Mid-term evaluation of the outcome of mini-open microscopic lumbar discectomy

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Abstract

Background:
The advantages of microscopic discectomy include a smaller incision, less amount of blood loss, less soft tissue, and muscular damage, which may decrease operative time, wound complications, hospital stay, and post-operative recovery. However, failed back surgery syndrome (FBSS) is a clinical situation in which patients still complaining of unsatisfactory long-term clinical and functional outcomes after surgical interference of lumbosacral disease. This study aimed to evaluate the results of mini-open microscopic lumbar discectomy after five years of follow-up.

Patient and methods:
This is a prospective study conducted on 25 patients who were surgically managed with mini-open microscopic lumbar discectomy after the failure of medical and conservative treatment of their lumbar pathology. The mean follow-up duration was 5 years (range, 3.8-7 years). Patients with single-level lumbar disc prolapse or adjacent double-level lumbar disc prolapse were included in the study, while those with central canal stenosis, and/or lumbar vertebral instability that needs fixation were excluded. The postoperative outcome was evaluated using the Oswestry Low Back Pain Disability Questionnaire (ODI), at 6-month, 2-year, and 5-year follow-up visits.

Results:
The patient's age ranged from 23 to 59 years, and the duration of symptoms before surgery ranged from one to eight years. The distribution of the patients (N=25 & %) between the different grades of the ODI score was reported. The patients had shown a highly significant improvement of ODI at different follow-up visits (P-value <0.0001), regarding the overall outcome of the procedure. Two cases developed moderate complaint at a 6-month follow-up, which had been deteriorated to become severe at a 2-year follow-up. After the fusion of these two cases with the severe complaint, ODI was improved and the complaint became moderate. The rate of FBSS and re-operation in this study was 2 cases (8%), who had returned to their heavy work within 3 post-operative weeks. However, the relation between failure rate and return to activity was insignificant.

Conclusion:
Minimally invasive microscopic lumbar discectomy is a technique that results in a satisfactory outcome and early recovery. However, segment instability and FBSS may be a sequel that needs further investigations, proper patient selection and may need future fusion.

Keywords:
Mid-term evaluation, lumbar spine, microscopic discectomy.

Introduction:

Mixter and Barr[1] (1934) reported discectomy for the first time as surgical management of lumbar disc prolapse. The concept of endoscopic lumbar discectomy was fashioned in (1973) by Kambin and Savitz[2], and this was the gate for the development of microsurgical technique by Caspar[3] (1977), Yasargil[4] (1977), and Williams[5] (1978). “Micro Endoscopic Discectomy” (MED) was introduced by Foley et al. (2003), as a modification of “Endoscopic Discectomy” described by Foley and Smith[6] (1997), by development a modified tubular system that allows microscope usage. However, the use of an endoscope or a microscope in discectomy using the tubular retractors, allow using of the term “Micro Endoscopic Discectomy” (MED) .[7]

The advantages of this technique (MED) include a smaller incision, less amount of blood loss, less soft tissue, and muscular damage, this will lead to a decrease in operative time, postoperative wound complications, short hospital stay, and early postoperative recovery.[8-10] Also is more effective in obese patients as they need more soft tissue dissection in open discectomy for proper visualization. On the other hand, the drawbacks of open surgery include the reverse of all described advantages, but it is preferable due to good visualization, better root decompression, proper hemostasis, the liability to operate multiple levels, and the longer learning curve in (MED)[11,12].

Failed back surgery syndrome (FBSS) is a clinical situation in which patients still complaining of unsatisfactory long-term clinical, and functional outcomes, although they underwent one or more surgical interference for the lumbosacral disease. Inappropriate patient selection, iatrogenic instability, and surgical complications are considered the most common etiologic factors. Lumbar spine segmental instability is considered one of the sources of failed back surgery syndrome.[13-15]
In a study by Arvind et al.,[16] reoperation rate was 4.2% while the reoperation rate in the MED series by Wu et al.[17]was 2.4%. The aforementioned authors[18-21] reported reoperation rates ranging from 3% to 14%.
The aim of surgical management of herniated disc is proper nerve root decompression and removal of sufficient nucleus tissue without destabilizing the motion segment[22,23]. No definite consensus about the contribution of nuclectomy in segmental stability and then in FBSS and reoperation, and even fusion. Also, there is a diagnostic problem in the identification of motion segment mechanical impairment after nuclectomy.[24-27]
Radiography in some instances is an unreliable indicator of biomechanical instability. The false radiographic outcome may be due to bad quality and the patient's spinal profiles.[28]
Herein, we evaluate the results of mini-open microscopic lumbar discectomy after five years of follow-up, using the Oswestry Low Back Pain Disability Questionnaire (ODI).

