Comparative Study between the Lumbar Microdiscectomy and Standard Open Lumbar Discectomy Techniques

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ABSTRACT

Standard open Discectomy is widely known as a common surgical procedure for lumbar disc herniation, while microdiscectomy in place of Caspar technique (the Caspar method) by a posterior approach is reported as less invasive surgical methods as a treatment modality. Nowadays "Minimal Invasive Surgery" is a trend setting catchword, but in the seventies the application of microsurgical techniques derived from intracranial procedures to the lumbar spine was a breakthrough. Caspar[2] in 1976 and 1977, Yasargil[14] in 1977, and Williams[12] in 1978 independently reported microtechniques in the treatment of lumbar disc herniations. ***Materials and Methods:*** *The objective of our study is to investigate the surgical outcomes of these two different modalities (The lumbar microdiscectomy and standard open lumbar discectomy) as surgical treatment of the disc prolapse. We evaluated 20 cases of microsurgical lumbar discectomy and 20 cases of standard discectomy performed at Ain shams university and Ain shams university specialized hospitals The target of our study was a group of 20 patients who underwent surgery by microdiscectomy in place of Caspar technique and a group of 20 patients who underwent surgery by standard open lumbar discectomy . The items investigated were the operation time, amount of bleeding, duration of hospitalization, amount of analgesic agent used after surgery, pre- and postoperative scores based on judgment criteria for treatment of lumbar spine disorders established by the Japanese Orthopaedic Association score, visual analog scales (VAS, 0 to 10) for back pain before surgery and at discharge, VAS for sciatica before surgery and at discharge, VAS for sciatica before surgery and at discharge, perioperative complications, and cases requiring further surgery.* ***Results:*** *There were no significant differences between the 2 surgical procedures in the frequency of use of an analgesic agent after surgery, the pre- and postoperative Japanese Orthopaedic Association scores or postoperative VAS for sciatica. Statistically significant differences were observed in the operation time, amount of bleeding, duration of hospitalization, and post-operative VAS for lumbar pain, but the differences were not large, and may not have been clinically significant.* ***Conclusions:*** *For surgical excision of lumbar disc herniation, both microsurgical lumbar discectomy and standard open discectomy are appropriate, as long as surgeons have mastery of the procedures, and the technique of lumbar microsurgery needs longer learning curve and has to be learned, carried out properly, practiced often and not just occasionally*

Key Words: *lumbar disc herniation, partial laminectomy, microscopic lumbar discectomy*

INTRODUCTION

Low back pain affects millions of people worldwide each year. Many of these patients respond well to conservative treatment. The remaining patients undergo approximately 700,000 disc related surgical procedures annually including discectomy and spinal fusion.

Nowadays "Minimal Invasive Surgery" is a trend setting catchword, but in the seventies the application of microsurgical techniques derived from intracranial procedures to the lumbar spine was a breakthrough. Caspar[2] in 1976 and 1977, Yasargil[14] in 1977, and Williams[12] in 1978 independently reported microtechniques in the treatment of lumbar disc herniations.

The introduction of the operating microscope in spine surgery allows the surgeon to use a smaller incision for this procedure while providing

excellent illumination and magnification of the operative field, thereby facilitating a less traumatic surgical technique. This study aimed at comparison of 2 different modalities of discectomy namely microdiscectomy and standard open discectomy via clinical trial in patients who suffer from prolapsed lumbar disc with back pain and or sciatica after failure of medical treatment. Its a prospective one that was held in Ain Shams University hospitals

MATERIALS & METHODS

Study Duration

The patients went under the chosen surgical treatment wither microdiscectomy or standard open discectomy and be prospectively followed for 24 months to assess therapeutic outcomes during a period from June2004 till June 2006. Patient assessments were required at baseline (preoperative), and at 1.5, three, six, and twelve months (24 months optional) follow up.

Patient Population

40 Patients were accrued from the population of patients of Ain Shams University Hospital outpatient clinic, diagnosed with degenerative disc disease and required surgical intervention at a single lumbar segment from L2 to S1.

20of them went under microsurgical discectomy and the other 20 went under open standard discectomy.

