoms of root involvement; additional operative intervention needed at the index level

Patients were evaluated radiologically by antero-posterior and lateral view X-rays of lumbar spine as well as flexion and extension x-rays and MRI or CT myelogram if there were any contraindications for an MRI. By definition herniation is a localized displacement of disc material beyond the confines of the IVD space. According to the MRI features in sagittal section disc prolapses can be classified, as (1) protrusion (focal displacement of the posterior margin of the disc beyond the intervertebral disc space, base wider than herniation and outer annular fibers intact), (2) extrusion (extension of disc material beyond the annulus fibrosus but has continuity with the disc of origin, base narrower than herniation dome, complete annular tear), and (3) sequestration (when there is lack of continuity with the disc of origin).[11] The location of disc herniation is also defined in MRI in axial view as central, paramedian, posterolateral, lateral recess, foraminal, extraforaminal and far lateral disc prolapse. [12]

Surgical procedure

Prior to obtaining written informed consent, detailed preoperative discussion was done with the patient about the goals of surgery, its limitations, and the possible complications. To determine the correct level of disc space, preoperative marker X-ray were obtained in all the cases. Further confirmation was ensured by fluoroscopy, after the patient was positioned in operating table and a skin scratch mark was made exactly over the disc space to be

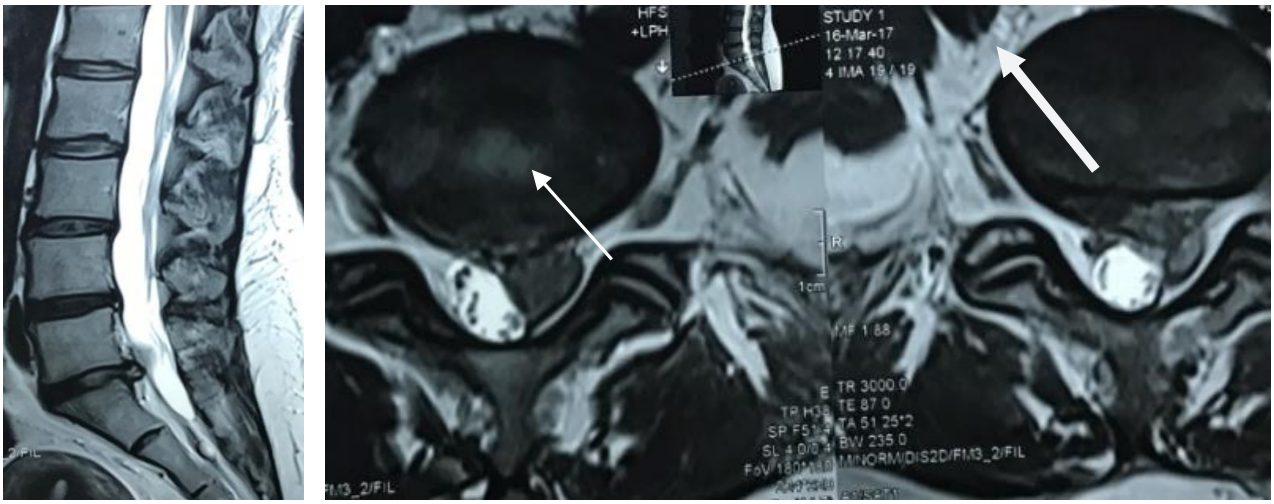

Figure 1: (a) Sagittal T2-weighted magnetic resonance image (MRI) shows lumbar disc herniation at L5-S1 level and corresponding (b, c) Axial T2 -weighted MRI shows left sided disc herniation causing root compression (arrow mark). Limited discectomy was done.