Patients and Methods:

This is a prospective study conducted on 25 patients who were surgically managed with mini-open discectomy, in the time interval from January 2012 to January 2013, after the failure of medical and conservative treatment of their lumbar pathology. The mean follow-up duration was 5 years (range, 3.8-7 years).

Inclusion criteria: Patients with single-level lumbar disc prolapse, and patients with adjacent double-level lumbar disc prolapse.

Exclusion criteria: Patients with central canal stenosis, patients with previous lumbar surgery, and patients with lumbar vertebral instability that needs fixation.

History taking: To detect the onset, course, duration of the back, and radicular pain. Patients were asked about any motor or sensory complaints, as well as the assessment of the functional disability preoperative and postoperatively by the ODI Arabic, validated questionnaire.[22] Histories previous related medical condition, drugs, ischemic manifestations other causes of back pain as urinary tract infection, or pelvic inflammatory diseases.

Examination: A full examination of the spine and relevant areas as hips, also neurological evaluation (eg. motor weakness, hypoesthesia or sensory loss, and sacral sparing area, including perianal sensation, rectal tone, bulbocavernosus reflex($S_{3,4}$), and cremasteric reflex ($S_{1,2}$).

Preoperative investigations: X-ray to detect any instability and narrowing of intervertebral disc spaces and degenerative changes. MRI to detect the level of the herniated disc, degree of herniation, direction of herniation, and to what extent it compromises the neurological structures.

Operative technique:

Under general anesthesia, a prone position was complimented on a radiolucent operating table, with soft bolsters under the iliac crest and chest, that allow free abdomen. The lumbosacral region was prepared then imaging fluoroscopy was used to detect the target level. A midline skin incision (3-5 cm long) was carried out, with the subperiosteal elevation of the muscles and keeping the soft tissue away by putting a self-retaining retractor to expose the inter-laminar space. Under proper illumination and visualization of the operating microscope, all the steps of the surgical procedures were done. Excision of laminae is limited to the lower half of the proximal and the upper quarter or third of the lower lamina (fenestration). The medial third or half of the articular processes are also excised. The intervertebral disc is exposed, and a discectomy is performed.
In cases with an extruded or sequestrated intra-foraminal or a sequestrated extra-foraminal herniation, the operating microscope is tilted upwards to examine the inferolateral part of the posterior aspect of the upper vertebral body. An extruded herniation is seen as an abnormal prominence of disc tissue, just above the lower margin of the vertebral body, and is removed after the incision of the peripheral layers of the annulus fibrosus or fibrous sheath over the herniated tissue.
Any free fragment of the disc is then grasped and removed. When no lesion is visible at this stage, the lamino-arthrectomy is enlarged cranially and laterally with care to preserve some of the pars interarticularis. Eventually, the sequestrated disc tissue is visible, either caudal or ventral to the nerve root within the intervertebral foramen. When a large disc fragment is removed, no further attempt is made to expose the nerve root, but Frazier's 90° angled probe is used to

explore the intervertebral foramen ventrally to the root.
When imaging studies show or suggest the presence of a contained intra-foraminal or a contained or extruded extra-foraminal herniation, the lateral portion of the disc is excised using a reversed 45° angled pituitary rongeur. Either before or after this, the lateral annulus fibrosus is ruptured with an angled probe where it protrudes into the intervertebral foramen. In most of these patients, a large amount of disc tissue can be removed from the lateral part of the disc, either in small pieces or as one large fragment. In patients with a preoperative diagnosis of intraforaminal herniation, when only a small amount of tissue is excised, further careful inspection of the inferolateral part of the posterior aspect of the upper vertebral body is performed to find any extruded fragments on the affected side. Achieving a pulsatile dural sac and mobile nerve root was considered as an adequate decompression surgery.
The epidural bleeding was controlled using a combination of bipolar cautery, bone wax, and Gelfoam®, then closure in layers.

Follow-up: All patients were ambulated on the first day after the operation and assessed on the second day by history and examination for pain improvement and motor power grade before being discharged. Patients were reviewed in the first 2 weeks postoperatively for wound care and sutures removal. Patients were followed up at 1, 3, 6-month, 2-year, and 5-year to assess the functional outcome and disability by the Oswestry Low Back Pain Disability Questionnaire (ODI).