Patient Selection

Patients enrolled into this study included those whom at least 18 and not older than 65 years of age with, unilateral symptomatic disc herniation, single level from L2 to S1 not associated with bony canal stenosis confirmed by physical examination and MRI lumbosacral spine. Only patients with signs of motor weakness and positive signs were operated on.

Cases in which patients not filling these criteria or had undergone any previous back surgery had severe osteoporosis or osteomalacia, had an active systemic, or localized infection at the area of the spine where the surgery will be performed or had a significant emotional or psychosocial disturbance were excluded from this study.

Most patients had been operated upon after a previous trial of conservative therapy that failed and suffered acute-onset disabling sciatic pain, relieved only by high doses of analgesics, in association with or without major objective neurological deficits.

Patient evaluation

Patients were required to undergo a thorough pre-operative evaluation prior to the surgery and return for follow-up evaluations according to a pre-determined follow-up schedule as shown in table (1) and during each surgical procedure we reported the operative duration, operative complication and blood loss by calculating the blood in the container of suction in every case.

Table (1): Evaluations performed for each group.

Evaluation	*Pre-op*	*Operative*	*1.5 month*	*3 months*	*6 months*	*12 months*	*24 months*
Demographics	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Back Pain History	Yes	N/A	No	No	No	No	No
Current Back Status	Yes	N/A	Yes	Yes	Yes	Yes	Yes
Physical Exam	Yes	N/A	Yes	Yes	Yes	Yes	Yes
JOA score	Yes	N/A	No	Yes	Yes	Yes	Yes
VAS for sciatica	Yes	N/A	No	Yes	Yes	Yes	Yes
VAS for lumbar pain	Yes	N/A	No	Yes	Yes	Yes	Yes
Operative Time	N/A	Yes	N/A	N/A	N/A	N/A	N/A
Bleeding during operation	N/A	Yes	N/A	N/A	N/A	N/A	N/A
Complications	N/A	If applicable	If applicable	If applicable	If applicable	If applicable	If applicable

Quantitation of Postoperative Pain Medication

Pain medication consumed by patients preoperatively, intraoperatively, and postoperatively was documented by chart review. Opiate analgesics consumed in the preoperative period were noted only if documented in the house officer's admission note and the admitting nurse's note. Because no preoperative (outpatient) quantitation of analgesia consumed was available, only a qualitative distinction was made to distinguish any tolerance effects intraoperatively and postoperatively.

Intraoperative opiate administered during anesthesia was recorded: 50μg/ml fentanyl was converted to 4 mg morphine sulfate. The amount of opiate analgesia consumed in the postoperative period was quantified to reflect postoperative pain.

Statistics

Linear regression and comparison groups were performed using a linear regression computer program and an unpaired two-tailed *t* test computer program, respectively; a *P* value of < 0.05 was considered to be statistically significant.

Surgical Techniques

Preoperatively, for both studied groups: the microsurgical lumbar discectomy and the standard open discectomy the patients were sedated and given an intravenous dose of prophylactic antibiotics. Patients were taken to the operating room, given general endotracheal anesthesia, and placed on the operating room table in a prone position or in a kneeling position according to the possibility of the operating table, the kneeling position actually allow for free suspension of the abdomen, thereby minimizing bleeding from the epidural veins. The back then was shaved and cleansed with an alcohol swab and preoperative radiographic labeling of the affected disc space; the level to be operated on is identified by inserting a spinal needle vertically to the inferior edge of the affected disc (Figure 1 & 2).

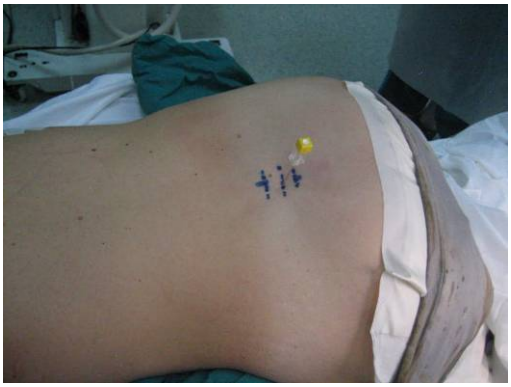

Figure (1)

