

Minimal Invasive Lumbar Spine Surgery

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Abstract: Objective: to discuss and evaluate different minimal invasive surgical approaches to lumbar spine (Endoscopic Discectomy & Percutaneous fixation) for treatment of lumbar spine pathology including lumbar disc herniation and spine fractures. **Patients and methods:** This study was conducted at the neurosurgery department, Al-Azhar university hospitals (Al-Hussein & Bab El-Sha'ariya University Hospitals) during the period from June 2012 to March 2017. This study involved **50** patients proved to have lumbar spine pathology. This study including 20 patients proved to have lumbar disc prolapsed, treated with percutaneous endoscopic lumbar discectomy by Destandau's technique using Endospine Karl Storz system, Also including 30 patients with lumbar spine fracture treated with percutaneous fixation. The patients are evaluated by outcome of surgical procedure and follow up (by clinical and radiological assessment) which was done immediate and 6 month after surgery for assessment of the result of each surgical approach used. **Results:** The data collected from the patients who were operated upon during the study were analyzed, and the results were concluded, compared and evaluated according to: Sex, Age, Symptoms, Signs, Radiological analysis, Surgery, Follow up and outcome, Causes of morbidity. The outcome for was excellent in 14 patients (70%); good outcome was achieved in 5 patients (20%). Abortion of the technique occurred in 2 patients (10%) who on follow-up one had good outcome and the other a fair outcome. postoperative CT the mean percentage of canal compromise was 18.7% ranging from **10%** to **58%**. The mean canal improvement and fragment reduction was 1.6% ranging from **3%** to **24%**, the highest canal improvement was 12% at L1, at D12 the highest canal improvement was 5%, at L2 the highest canal improvement was 8%.
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1. Introduction:

Virchow first described traumatic lumbar intervertebral disc disease in 1857. Contributions from physicians striving to understand back pain and sciatica have encouraged the development of new surgical interventions, as well as conservative modalities, for the treatment of spinal disorders. In 1909, Oppenheim and Kruse described a low lumbar midline posterior transdural approach for the resection of an "endochondroma". In 1911, Goldthwait described the consequences of trauma to the annulus, resulting in extrusion of the nucleus pulposus. In 1901, Horsley decompressed the spinal cord of a patient with progressive spondylotic myelopathy. In 1913, Elsberg described a laminectomy for removal of a spinal chondroma. In 1934, Mixter and Barr established the relationship between disc herniation and sciatica. (7).

After establishment of the basic cause and effect relationship between disc herniation (both extruded and sequestered discs) and sciatica, investigations were performed to better elucidate the pathophysiological features of spinal disorders. Intraoperative observational aids were developed to facilitate surgical approaches. Pool used a modified otoscope, with illumination, to perform myeloscopic examinations of the dorsal nerve roots in cases of

herniated discs, hypertrophied ligamentum flavum, adhesive arachnoiditis, benign neoplasma, and metastatic carcinoma. In 1955, Malis began intraoperatively using a binocular microscope, in conjunction with bipolar coagulation, to aid his surgical approach. After the introduction of the intraoperative use of an operating microscope for discectomies, Yasargil and Caspar introduced the minimally invasive concept of microdiscectomy. (8).

With better observation of spinal disorders, a number of other treatment modalities were considered for the management of intervertebral disc disease. Biochemical advances in the treatment of disc herniations paralleled microsurgical treatments. In 1963, Smith et al., described percutaneous enzymatic dissolution of nucleus pulposus in a rabbit model this technique was later successfully applied to human subjects. As the biochemical properties of the nucleus pulposus were elucidated and its high water content was identified, it was postulated that heat from either a thermal probe or a laser could help shrink the disc and relieve nerve compression. In 1984, Ascher and Heppner used a neodymiumyttrium-aluminum garnet (YAG) laser to ablate the nucleus pulposus. (9).

In 1975, Hijikata described the first percutaneous discectomy. Since then, automated discectomies have

replaced percutaneous discectomies. Current concepts include the use of adjuvant therapy in addition to automated techniques involving lasers and thermal heating probes. The concept of minimally invasive spine surgery is advancing rapidly, as new developments and new applications are being explored. (10).

Minimally invasive spinal procedures result in less tissue trauma and therefore reduce a patient's postoperative pain and discomfort, shorten hospital stays and allow a quicker return to activities of daily living. Complications such as iatrogenic instability or hastened degeneration at an adjacent level can potentially be reduced using these techniques by maintaining the integrity of normal anatomic tissue structures (i.e. muscular and ligamentous attachments) while limiting retraction related injuries (i.e. muscle denervation).

Complication of minimally invasive lumbar spinal surgery can be related to anesthesia, patient positioning and surgical technique. The performance of successful minimally invasive spinal surgery is beset with several technical challenges, including the limited tactile feedback, two -dimensional video image quality of three - dimensional anatomy and the manual dexterity needed to manipulate instruments through small working channels.

The phrase "minimally invasive spine surgery" is still met with skepticism by most neurosurgery. We have seen chymopapain come and go, and we have noted the same fate for automated percutaneous lumbar discectomy. We have heard the virtues of laser discectomy, foraminal epidural endoscopic discectomy, and recently intradiscal electrothermy. None of those procedures has been scientifically scrutinized, however, and most have failed to fulfill their initial promises with time.

Different techniques in Minimally invasive lumbar spine surgery include Arthroscopic Microdiscectomy it provides an alternative methods for treatment of symptoms producing lumbar disc herniation Arthroscopic illumination and magnification permits excellent visualization of the anatomic structures and make it possible to extract offending pathology under direct visualization.