Oswestry Low Back Pain Disability Index (ODI) [29]:

Also known as the Oswestry Low Back Pain Disability Questionnaire, is an important tool to measure a patient's permanent functional disability, and it is considered the ‘gold standard of low back functional outcome tools. Interpretation of scores as following: 0% to 20%: minimal disability, 21%-40%: moderate disability, 41%-60%: severe disability, 61%-80%: crippled, and 81%-100%: These patients are either bed-bound or exaggerating their symptoms.[30]

Results

The study included 25 patients from different age groups ranging from 23 to 59 years, 15 males (60%), 10 females (40%) with different occupations. The duration of symptoms ranged from 1-8 years. The back pain preceded the appearance of sciatica pain in 21 patients (84%) and sciatica appeared from the start in 4 patients (16%) and neurogenic claudication was present in 13 patients (52%) only.
Clinically, the straight leg raising test was positive in 16 patients (64%) and negative in 9 patients (36%), motor weakness(grade 2 to 3) in 1 patient (4%), and no weakness in 24 patients (96%).
Radiological evaluation regarding X-ray revealed obvious lumbosacral degenerative changes (narrow disc space, anterior and posterior osteophytes) in 15 patients (60%) and no significant changes in 10 patients (40%). Also, MRI finding shows single-level disc prolapse in 20 patients (80%) and double-level disc prolapse in 5 patients (20%).
The 25 patients were assessed before and after the MLD operation by using the ODI to assess the functional improvement. Before the operation, the patients were classified by ODI as shown in table 1.

Table 1: ODI score for all patients before MLD and post-operative at different intervals, 6months, 2 years, and 5 years.

Time		
	Mean	**SD**
Before	45.68	10.16
After 6 months	17.2	6.78
After 2 years	20.96	11.56
After 5 years	20.96	11.56
P-value Before vs. After 6 months, After 2 years and After 5 years: ***<0.0001****		
P-value After 6 months vs. After 2 years and After 5 years = 0.084		

The patients show a highly significant improvement in ODI (P-value <0.0001) regarding the overall outcome of the procedure at different times of follow-up.
The distribution of the patients (N=25 & %) between the different grades of the ODI score was reported. Two cases developed moderate complaint at a 6-month follow-up, which had been deteriorated to become severe at a 2-year follow-up. After the fusion of these two cases with the severe complaint, ODI was improved and the complaint became moderate once again (table 2) (Fig1-4).

Table 2: distribution of the patients (N=25 & %) between the different grades of the ODI score:

	Before		**After 6 months**		**After 2 years**		**After 5 years**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Minimal	0	0.0 %	21	84.0 %	17	68.0 %	17	68.0 %
Moderate	7	28.0 %	3	12.0 %	5	20.0 %	7	28.0 %
Severe	16	64.0 %	1	4.0 %	3	12.0 %	1	4.0 %
Crippled	2	8.0 %	0	0.0 %	0	0.0 %	0	0.0 %

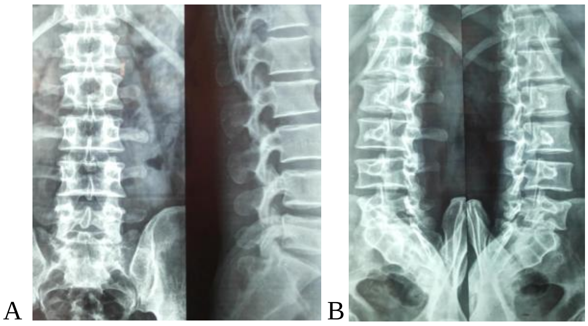


Figure 1: A, B: Preoperative x-ray evaluation of a case with FBSS AP, lateral, and oblique views.

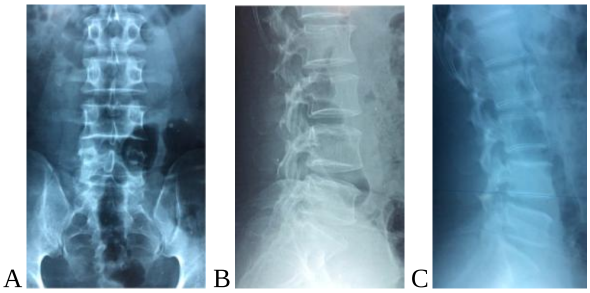


Figure 2: A,B,C: postoperative x-rays of the same case showing left side foraminotomy and fenestration at L5-S1 level.