operated. Patients were placed prone position on a Relton-Hall frame under general anesthesia which allows the abdomen hang free, to avoid pressure on the inferior vena cava, minimizing epidural venous dilation and bleeding. Superficial bony points were well-padded to prevent pressure sore as well as radial and ulnar nerve palsy. Before marking the surgical incision, a first-generation cephalosporin such as 1 gm of ceftriaxone was administered intravenously as a bolus dose. After prepping of skin with standard 10% Povidone- iodine solution, a proper draping was done. Then centering over the scratch mark, a 3.5 cm posterior midline longitudinal incision was made and the paraspinal muscles were elevated to gain access to the inter-laminar space. The inter-laminar space was exposed by Casper retractor or microlumbar retractor. Either unilateral fenestration (excision of ligamentum flavum only) or laminotomy (excision of ligamentum flavum along with cutting of portion lamina above and below) was done to expose the spinal nerve root and the dura**.** The spinal nerve root was retracted medially or laterally depending on the position of the disc. A transverse incision was given over the annulus and LD was performed (Fig 1).

The interspinous ligaments, facet joints, and lamina were left intact. The operating microscope or optical loupe was used.

Postoperatively on same day, bed side mobilization of all patients were encouraged as tolerated and were discharged, usually at 3rd post-operative day (range, 2–5). Patients were advised for removal of suture at 10-12th post-operative day and then follow up at 1, 3, 6, 12 months consequently and yearly thereafter. Further, patents were assessed for long-term by telephone questionnaire or mail-in survey. Chi-squared test and paired-t test were used for statistical analysis by using SPSS (version 22, Chicago, IL, USA). Statistical significance was set at $p < 0.05$ and confidence interval set at 95% level.

Ethical clearance: The study commenced after an approval from our Institutional Review Board.

Results

The mean follows-up was 24.5 (range, 24-70) months. Majority of the patients (76.5%) were in age range of 16-40 years, whereas male to female ratio was 2.92:1 and most common level of involvement was at L4-5 (64%), left sided involvement was 65%, mean operative time period was 55 ±8 minutes (range, 25–105 minutes) and average duration of hospital stay about 3 days (range, 2–5) and mean intraoperative blood loss was 34.9±18.46 cubic centimeters (range 10-70). Long-term results were evaluated according to the modified Mcnab criteria, results were excellent in 525 (52.50%), good in 325 (32.50%), fair in 140 (14.00%) and poor in 10 (1.00%) cases following surgery. The mean pre-operative VAS for back pain, radicular pain and ODI score were 3.21±2.12, 7.3±0.77 and 72.97±6.16% respectively, 2 weeks after operation VAS for back pain, radicular pain and ODI score were 1.88±0.78, 2.2±0.60 and 18.46±8.0 respectively and at the end of 2 years VAS score for back pain and radicular pain, and ODI score were 0.98 ± 0.88, 1.47 ±1.10,

and 05.83±1.783% respectively (Table 3).

Complications found were reherniation (n=52), discitis (n=19), superficial wound infection (n=7), dural tear (n=7) and foot drop (n=2). Superficial wound infections and the dural tear were managed conservatively and resolved with oral antibiotics treatment. Among post-operative discitis patients, 15 were treated conservatively with intravenous antibiotic therapy, bed rest, analgesic, orthosis. The four other remaining patients were opted for surgical management, which included simple posterior debridement and drainage (n=3) or posterior instrumentation and postero-lateral fusion (n=1). Fifty-two patients (5.2%) developed recurrent disc herniation and required revision surgery, three of them (0.3%) developed recurrence at 1-2 month after surgery, 20 patients (2.0%) after 3-24 month, 24 patients (2.4%) after 25-42 month while 5 patients (0.5%) developed recurrence after 43-60 months of surgery (Table 2). Among reherniation patients, 50 were successfully treated with re-exploration and discectomy (Fig 2 c, d) and transforaminal lumbar interbody fusion (TLIF) and stabilization was performed in remaining 2 patients. Recurrent attacks (1-3) of back pain were observed in sixty-five patients (6.5%) after 2-5 years of surgery. Except for 13 patients who required epidural steroid injection along with analgesic and physiotherapy, all other patients responded well to conservative treatment.