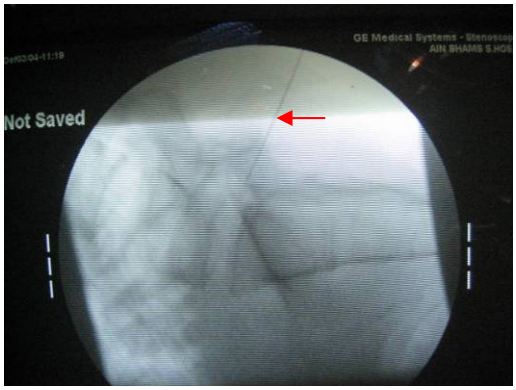

Figure (2)

Figure 1 & 2 showing the marking the affected level before operation

We noted the following points:

- Avoid puncturing the dural sac by inserting the needle one finger's breadth lateral to the spinous process on the side contralateral to the intended skin incision.
- Insert the needle perpendicularly to the interspace. With an oblique puncture parallel to the spinous processes, the tip of the needle and the entry point in the skin may differ by up to one level!
- If preoperative radiographic labeling is not properly carried out or not performed at all, exploration of the wrong level will be the most common and at the same time most avoidable error in lumbar microdiscectomy.

For the microsurgical lumbar discectomy group:

Soft tissue dissection (one level operation); a skin incision of approximately 2-3 cm is done just midline. The musculature is then detached bluntly and pulled laterally with a fluted introducer (Figure 3).

Preparation of the interlaminar space; The appropriate speculum-like muscle retractor (The Caspar retractor-counterretractor system) is inserted as vertically as possible. Then retractor is rotated by 90° clockwise, so that the handle is facing the assistant and the leaves are then opened (Figure 4). This special design ensures unobstructed view along with a lateral enough muscle retraction.

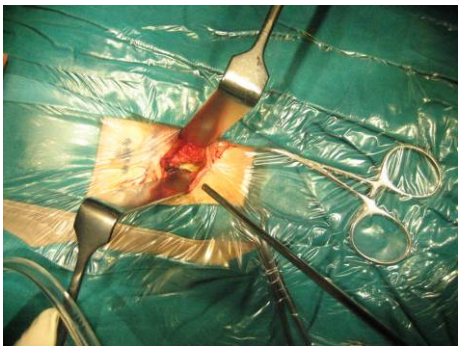

Figure (3) : Unilateral muscle separation

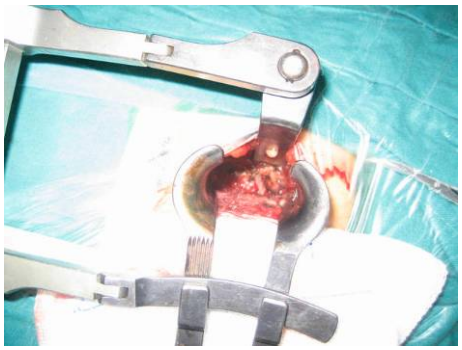

Figure (4): Application of the Casper retractor

Microscopic decompression at this stage the microscope should be used. The Zeiss OPMI H-6 Contraves (Carl Zeiss Co., Thornwood, NY) microscope was then sterilely draped and brought into the operative field. (The entire operation from skin incision to skin closure could be performed with the aid of the microscope), using a 300-mm lens and 12.5 x oculars; a limited bony resection (lower one quarter of the upper lamina and medial portion of the medial facet joint) is performed with a Kerrison punch or high-speed drill. Mediolateral fenestration and adequate removal of the yellow ligament is carried out to gain access to the epidural space, the removal of the ligamentum flavum or yellow ligament can be done in one of three ways:

- The ligamentum flavum can be detached from the undersurface of the rostral lamina and then be removed in a superior to inferior manner.
- It can be detached from the rostral end of the inferior lamina and be removed in an inferior to superior manner.
- The fibers can be cut and further separated with a small dissector such as a Penfield 4 in a longitudinal fashion and subsequently be removed with Kerrison punches.