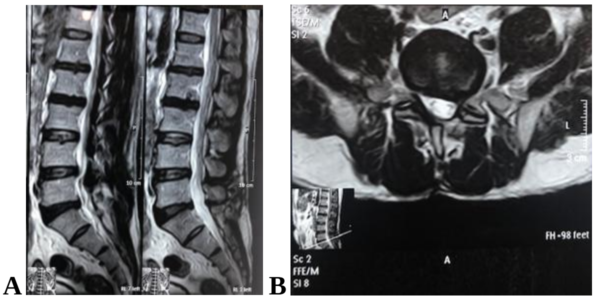


Figure 3: A, B: 2 years MRI finding in the same case with FBSS, showing recurrent disc.

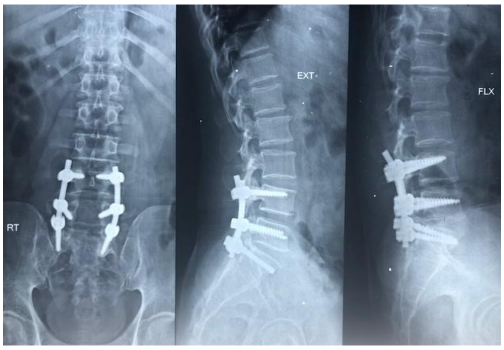


Figure 4: 5-years follow-up of the same case with FBSS (2 years after fixation).

There was no significant relation between FBSS and general patient characteristics.

There is no significant relationship between different study patients' parameters as pain onset, symptoms, signs, radiological finding, and the average ODI score as it improved with all of them whatever the variability.

Regarding MLD complications; 17 patients (68%) did not show either intraoperative complications (such as marked bleeding, dural tear, nerve root injury, and the need for blood transfusion), or postoperative complications (such as early wound hematoma collection and reactionary hemorrhage) and nor late complications (such as wound infection or dehiscence). The main postoperative complaints were persistent back pain in 7 patients (28%) and mild leg tingling and numbness in 1 patient (4%) (Table 3,4).

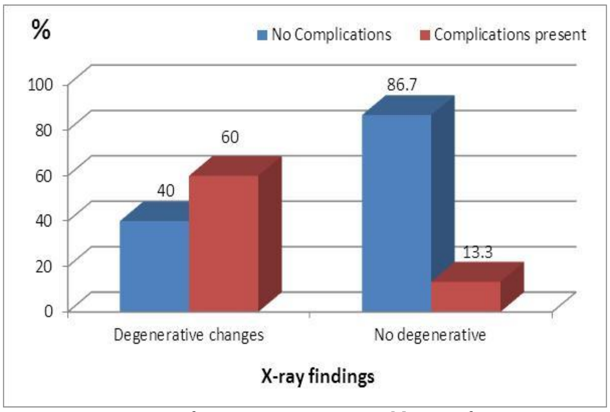
Table 3: FBSS with different characteristics of the patients.

	Failure & revision of the surgery				P-value
	Yes (N=2)		**No (N=23)**		
Age; Mean ± SD	34	5.7	40.4	9.9	0.386
Occupation; N, %					
Housewife	0	0.0%	8	100.0%	-----
Builder	1	16.7%	5	83.3%	0.369
Farmer	1	33.3%	2	66.7%	0.085
Teacher	0	0.0%	3	100.0%	-----
Porter	0	0.0%	2	100.0%	-----
Trainer	0	0.0%	1	100.0%	-----
Clerk	0	0.0%	1	100.0%	-----
Student	0	0.0%	1	100.0%	-----
Return to work					
< 3 weeks	2	100.0%	0	0.0%	-----
6-8 weeks	0	0.0%	23	100.0%	
Degenerative changes	1	10.0%	9	90.0%	1.000
No degenerative changes	1	6.7%	14	93.3%	
MRI; N, %					
Single	1	5.0%	19	95.0%	0.367
Double	1	20.0%	4	80.0%	

Table (4): Occurrence of postoperative complications with preoperative variables among study patients (N=25).