Discussion

Conventionally, fenestration or laminotomy followed by lumbar discectomy is the gold standard technique for symptomatic LDH. This comprises extraction of offending disc fragment either by limited or aggressive excision of prolapsed intervertebral disc. First successful disc resection for LDH was done by Mixter and Barr[13]in 1934 by extensive laminectomy. Surgical microscope was introduced in 1977 by Yasargil and Caspar that resulted in smaller skin incision and good visualization.[14,15]Subsequently, in 1978 Williams[7] introduced sequestrectomy, a new surgical technique for virgin LDH which incorporated only a blunt perforation of the annulus fibrosus, therefore minimizing reherniation and adhesion reactions. Then in 1990, Sprengler et al.[8] termed limited discectomy, a less invasive method, where only the sequestered fragment was removed without invasion of intervertebral disc space which achieved 90% success rate without increase in reherniation rate. This technique avoids mishandling of the IVD space and thus prevents end plate erosion as well as its subsequent complications. On the other hand, conventional micro-discectomy or AD procedure where the surgeon excised herniated and nonherniated parts of the disc, results in early disc degeneration and disc space collapse. This further lead to spondylosis and spinal instability due to abnormal axial loading on the annulus and facet joints.[16]In the late 1990s, surgeons engaged in various minimally invasive operative technique such as percutaneous endoscopic discectomy that hasten the recovery period by minimizing the soft tissue trauma, however their superiority over the microsurgical lumbar disc surgery was debatable in various literature.[17] Two retrospective study comparing LD (fragmentectomy) against conventional microdiscectomy in single level LDH, showed there was no significant differences in VAS scores as well as in recurrence rate.[18.19]but another two comparative studies showed that there was a significant improvement of VAS score with removal of the fragment only but recurrence rate was higher than microdiscectomy.[20,21] After discectomy, incidence of recurrent radiculopathy varies from 17 to 33% and reherniation from 7 to 26%.[21,22,23] Different literature has shown that the reherniation rate were more following LD, whereas recurrent back pain and leg pain were more following AD.[24]A follow-up study of more than 10 years by Yorimitsu et al [25] showed better clinical outcome following standard discectomy in cases where adequately maintained disc height postoperatively, however recurrent herniation was more in this group. Another comparative analysis of sequestrectomy and aggressive discectomy showed that both are associated with recurrent lumbar disc herniation without substantial difference between them, but post-operative back pain is more in AD than sequestrectomy.[26] Though there is no significant association between volume of disc tissue removed and recurrence rate or postoperative instability but there is clear evidence that if disc space is reduced more than 30%, patients may develop post-operative segmental instability.[27,28] Recent studies have demonstrated better outcome in terms of shorter operating time, fewer intraoperative complications and a reduced rate of reherniation in patients that underwent asequestrectomy only as compared to those that underwent sequestrectomy and disc space exploration as well. [12]

Ran J et al. has shown that the reherniation rate in AD and LD group ranged from 0 to 10.5% (average of 4.7%) and 1 to 21.2% (average of 6.6%) respectively.

[29]Also in other studies, following LD re-herniation rate were reported to be 5% by Kast and Thome [30,31]; 4.2% by Williams et al.[32]; 8% by Goald et al.[33;] and 5.8% by Wenger et al. study[34]which were comparable to our study (5.2%). In this study recurrences developed (n=3) at 1-2 months, (n=20) at 3-24 months, (n=24) at 25-42 months and (n=5) at 43-60 months. Out of 52 reherniation patients, two patients underwent TLIF and posterior stabilization by pedicle screw and rod due to disc degeneration, >30%-disc space reduction and instability. Carragee et al.[35]compared LD against subtotal discectomy, the patients who underwent LD exhibited better clinical outcomes and a higher overall satisfaction rate, but had greater possibility of reherniation (18% versus 9%) and also reported that, annular defect of >6 mm in width following LD, has six times greater risk of developing re-herniation than smaller defects (27.3% vs. 4.8%). The incidence of post-operative discitis (POD) varies from 0.2% to 4%.[36,37] 19 patients (1.9%), developed post- operative discitis in this present study which were similar to study done by Moon et al[36] and Chen et al.[37]