All three methods will reveal the epidural space. At this point in time, the dura of the thecal sac and the nerve root that is compressed by the herniated disc are identified. Occasionally epidural fat will obscure these structures. This fat could be removed with a pituitary rongeurs or shrunk back with bipolar forceps. The nerve root can be gently mobilized medially to reveal the disc space and the overlying epidural veins. The veins must be coagulated with bipolar forceps and cut with fine microscissors. Blunt nerve hooks, down-angled curettes, and Penfield dissectors can be used to mobilize free disc fragments that can then be removed with pituitary rongeurs. With the nerve root protected medially by a nerve root retractor or a blunt suction tip, the posterior longitudinal ligament is inspected. If it is healed over and no further disc fragments are encountered, the operation is completed. When an opening in the posterior longitudinal ligament is encountered, the opening is incised and disc material from the disc space can be extracted using he instruments previously mentioned. It is important to put the pituitary instrument in the disc space no further than approximately 2.5 cm to avoid penetrating the anterior longitudinal ligament. Traction or penetrating this ligament can lead to catastrophic injury to the great vessels.

The nerve root and its foramen are gently palpated with microdissectors to assure the surgeon that the nerve root is adequately decompressed. After hemostasis is achieved, the fascia, subcutaneous tissue, and skin are closed in standard fashion. Drainage is usually not necessary.

For the Standard open discectomy group :

The length of the skin incision was 5 cm. the fascia incision was of the same length as the one in the skin. The smallest possible partial laminectomy with removal of a variable amount of the medial facet was made. The ligamentum flavum was removed, and careful hemostasis was ensured by using bipolar diathermy. Decompression of the root with removal of disc fragment. An operating microscope was not used. In each case, the disc space itself was also entered and all available disc material was removed.

Wound closure; the fascia and subcutaneous tissue are sutured to avoid muscle herniation. Drainage is usually necessary.

RESULTS

The results of 20 consecutive patients operated on microsurgically Group A are compared with a group of 20 patients who underwent a conventional open standard discectomy Group B. The microsurgically operated group consisted of 9 men and 11 women with a mean age of 41 (24-58) years. The conventional standard discectomy group comprised 12 men and 8 women with a mean age of 41.5 (23-62) years.

All our 40 patients were operated at either level L4-L5 or L5-S1; there were no other affected levels in our study. There was high incidence at operative level L4-L5 in both groups of treatment modalities, and more in males than in females. While L5-S1 was the least incidence especially for females whom underwent microsurgical discectomy as shown in table 2.

Table (2): Showing the operative level of our patients in relation n to their sex and the treatment modalities they had received.

Operative level	***Microsuraical discectomy***		***Open standard Discectomy***	
	Male	*Female*	*Male*	*Female*
L4-L5	5 Patients	7 Patients	8 Patients	6 Patients
L5-S1	4 Patients	4 Patient	4 Patients	2 Patients

All patients in the 2 groups had sciatica in addition some patients had back pain or sensory manifestation in the form of numbness table (3).

Table (3): Showing clinical presentation finding

	Microsurgical discectomy	***Open standard discectomy***
Back pain	17 Patients (85%)	15 Patients (75%)
Sensory in the form of numbness	15 Patients (25%)	3 Patients (15%)

The mean operation time (Table 4) was 110 ± 12 minutes (90 to 150 minutes) in microsurgical discectomy, and 100 ± 10 minutes (85 to 140 minutes) in Open standard discectomy ($P > 0.05$); the mean amount of bleeding (Table 4) was 50±52 cc in microsurgical discectomy group, and 307.5±112 in Open standard discectomy Group ($P<0.05$); and the mean duration of hospitalization (Table 4) was 8.3 ± 0.8 days (6 to 10 days) microsurgical discectomy group, and in Open standard discectomy Group was 8.5 ± 2.3 days (5 –25 days) ($P<0.005$); with these data showing significant differences for each parameter except for the operative timing which did not differ significantly between the 2 groups.

Table (4): Showing mean values of operative time, bleeding, inpatient Stay and use of Analgesic Agent in the 2 surgical treatment modalities

Factor	*Microsurgical discectomy*	*Open standard discectomy*	*P value*
Operative time (minutes)	110 ± 12	100±10	> 0.05
Blood loss (cc)	50±52	307.5±112	< 0.05
Inpatient stay (days)	8.3 ± 0.8 (6 - 10)	8.5 ± 2.3 (5 - 25)	< 0.05

The Clinical Results

We used assessment tools as Questionnaires or scales, which helped to translate the subjective experience of pain into more objective evidence that can be analyzed and used for comparison on subsequent visits. We used the JOA score (The Japanese orthopedic associations evaluation system), VAS for lumbar pain and AS for sciatica[5].