Variable	No Complications	Complications present	P-value
Leg pain:			
Early back pain then sciatica	14 (66.7)	7 (33.3)	1.000
Sciatica from start	3 (75.0)	1 (25.0)	
Claudication:			
Yes	9 (75.0)	3 (25.0)	0.673
No	8 (61.5)	5 (38.5)	
Leg raising:			
Positive	11 (68.8)	5 (31.2)	1.000
Negative	6 (66.7)	3 (33.3)	
Motor weakness:			
Positive	0 (0.0)	1 (100.0)	0.320
Negative	17 (70.8)	7 (29.2)	
X-ray:			
Degenerative changes	4 (40.0)	6 (60.0)	0.028*
No degenerative	13 (86.7)	2 (13.3)	
MRI:			
Double	2 (40.0)	3 (60.0)	0.283
Single	15 (75.0)	5 (25.0)	
back pain onset (years):			
1	5 (71.4)	2 (28.6)	0.878
2	4 (80.0)	1 (20.0)	
3	3 (60.0)	2 (40.0)	
4	3 (75.0)	1 (25.0)	
>4	2 (25.0)	2 (25.0)	

There is a significant relation between X-ray findings of degenerative changes in the lumbosacral region and postoperative persistent back pain as a complication with a p-value <0.028. There is no significant relationship between complications and other clinical or radiological variables(figure 5).



*Significant ** Highly significant

Fig (5): Graph showing the relation between X-ray degenerative changes and postoperative back pain.

Discussion:

A proper technique should lead to satisfactory outcomes, minimal morbidity, and good cosmoses. It should be cost-effective, able to adjust to patient factors like obesity. Open discectomy (OD) and microscopic discectomy considered the standard techniques in the surgical management of disc herniation.[31,32]

There is a significant relation between ODI score before and after MLD and this was in the agreement with R. Granier Perth et al.,[33] who performed MLD on 15 patients with post-operative follow-up for 11 months, and found that ODI improved from 30.6% pre-operative to 14.3% postoperative. Also, Karishma Parkish et al.,[34] whom study was conducted on 198 patients showed improvement in ODI from 56% preoperative to 26.4% postoperative. Also, Sylvian Palmer et al.,[35] who studied 129 patients, and Kotryna V. et al.,[36] who studied 100 patients, showed marked ODI improvement. In contrast to our finding, Tore K. Salberg et al.,[37] who studied 180 patients at 12-month follow-up, stated that 4% of the patients showed more disability on ODI assessment.

In the current study, there was no significant relation between ODI improvement and different patient parameters including back pain, sciatica, neurogenic claudications, straight leg raising, motor weakness, X-ray degenerative changes, and MRI findings. Similar results were stated by E. Kotilainan, (1998) who studied 39 patients and showed no significant relation between all patients' parameters, and ODI improved in all cases.[38] Also Marco Teli et al.,(2010) who studied 70 patients, found the same results.[39] In opposite to our findings Kotryna Veresciagina et al.,(2010) studied 100 patients with single-level disc prolapse and showed marked ODI improvement.[36]

In this study, there is a significant relation between X-ray degenerative changes and postoperative back pain. Also Bok. Hyun Cho et al.,(2006) showed a significant relation between X-ray degenerative changes and postoperative back pain.[40] Similar findings by Barth, Martin, et al.,(2008) who studied 84 patients, showed that there is a significant correlation between pre and postoperative radiological degenerative changes and postoperative back pain.[41]

Also, E. Kotiainen, (1998) who studied 39 patients showed that there is a significant relation between X-ray degenerative changes and postoperative back pain with 19% persistent pack pain and 3% increased back pain.[38] All of the previous results assumed that the presence of degenerative lumbar changes is a bad prognostic factor in the outcome of MLD may be due to permanent facet joint arthritic changes or the occurrence of future vertebral instability.

In this study, there is no significant relationship between different patients parameters as back pain, sciatica, neurogenic claudications, straight leg raising, motor weakness, and MRI findings with postoperative back pain. Similarly, Marco Teli et al.,(2010) showed that there is no significant correlation between different patients parameters and postoperative back pain.[39] Also Kudret Tureyen.,(2003) and Sang Mok Yon et al.,(2012) found the same results.[42,43] In contrast Bok Hyun Cho et al,.(2006) found that there is a significant correlation between different parameters and postoperative persistent back pain.[40] Also, P. ralaya et al.,[44] found three is a significant correlation between MRI finding as single level disc prolapse and postoperative back pain as it markedly improves with single level disc prolapse.

Regarding blood loss, this study showed that all cases had minimal intraoperative blood loss with an average of 100 ml (± 25.00 SD). Similarly Kudret et al,[42] found that MLD has intraoperative blood loss less than open lumbar discectomy. Also Manish et al,[45] found that open lumbar discectomy had an average blood loss of 180 ml that is more than our study.