Throughout the 24 months post-operative follow-up period, VAS scores for back pain, leg pain and ODI scores were significantly reduced (p<0.0001, Wilcoxon Rank-Sum test) (Table-3) which were comparable to Fakouri B et al.[19]and Carragee EJ et al[35] reviewed articles. Overall satisfactory outcome was 85% according to modified Mcnab criteria. It is suggested from the results of this study that the surgical treatment by limited discectomy may not increase the recurrence rates or cause any significant differences in postoperative VAS score for back pain and radicular pains. Surgical success in the disc surgeries depends approximately 10% on technique and 90% on proper patient selection.[38]

Conclusion: With well-defined criteria and appropriate patient selection, surgical management of LDH by limited discectomy could be considered a safe, effective and noble surgical option; which maintains the healthy intervertebral disc materials and, in the end, maintains excellent patients' satisfaction.

Acknowledgement

This study was supported by the department of Orthopaedic surgery at the Bangabandhu Sheikh Mujib Medical University and IBN Sina Hospital, Dhaka, Bangladesh and we thank them.

Conflict of interest: No conflict of interests.

Table 2: Characteristics and outcomes of patients with limited discectomy (LD) of lumbar disk herniation (LDH)

Characteristics	Number of patients	Percentage (%)
Age (years)		
16–40	765	76.5%
41–65	235	23.5%
Mean	38.03±9.14	
Range	19-55	
Sex		
Male	745	74.5%
Female	255	25.5%
Involved level		
L3-4	08	0.8%
L4-5	640	64.0%
L5-S1	352	35.2%
Involved side		
Right	340	34.0%
Left	650	65.0%
Bilateral (central)	10	1.0.0%
Recurrence (months)	**52**	**5.2.0%**
1–2	3	0.3.0%

3–24	20	2.0.0%
25–42	24	2.4.0%
43-60	5	0.5.0%
Discitis	**19**	**1.9%**
Outcome		
Excellent	525	52.50%
Good	325	32.50%
Fair	140	14.00%%
Poor	10	1.00%

Table 3: Clinical outcomes of Limited discectomy (LD)

Clinical outcome	Preoperative (n=1000) Mean±SD	Post- op after 2 weeks (n=1000) Mean±SD	Post- op after 2 years (n=1000) Mean±SD
VAS			
Back pain	3.21±2.12	1.88±0.78	0.98±0.88
Radicular pain	7.3±0.77	2.2±0.60	1.47±1.10
ODI	72.97±6.16	18.46±8.0	05.83±1.78
	Statistical analysis		p-value
	Preoperative vs Postoperative after 2 weeks		<0.001*
	Preoperative vs Postoperative after 2 years		<0.001*
	Postoperative 2 weeks vs Postoperative after 2 years		<0.001*