Table (5): Summary of the Preoperative mean value results in our clinical assessments score and scale for microsurgical discectomy and Open standard discectomy treated Patients

Assessment questionnaires and scales	*Preoperative*		
	Microsurgical discectomy	*Open standard discectomy*	*P*
Mean JOA score	16 ± 2	16 ± 2	0.6773
Mean VAS for lumbar pain	7.6 ± 0.9	8.5 ± 0.7	<0.0001
Mean VAS for sciatica	7.9 ± 0.6	8.1 ± 0.9	0.0537

Table (6): Summary of the Postoperative mean value results in our clinical assessments score and scales for microsurgical discectomy and Open standard discectomy treated Patients

Assessment questionnaires and scales	***Postoperative***		
	Microsurgical discectomy	*Open standard discectomy*	*P*
Mean JOA score	27 ± 1	27 ± 1	0.0778
Mean VAS for lumbar pain	1.2 ± 0.4	1.6 ± 0.7	0.0023
Mean VAS for sciatica	1.2 ± 0.4	1.3 ± 0.5	0.2730

Table (7): Showing the incidence of intra operative complications in each group

Complications	*Microsurgical discectomy*	*Open standard discectomy*
Superficial wound infection	2 Patients	Non
Dural tear	1 Patient	Non

The JOA score (Table 5 & 6) improved from 16 ± 2 points before surgery to 27 ± 1 points at the last follow-up time in both Groups (improvement rate: 77%), showing no significant difference between the 2 groups (before surgery: P = 0.6773, after surgery: P = 0.0778).

VAS for lumbar pain (Table 5 & 6) improved from 7.6 ± 0.9 to 1.2 ± 0.4 in Microsurgical discectomy group, and from 8.5 ± 0.7 to 1.6 ± 0.7 in Open standard discectomy group, with these data showing significant differences between the 2 groups before and after surgery (before surgery: P = 0.0001, after surgery: P = 0.00023).

VAS for sciatica (Table 5 & 6) improved from 7.9 ± 0.6 to 1.2 ± 0.4 in Microsurgical discectomy group, and from 8.1 ± 0.9 to1.3 ± 0.5 in Open standard discectomy group , showing no significant difference between the 2 groups either before or after surgery (before surgery: P = 0.0537, after surgery: P = 0.2730).

Regarding complications **(table7)** superficial infection occurred in 2 patients and dural tear in one patient in the microsurgical discectomy group, but no complications occurred in Open standard discectomy treated Patients.

DISCUSSION

Macro discectomy (the Love method), first reported by Love in 1939[7], is a very well known surgical treatment for lumbar disc herniation. In this procedure, the affected region is reached only by resection of the yellow ligament between the vertebral arches, without resection of bone, and the disc herniation is removed. Intracanal lumbar discectomy with posterior partial hemilaminectomy or fenestration, the so-called modified Love method, is widely used in Egypt. Less invasive surgical procedures have been introduced more recently; the microdiscectomy procedure has been performed by surgeons since its introduction by Yasargil[14] and Caspar[2]. Although the evaluation methods and follow-up periods in the subsequent studies differed, excellent or good outcomes were obtained in 85% to 92% of patients[3,4,9,10,13]. There are numerous articles in the literature in which authors have reported success rates ranging from 70% to 95% for standard discectomy[8,12]. Compared with the standard operation, microdiscectomy has the advantage of being less invasive because the skin incision is small and dissection is performed with clear visualization of structures under a microscope[10]. Others have reported no difference in long-term results but advantages in the short-term outcome when performing microsurgery[1,6,11]. Several earlier studies have shown a significantly shorter inpatient stay for microsurgical operations compared with a standard operation. This difference could be explained partly because these were retrospective studies, and postoperative courses of therapy may have differed. Therefore, in this study, we performed a prospective investigation of the surgical outcomes of the standard open discectomy and microdiscectomy. In particular, we focused on a comparison of the operation time, amount of bleeding, duration of hospitalization, improvement rate pain after surgery, and complications.