Regarding the time of operation, this study showed an average mean operative time, which was 1.34 hours (± 0.37sd). Also Kudret et al,[42] found in a comparative study between MLD & open discectomy that operative time with MLD is longer. Manish et al,(2001) found that the average operative time in open lumbar discectomy was 75 min which was almost like our study.[45]

Regarding postoperative complications, this study showed that no postoperative complications occurred. Similar results by Shousha M et al,[46] reported that the risk of infection after MLD is very low at 0.09%. Also Manish Garg et al,[45] reported that there were postoperative complications after open discectomy as dural tear and superficial wound infection, which did not occur in our study. In contrast, Tassi et al.,[47] found that complications occurred in 2,2% of patients after MLD. Also Kudret et al,[42] found that no serious infection occurred after MLD nor open discectomy.

The rate of Failed Back Surgery Syndrome and re-operation in our study was 2 cases (8%) while the rate in the MED series by Wu et al.[17]was 2.4%. We had a higher complication rate in the earlier cases at the beginning, but when the learning curve had raised in subsequent cases, the complication rates decreased. Other authors[18-21] reported reoperation rates in OD ranging from 3% to 14%.

Also one of the most important advantages of this technique is an early return to the previous job. Regarding our study, we found that failure may be due to early return to heavy work, although the relation between failure rate and return to activity was insignificant. Another factor that may influence the results is the pre-operative job, although insignificant relation with different jobs was detected, we found that patients with heavy work are more susceptible to FBSS. In a study by Bookwalter et al.[48], 40% of their patients returned to a previous job after less than 5 weeks proving its cost-effectiveness. The mean time to return to work is 18.6 weeks, in a study by Caspar et al.[3] while Foley and Smith[6] reported the meantime of 17.6 days to return to work. The protocol of MLD allowed patients to resume work after 2 weeks following surgery, but in our study, this protocol failed with the heavy workers.

The limitations of this study were the small number of patients, the relatively short postoperative follow-up period, the high cost of the microscope, and the patients lost to follow-up.

Conclusion

Minimally-invasive Microscopic lumbar discectomy is one of the most widely used techniques as it results in the satisfactory outcome as minimal blood loss, minimal soft tissue surgical trauma thus decreasing postoperative wound infection, short postoperative hospital stay, early recovery, and early regaining activity, however, segment instability and Failed Back Surgery Syndrome may be a sequel that needs further investigations and the possibility of future fusion.

References

1. Mixter WJ, Barr JS. Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 1934;211:210-5.
2. Kambin P, Savitz MH. Arthroscopic microdiscectomy: An alternative to open disc surgery. Mt Sinai J Med 2000;67:283-7.
3. Caspar W. A new surgical procedure for lumbar disc herniation causing less tissue damage through a microsurgical approach. In: Wullenweber R,

Brock M, Hamer J (Editors), Advances in Neurosurgery. Berlin: Springer-Verlag; 1977. p. 74-7.