VAS: Visual analogue scale

P-value reached from paired to test, * = significant

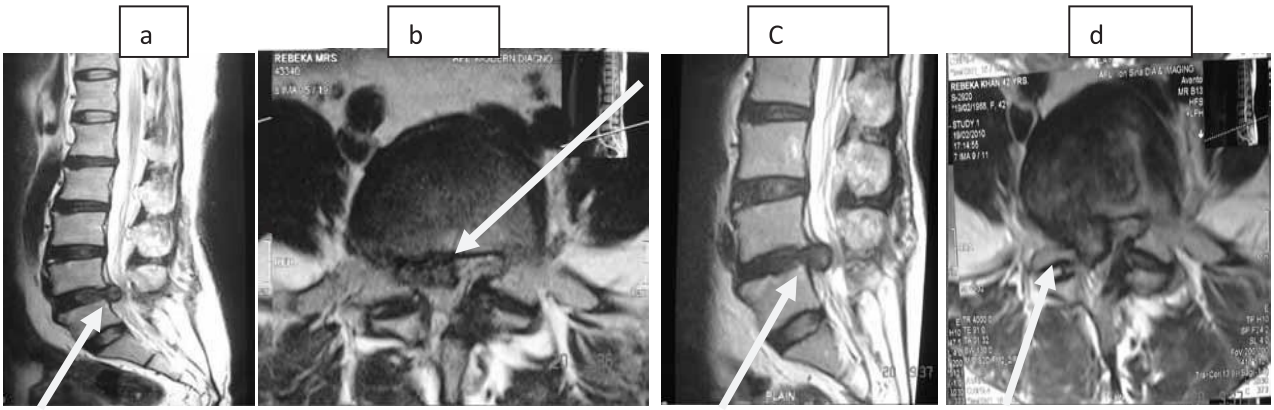

Figure 2:(a, b) Sagittal and corresponding axial T2-weighted magnetic resonance image (MRI) shows lumbar disc herniation at L4-5 level (right), limited discectomy was done on 15.1. 2004 and (c, d) same patient showed recurrent disc prolapse after 1.5 years at same level and same side which is shown at sagittal and corresponding axial T2-weighted MRI (arrow mark).