In our study, the mean operation time was 110 ± 12 minutes for the microsurgical lumbar discectomy, and 100±10 minutes for Standard open discectomy, showing that the microdiscectomy required approximately 12 more minutes on average. However, time for microscope preparation is required approximately 10 more minutes on average. But

whatever the time for microscope preparation required during surgery by microdiscectomy it may have been one of the reasons for the longer operation time.

The mean amount of bleeding was 50 ± 52 cc with the microsurgical lumbar discectomy and 307.5±112 cc with Standard open discectomy. From that we found more bleeding occurred in the Standard open discectomy with significant difference.

The mean duration of hospitalization was 8.3 ± 0.8 days after surgery by the microsurgical lumbar discectomy and 8.5 ± 2.3 days with Standard open discectomy; again the difference was not large. The frequency of use of an analgesic agent after surgery did mean administration frequency was less than once per patient, suggesting that pain after either surgery was not severe.

The JOA scores improved from 16 ± 2 points before surgery to 27 ± 1 points for the last follow-up time for both procedures, giving an improvement rate of 77%; that shows the outcomes of both methods are good.

The VAS for lumbar pain after surgeries with the microsurgical lumbar discectomy and Standard open discectomy were 1.2 ± 0.4 and1.6 ± 0.7, respectively, showing a significant difference between the 2 groups, but this difference was still small. In addition, because there was a significant difference in preoperative VAS for lumbar pain between the 2 groups: 7.6 ± 0.9 and 8.5 ± 0.7, respectively, it is difficult to judge whether the difference in post-operative VAS for lumbar pain was due to a difference in the surgical procedure or due to the degree of the original pain.

The postoperative VAS of sciatica after surgeries by the microsurgical lumbar discectomy and Standard open discectomy were not significantly different: 1.2 ± 0.4 and 1.3 ± 0.5, which is the main symptom of lumbar disc herniation, improved smoothly after both types of surgery. Highly positive neurological improvement has been evident in each group.

Significant difference in complications was noted between the 2 methods as there was superficial infection occurred in 2 patients and dural tear in one patient in the microsurgical discectomy group, but no complications occurred in Open standard discectomy treated Patients .

By analyzing these complications we had in our study we found them either intraoperative or postoperative complications but occurred only in the microsurgical lumbar discectomy group. The intraoperative complication was in the form of dural tear in one patient with an incidence of (3%). The tear was sutured intraoperative and there were neither CSF leak nor collection postoperative. The postoperative complications included postoperative superficial wound infection in two patients with an incidence of (6%) of the same group of microsurgical lumbar discectomy.

As described above, there were no significant differences between the microsurgical lumbar discectomy and Standard open discectomy in the operation time and the use of an analgesic agent after surgery, the pre- and postoperative JOA scores, or postoperative VAS of sciatica. Statistically significant differences were observed in the amount of bleeding, duration of hospitalization, and postoperative VAS of lumbar pain, but the differences were not large,

Also as shown in the study there was Significant difference in complications as rate of complication we had were only in the microsurgical lumbar discectomy group but this was

mainly in the early cases before building up our learning curve .

The microsurgical lumbar discectomy discectomy is a safe and effective procedure for intervertebral discs. Its results are comparable to standard open discectomy procedure. The microscopic procedure technique offers the benefits of a smaller incision than open discectomy and limited tissue trauma. The microsurgical lumbar discectomy has advantages over other minimally invasive surgical techniques because it can address lesions other wise inaccessible to percutaneous or endoscopic techniques with better visualization, illumination and magnification, on the other hand the difficulties of the microsurgical lumbar discectomy procedure are evident because of the limited exposure and the high magnification which could make us miss sometimes the root anomalies causing injury to conjoint root (if our learning curve is not built enough to experience variable structural difference of the anomalies found in the field under high magnification), actually it happened to us in one of the cases of microsurgical lumbar discectomy but it was double level so it was not included in this study however I think it worth to be mentioned here as considered one difficulty faced in the technique of microsurgical lumbar discectomy, so the potential injury of the nerve root due to the limited working space and field of vision remains a serious concern.

Like other new minimally invasive techniques, microsurgical discectomy has a learning curve which is related to surgery time, complications, conversion to the open procedure and recurrent disc herniation. It is advisable to start with herniation free fragments in younger patients, and only later treat older patients with bony and ligamentous pathology associated with disc herniation.