4. Yasargil MG. Microsurgical operation for herniated disc. In: Wullenweber R, Brock M, Hamer J, Klinger M, Spoerri O, (Editors). Advances in Neurosurgery. Berlin: Springer-Verlag; 1977. p. 81.
5. Williams RW. Microlumbar discectomy: A conservative surgical approach to the virgin herniated lumbar disc. Spine (Phila Pa 1976) 1978;3:175-82.
6. Foley KT, Smith MM. Micro endoscopic discectomy. Techniques in Neurosurgery1997;3:301-7.
7. Kulkarni AG, Dhruv AN, Bassi AJ. Microendoscopic Excision of C2 osteoid osteoma: A Technical Report. Spine (Phila Pa 1976) 2008;38:E1231-4.
8. Schick U, Döhnert J, Richter A, König A, Vitzthum HE. Microendoscopic lumbar discectomy versus open surgery: An intraoperative EMG study. Eur Spine J 2002;11:20-6.
9. Shin DA, Kim KN, Shin HC, Yoon H. The efficacy of Microendoscopic discectomy in reducing iatrogenic muscle injury. J Neurosurg Spine 2008;8:39-43.
10. Kotil K, Tunckale T, Tatar Z, Koldas M, Kural A, Bilge T. Serum creatine phosphokinase activity and histological changes in the multifidus muscle: A prospective randomized controlled comparative study of discectomy with or without retraction. J Neurosurg Spine 2007;6:121-5.
11. Harrington JF, French P. Open versus minimally invasive lumbar microdiscectomy: Comparison of operative times, length of hospital stay, narcotic use and complications. Minim Invasive Neurosurg 2008;51:30-5.
12. Yeung AT, Yeung CA. Minimally invasive techniques for the management of lumbar disc herniation. Orthop Clin North Am 2007;38:363-72.
13. Barr JS. Protruded disc and painful backs. J Bone Joint Surg Br. 1951;33:3–4.
14. Frymoyer JW. The role of spine fusion: Question Spine. 1981;6:284–90.
15. Hakelius A. Prognosis in sciatica: A follow-up of surgical and non-surgical treatment. Acta Ortho Scand (Suppl) 1970;129:3–76.
16. Arvind G Kulkarni, Anupreet Bassi, Abhilash Dhruv. Microendoscopic lumbar discectomy: Technique and results of 188 cases. Indian Journal of Orthopaedics. 2014; 48: 81-87.
17. Wu X, Zhuang S, Mao Z, Chen H. Microendoscopic discectomy for lumbar disc herniation: Surgical technique and outcome in 873 consecutive cases. Spine (Phila Pa 1976) 2006;31:2689-94.
18. McGirt MJ, Ambrossi GL, Datoo G, Sciubba DM, Witham TF, Wolinsky JP, et al. Recurrent disc herniation and long term back pain after primary lumbar discectomy: Review of outcomes reported for limited versus aggressive disc removal. Neurosurgery 2009;64:338-45.
19. Ebling U, Reichenberg W, Reulen HJ. Results of microsurgical lumbar discectomy. Review on 485 patients. ActaNeurochir 1986;81:45-52.
20. Caspar W, Campbell B, Barbier DD, Kretschmmer R, Gotfried Y. The Caspar microsurgical discectomy and comparison with a conventional standard lumbar disc procedure. Neurosurgery 1991;28:78-87.
21. Pappas CT, Harrington T, Sonntag VK. Outcome analysis in 654 surgical treated lumbar disc herniations. Neurosurgery 1992;30:862-6.
22. Saruhashi Y, Mori K, Katsuura A, Takahashi S, Matsusue Y, Hukuda S. 2004 Evaluation of standard nucleotomy for lumbar disc herniation using the Love method: results of follow-up studies after more than 10 years. Eur. Spine J. 13, 626 630. (DOI:10.1007/s00586-004-0690-8)
23. Yorimitsu E, Chiba K, Toyama Y, Hirabayashi K. 2001 Long-term outcomes of standard discectomy for lumbar disc herniation: a follow-up study of more than 10 years. Spine 26, 652–657. (DOI: 10.1097/00007632-200103150-00019)
24. Katz JN. 2006 Lumbar disc disorders and low-back pain: socioeconomic factors and consequences. J. Bone Joint Surg. Am. 88(Suppl. 2), 21–24. (doi:10.2106/JBJS.E.01273)
25. Zollner J, Heine J, Eysel P. 2000 Effect of enucleation on the biomechanical behavior of the lumbar motion segment. Zentralbl. Neurochir. 61, 138–142.
26. Halldin K, Zoega B, Lind B, Cederlund CG. 2005 Clinical application of a new three-dimensional radiological classification of lumbar disc herniations. Ups. J. Med. Sci. 110, 159–165.
27. Halldin K, Zoega B, Nyberg P, Karrholm J, Lind BI. 2005 The effect of standard lumbar discectomy on segmental motion: 5-year follow-up using radiostereometry. Int. Orthop. 29, 83–87. (doi:10. 1007/s00264-005-0636-8)
28. Shaffer WO, Spratt KF, Weinstein J, Lehmann TR, Goel V. 1990 1990 Volvo Award in clinical sciences. The consistency and accuracy of roentgenograms for measuring sagittal translation in the lumbar vertebral motion segment. An experimental model. Spine 15, 741–750.