References

1. Cunningham L S, Kelsey JL: Epidemiology of musculoskeletal impairments and associated disability, *Am J Public Health* 1984;**74:**574-9.. https://doi.org/10.2105/AJPH.74.6.574
2. Frymoyer JW: Back pain and sciatica. *N Engl J Med* 1988; **318**:291-300. https://doi.org/10.1056/NEJM198802043180506
3. Deyo RA, Tsui-Wu YJ. Descriptive epidemiology of low-back pain and its related medical care in the United States. *Spine* (Phila Pa 1976).1987; **12**: 264-268. https://doi.org/10.1097/00007632-198704000-00013
4. Rhee JM, Schaufele M, Abdu WA. Radiculopathy and the Herniated Lumbar Disc. Controversies Regarding Pathophysiology and Management. *J Bone Joint Surg Am*. 2006; **88**: 2070-2080. https://doi.org/10.2106/00004623-200609000-00023
5. Kreiner DS, Hwang SW, Easa JE, Resnick DK, Baisden JL, Bess S, et al. An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. *Spine J*. 2014;**14:** 180-191. https://doi.org/10.1016/j.spinee.2013.08.003
6. Andersson GB, Brown MD, Dvorak J, Herzog RJ, Kambin P, Malter A, et al. Consensus summary of the diagnosis and treatment of lumbar disc herniation. *Spine* (Phila Pa 1976). 1996; **21**: 75S-78S. https://doi.org/10.1097/00007632-199612151-00009
7. Williams RW. Micro lumbar Discectomy: A Conservative Surgical Approach To The Virgin Herniated Lumbar Disc. *Spine* (Phila Pa 1976). 1978; **3**: 175-182. https://doi.org/10.1097/00007632-197806000-00015
8. Spengler DM. Lumbar discectomy. Results with limited disc excision and selective foraminotomy. Spine (Phila Pa 1976). 1982; 7: 604-607. https://doi.org/10.1097/00007632-198211000-00015
9. M Morgan-Hough CV, Jones PW, Eisenstein SM. Primary and revision lumbar discectomy. A 16-year review from one centre. *J Bone Joint Surg Br* 2003; **85**:871-4. https://doi.org/10.1302/0301-620X.85B6.13626
10. Macnab I. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty- eight patients. *J Bone Joint Surg Am* 1971; **53**:891-903. https://doi.org/10.2106/00004623-197153050-00004
11. Acharya KN, Nathan TS, Kumar JR, Menon KV. Primary and revision lumbar discectomy: a three- year review from one center. *Indian J Orthop* 2008; **42**:178-81. https://doi.org/10.4103/0019-5413.40254
12. Rajasekaran S, Balmurali G, Kanna RM, Shetty AP. Microsurgical lumbar disc surgery. In Roger Haertl, Andreas Korge, editors. Minimally Invasive Spine Surgery: Techniques, Evidence, and Controversies. by AOSpine, Thieme publisher, New York; 2012:289-311
13. Mixter WJ, Barr JS. Rupture of the Intervertebral Disc with Involvement of the Spinal Canal. *N Engl J Med*. 1934**; 211:** 210-215. https://doi.org/10.1056/NEJM193408022110506
14. Yasargil M.G. Microsurgical Operation of Herniated Lumbar Disc. *Advances in Neurosurgery* (1977) **4**:81 https://doi.org/10.1007/978-3-642-66578-3_16
15. Caspar W. A New Surgical Procedure for Lumbar Disc Herniation Causing Less Tissue Damage Through a Microsurgical Approach. Advances in Neurosurgery (1977) 4: 74-80. https://doi.org/10.1007/978-3-642-66578-3_15
16. Audat ZA, Al-Omari AA, Barbarawi MM, Radaideh AM, Hajyousef MH, et al. Treatment of Lumbar Intervertebral Disc Prolapsed with Fragmentectomy, more than Ten Years Follow Up. *J Spine* 2015; **4**: 228. https://doi.org/10.4172/2165-7939.1000228
17. Schroeder JE, Dettori JR, Brodt ED, Kaplan L. Disc degeneration after disc herniation: are we accelerating the process? *Evid Based Spine Care J.* 2012 Nov;**3**(4):33-40. https://doi.org/10.1055/s-0032-1328141
18. Baek GS, Kim YS, Lee MC, Song JW, Kim SK, Kim IH. Fragmentectomy versus Conventional Microdiscectomy in Single-Level Lumbar Disc Herniations: Comparison of Clinical Results and Recurrence Rates. *J Korean Neurosurg Soc.* 2012 Sep;**52**(3):210-4. https://doi.org/10.3340/jkns.2012.52.3.210
19. Fakouri B, Shetty NR, White TC. Is sequestrectomy a viable alternative to microdiscectomy? A systematic review of the literature. *Clin Orthop Relat Res*. 2015 Jun;**473**(6):1957-62. https://doi.org/10.1007/s11999-014-3904-3
20. Soliman J, Harvey A, Howes G, Seibly J, Dossey J, Nardone E. Limited microdiscectomy for lumbar disk herniation: a retrospective long-term outcome analysis *Spinal Disord Tech*. 2014 Feb;**27**(1): E8-E13. https://doi.org/10.1097/BSD.0b013e31828da8f1
21. Connolly ES. Surgery for recurrent lumbar disc herniation. *Clin Neurosurg*. 1992; **39**:211-216.
22. Eismont FJ, Currier B. Surgical management of lumbar intervertebral-disc disease. *J Bone Joint Surg Am.* 1989; **71**:1266-1271. https://doi.org/10.2106/00004623-198971080-00024
23. Kahannovitz N, Viola K, McCulloch J. Limited surgical discectomy and microdiscectomy. A clinical comparison. *Spine* 1989; **14**(1): 79-81. https://doi.org/10.1097/00007632-198901000-00016
24. McGirt MJ, Ambrossi GL, Datoo G, Sciubba DM, Witham TF, Wolinsky JP, Gokaslan ZL, Bydon A. Recurrent disc herniation and long-term back

pain after primary lumbar discectomy: review of outcomes reported for limited versus aggressive disc removal. *Neurosurgery*. 2009; **64**(2):338-44. https://doi.org/10.1227/01.NEU.0000337574.58662.E2