CONCLUSION

For lumbar disc herniation, the surgical outcomes of the microsurgical lumbar discectomy and Standard open discectomy there were no significant differences in the operation time and the frequency of use of an analgesic agent after surgery, in the pre- and postoperative JOA scores, or in the postoperative VAS for sciatica. There were statistically significant differences between the microsurgical lumbar discectomy and Standard open discectomy in the amount of bleeding, duration of hospitalization and postoperative VAS for lumbar pain, but the differences were not large. Also a significant difference in complications was noted only in the microsurgical lumbar discectomy.

From that we found that the microsurgical lumbar discectomy has the advantages of smaller skin incision, less tissue trauma, less time of hospitalization and less intraoperative blood loss better illumination and magnification at the surgical field but our own clinical results showed equivalent clinical results to those of standard open discectomy.

The clinical results advantages of microsurgical lumbar discectomy over classic discectomy might be limited and they do not seem to last longer than the early initial post operative period.

For discectomy of lumbar disc herniation both microsurgical lumbar discectomy and Standard open discectomy are appropriate, as long as surgeons have mastery of the procedures.

The following points should be kept in mind in order to deal successfully with the microsurgical technique:

1. The technique of lumbar microsurgery has to be learned, carried out properly, practiced often and not just occasionally.
2. The pre/intraoperative radiographic check is a mandatory and essential guide to the target area.
3. The microtechnique cannot be used to solve all spinal problems.
4. The results are best when surgery is performed within 3 months of the onset of symptoms.
5. Lumbar microsurgery is highly effective in the decompression of the neurostructures and at the same time minimally invasive and traumatizing to the soft tissues.
6. The lumbar microsurgery preserves stability; therefore the need of subsequent fusion procedures is most unlikely.

REFERENCES

1. **Barrios C, Ahmd M, Arrotegui J, et al.** Microsurgery versus standard removal of the herniated lumbar disc. A 3-year comparison in 150 cases. *Acta Orthop Scand.* 1990; 61:399-403.
2. **Caspar W.** A new surgical procedure for lumbar disc herniation causing less tissue damage through a microsurgical approach. Advances in Neurosurgery 1977; 4:74-77.
3. **Caspar W, Campbell B, Barbier DD, et al.** The Caspar microlumbar disc procedure. *Neurosurgery.* 1991; 28:78-87.
4. **Goald HJ.** Microlumbar discectomy: follow-up of 477 patients. *J Microsurg.* 1980; 2:95-100.
5. **Jensen MP, Karoly P, Eoghan FO and Burns RS:** The subjective experience of acute pain. An Assessment of the utility of 10 indices. Journal of Bone Joint Surgery, 1986.
6. **Kahanovitz N, Viola K, Muculloch J.** Limited surgical discectomy and microdiscectomy: a clinical comparison. *Spine.* 1989; 14:79-81.
7. **Love JG.** Removal of protruded intervertebral disc without laminectomy. *Proc Staff Meet Mayo Clin.* 1939; 14:800-805.
8. **Sachdev VP.** Microsurgical lumbar discectomy: A personal series of 300 patients with at least 1 year of follow-up. *Microsurgery.* 1986; 7:55-62.
9. **Silvers HR.** Microsurgial versus standard lumbar discectomy. *Neurosurgery.* 1988; 22 :837-841.
10. **Tullberg T, Isacson J, Weidenhielm L.** Does microscopic removal of lumbar disc herniation lead to better results than the standard procedure? Result of a one-year randomized study. *Spine.* 1993; 18:24-27.
11. **Tureyen K.** One-level one-sided lumbar disc surgery with and without microscopic assistance: 1-year outcome in 114 consecutive patients. *J Neurosurg Spine.* 2003; 99(Suppl 3):247-250.
12. **Williams RW.** Microlumbar discectomy. A conservative surgical approach to the virgin herniated lumbar disc. Spine 1978; 3(2):175-182.
13. **Wilson DH, Harbaugh R.** Microsurgical and standard removal of the protruded lumbar disc: a comparative study. *Neurosurgery.* 1981; 8:422-427.
14. **Yasargil MG.** Microsurgical operation of herniated lumbar disc. Advances in Neurosurgery 1977; 4:81-88.