29. Ramzy Raafat, Validation of the Arabic version of the Oswestry Disability Index developed in Tunisia for low back pain patients in the UAE, Thesis (MScPhysio (Physiotherapy))--Stellenbosch University, 2008.
30. Fairbank JC, Pynsent PB. The Oswestry Disability Index. Spine 2000 Nov 15;25(22):29-40
31. Tait MJ, Levy J, Nowell M, Pocock C, Petrik V, Bell BA, et al. Improved outcome after lumbar microdiscectomy in patients shown their excised disc fragments: A prospective, double-blind, randomized, controlled trial. J Neuro. Neurosurg Psychiatry 2009;80:1044-6.
32. Katayama Y, Matsuyama Y, Yoshihara H, Sakai Y, Nakamura H, Nakashima S, et al. Comparison of surgical outcomes between macro discectomy and microdiscectomy for lumbar disc herniation: A prospective randomized study with surgery performed by the same spine surgeon. J Spinal Disord Tech 2006;19:344-7.
33. R. Greiner-Perth Affiliated with Department of Orthopaedic Surgery, Spine Surgery and Paraplegiology, Zentralklinik Bad Berka, Robert-Koch-Allee 9, 99437 Bad Berka, Germany. A new technique for the treatment of lumbar far lateral disc herniation: technical note and preliminary results.European Spine Journal, June 2003, Volume 12, Issue 3, pp 320-324.
34. Karishma Parikh, B.S., Andre Tomasino, M.D., Jared Knopman, M.D., John Boockvar, M.D., and Roger Härtl, M.D.: Operative results and learning curve: microscope-assisted tubular microsurgery for 1- and 2-level discectomies and laminectomies, Neurosurgical Focus, Vol. 25, No. 2, Page E14, Aug 2008
35. Sylvain Palmer, M.D.: Use of a tubular retractor system in microscopic lumbar discectomy:1 year prospective results in 135 patients. Neurosurgical Focus Vol.13, No. 2,Pages 1-4,August 2002.
36. Kotryna Veresciagina Bronius SpakauskasKazys Vytautas Ambrozaitis: Clinical outcomes of patients with lumbar disc herniation, selected for one-level open-discectomy and microdiscectomy. European Spine Journal, Volume 19, Issue 9, pp 1450-1458, September 2010.
37. Tore K. Solberg, Oystein P. Nygaard, Kristin Sjaavik, Dag Hofoss Affiliated with Foundation for Health Services Research, Tor Ingebrigtsen: The risk of "getting worse" after lumbar microdiscectomy. European Spine Journal, Volume 14, Issue 1, pp 49-54, February 2005.
38. E. Kotilainen: Long-Term Outcome of Patients Suffering from Clinical Instability after Microsurgical Treatment of Lumbar Disc Herniation. Acta Neurochirurgica, Volume 140, Issue 2, pp 120-125 February 1998.
39. Marco Teli, Alessio Lovi, Marco Brayda-Bruno, Antonino Zagra, Andrea Corriero, Fabrizio Giudici, Leone Minoia: Higher risk of dural tears and recurrent herniation with lumbar micro-endoscopic discectomy. Eur Spine J,19:443–450,2010.
40. Bok- Hyun Cho, MD., Soek Won Kin MD., Seung Myung Lee, MD, And Ho Shin, MD. The factors affecting low back pain after microscopic lumbar discectomy, Kor J spine, 3(3):158-161, 2006.
41. Barth, Martine MD, Diepers, Micheal MD, Weiss, Christel MD, Thome Claudius MD: Two years follow up after lumbar microdiscectomy versus microscopic sequestrectomy, spine, volume 33, issue 3, pp 273-279,2008.
42. Kudert Tureyen, MD: One level one-sided lumbar disc surgery with and without microscopic assistance. J Neurosurg (spine 3), 99:247-250,2003.
43. Sang Mok Yon, Soon. Soeb Ahn, Ki Hong Kim. Comparative study of percutaneous Endoscopic lumbar discectomy & Microscopic lumbar discectomy.Korea. J spine, 9(3):215-222, September 2012.
44. P. Ralaya Kishore Nayak, MS, MCH, Laxmiderhar Parhi, MD, Girish Chandra Sahoo, MS: The study of outcome in minimally invasive microdiscectomy for single-level lumbar disc prolapse, pp 6:210-216,2006.
45. Manish Garg, Sudhir Kumar: Interlaminar discectomy & selective foraminotomy in lumbar disc herniation, J of orthopedic surgery, 9(2): 15-18,2001.
46. Shousha M, Cirvic D, Bochen. Infection rate after minimally invasive non-instrumented spinal surgery based on 4350 procedure, spine,140(3): 201-205, Feb 2015
47. Tassi GP: Comparison of results of 500 microdiscectomy and 500 percutaneous laser decompression of lumbar disc herniation, Surg, 24: 694-7, 2006.
48. Nakagawa H, Kamimura M, Uchiyama S, Takahara K, Itsubo T, Miyasaka T. Microendoscopic discectomy (MED) for lumbar disc prolapse. J Clin Neurosci 2003; 10:231-5.