25. Yorimitsu E, Chiba K, Toyama Y, Hirabayashi K. Long-term outcomes of standard discectomy for lumbar disc herniation: a follow-up study of more than 10 years. *Spine* (Phila Pa 1976). 2001; **26**(6):652-7. https://doi.org/10.1097/00007632-200103150-00019
26. Balderston RA, Gilyard GG, Jones AA, Wiesel SW, Spengler DM, Bigos SJ, Rothman RH. The treatment of lumbar disc herniation: simple fragment excision versus disc space curettage. *J Spinal Disord.* (1991) **4**(1):22-5.
27. Fountas KN, Kapsalaki EZ, Feltes CH, Smisson HF 3rd, Johnston KW, Vogel RL, Robinson JS Jr. Correlation of the amount of disc removed in a lumbar microdiscectomy with long-term outcome. Spine (Phila Pa 1976). (2004) **29**(22):2521-4. https://doi.org/10.1097/01.brs.0000145413.79277.d0
28. Schaller B. Failed back surgery syndrome: the role of symptomatic segmental single-level instability after lumbar microdiscectomy. *Eur Spine J.* (2004) **13**(3):193-8. https://doi.org/10.1007/s00586-003-0632-x
29. Ran J, Hu Y, Zheng Z, Zhu T, Zheng H, Jing Y, et al. Comparison of discectomy versus sequestrectomy in lumbar disc herniation: a meta-analysis of comparative studies. *PLoSOne.* 2015;**10(**3): e0121816. https://doi.org/10.1371/journal.pone.0121816
30. Kast E, Oberle J, Richter HP, Börm W. Success of simple sequestrectomy in lumbar spine surgery depends on the competence of the fibrous ring: a prospective controlled study of 168 patients. *Spine* (Phila Pa 1976) 2008; **33**(14):1567-71. https://doi.org/10.1097/BRS.0b013e3181788ede
31. Thomé C, Barth M, Scharf J, Schmiedek P. Outcome after lumbar sequestrectomy compared with microdiscectomy: a prospective randomized study. *J Neurosurg Spine* 2005; **2**(3):271-8. https://doi.org/10.3171/spi.2005.2.3.0271
32. Williams RW. Microlumbar discectomy. A 12-year statistical review. *Spine* (Phila Pa 1976). 1986;**11**(8):851-2.https://doi.org/10.1097/00007632-198610000-00023
33. Goald HJ. Microlumbar discectomy: follow-up of 477 patients. *J Microsurg*. 1980**;2**(2):95-100. https://doi.org/10.1002/micr.1920020204
34. Wenger M, Mariani L, Kalbarczyk A, Gröger U. Long-term outcome of 104 patients after lumbar sequestrectomy according to Williams. *Neurosurgery.* (2001)**49**(2):329-34; discussion 334-5. https://doi.org/10.1227/00006123-200108000-00013
35. Carragee EJ, Han MY, Suen PW, Kim D. Clinical outcomes after lumbar discectomy for sciatica: the effects of fragment type and annular competence. *J Bone Joint Surg Am.* 2003 Jan;**85**(1):102-8. https://doi.org/10.2106/00004623-200301000-00016
36. Moon MS, Kim SS, Lee BJ, et al. Pyogenic discitis following discectomy. *J Orthop Surg* 2012: **20**(1): 11-17.https://doi.org/10.1177/230949901202000103
37. Chen SH, Chen WJ, Wu MH, et al. Postoperative infection in patients undergoing posterior lumbosacral spinal surgery: a pictorial guide for diagnosis and early treatment. *Clin Spine Surg* 2018; **31**(6): 225-238. https://doi.org/10.1097/BSD.0000000000000633
38. Junge A, Dvorac J, Ahrens S. Predictor of bad and good outcomes of lumbar disc surgery. A prospective clinical study with recommendations for screening to avoid bad outcomes. *Spine* 1995; **20(**4):460-468. https://doi.org/10.1097/00007632-199502001-00009