Endoscopic lumbar discectomy with Minimal trauma, the spinal canal is reached through the inter laminar window, with excellent visual conditions and bleeding can be reduced.

Microendoscopic lumbar discectomy the most popular and successful Endoscopic system currently in use combines the technique of standard open microsurgery disc removal with Endoscopic observation, the so called Microendoscopic discectomy (MED).

Vertebroplasty for osteoporotic compression was developed in France by Deramond, in 1987 this minimal invasive procedures uses a large pore-bone-cutting needle to percutaneously access a vertebral body inject bone cement and thereby structure.

Microendoscopic Decompressive laminotomy for the treatment of lumbar stenosis as lumbar stenosis in one of the most common diseases of spine in geriatric population for patients over 65y, it has now become the leading indication for spinal surgery by modifying existing Microendoscopic discectomy and using fluoroscopic guided percutaneous technique the working portal was docked on the lamina with minimal soft tissue injury with the angle of the endoscope combined with an oblique entry, a bilateral bone and ligamentous decompression was achieved under the midline.

Percutaneous posterior lumbar interbody fusion the wide exposure required for a standard posterior lumbar interbody fusion (PLIF) can cause unnecessary trauma to the lumbar musculoligamentous complex, by exiting Microendoscopic, percutaneous instrumentation and interbody fusion technology. Minimally invasive percutaneous PLIF technique was developed to minimize such iatrogenic tissue injury (MIP-PLIF).

A laparoscopic approach to the anterior lumbar spine has been described in the literature as a safe and effective surgical technique its use in spinal surgery to achieve interbody fusion in the lower lumbar spine is an attractive alternative to traditional open anterior procedures. The open approach has along postoperative recovery time. In addition, a laparoscopic anterior lumbar interbody fusion (LALIF) procedure may negate the need to perform a posterior approach, along with its associated muscle dissections, nerve root retractions and significant postsurgery pain.

Anterior approaches to the lumbar spine for the interbody fusion and total disc replacement and treatment of various degenerative or postoperative abnormalities associated with low back pain have always been a matter of debate they are known to be associated with considerable surgical trauma, high postoperative morbidity, occasionally and unacceptably high complication rates.

The approaches are performed with the use of a surgical microscope lumbar segments L2-L5 are exposed through a lateral retroperitoneal approach. L5-S1 can be reached through a midline retroperitoneal or Tranperitoneal approach. Both approaches can be performed through a limited skin incision of 4 cm.

2. Patients and methods:

This study was conducted at the neurosurgery department, Al-Azhar university hospitals (Al-Hussein

& Bab El-Sha'ariya University Hospitals) during the period from June 2012 to March 2017.

This study involved 50 patients proved to have lumbar spine pathology. This study including 20 patients proved to have lumbar disc prolapsed, treated with percutaneous endoscopic lumbar discectomy by Destandau's technique using Endospine Karl Storz system, Also including 30 patients with lumbar spine fracture treated with percutaneous fixation.

The patients are evaluated by outcome of surgical procedure and follow up (by clinical and radiological assessment) which was done immediate and 6 month after surgery for assessment of the result of each surgical approach used.

Our inclusion criteria for endoscopic discectomy is:

- ✓ Unilateral Radicular pain correlated with MRI finding,
- ✓ Failure of conservative measures for at least 6 weeks,
- ✓ Single level disc prolapse,
- ✓ Disc prolapse is paracentral.

Our inclusion criteria for percutaneous fixation is:

- *Unstable wedge or burst fractures.*
- *More than 30% anterior height loss.*
- *Patients with No neurological deficits.*
- *Canal encroachment must be less than 67%.*
- *Gains score (Load sharing classification) less than 7.*

3. Results:

The data collected from the patients who were operated upon during the study were analyzed, and the results were concluded, compared and evaluated according to: Sex, Age, Symptoms, Signs, Radiological analysis, Surgery, Follow up and outcome, Causes of morbidity.

In Endoscopic discectomy study:

The outcome for was excellent in 14 patients (70%); good outcome was achieved in 5 patients (20%). Abortion of the technique occurred in 2 patients (10%) who on follow-up one had good outcome and the other a fair outcome.

This outcome was consistent with the findings by Brayda-Bruno where among 100 patients, using modified MacNab criteria, good to excellent results have been recorded in 85% of cases, and poor or bad outcomes in only 15%. (1)

The operative time for the cases operated upon endoscopically ranged from 70 min. up to 180 min. with a mean of 106 min.

The duration of hospital stay for the cases that underwent endoscopic discectomy ranged from 1 day to 21 days with a mean of 2.68 days.

As regards postoperative complications, there was 3 cases of discitis with severe back spasm (good outcome).

Among the patient selection criteria was the predominant symptom that was correlated with the final outcome. Out of the 20 cases in the study, 18 cases (90%) in the study complained of sciatica as the predominant symptom. Of this group 18 patients had a successful outcome (94%), and one case had failure of the operative technique (5,5%).

On the other hand, of all the cases included in the study, only 2 patients presented with backache as the predominant symptom (10%). Of those a successful outcome was noted in only 50%.

In percutaneous fixation study:

Postoperative CT the mean percentage of canal compromise was 18.7% ranging from 10% to 58%. The mean canal improvement and fragment reduction was 1.6% ranging from 3% to 24%, the highest canal improvement was 12% at L1, at D12 the highest canal improvement was 5%, at L2 the highest canal improvement was 8%.

Percutaneous trans pedicular screw technique represents a viable option in treatment of pre selected thoracolumbar fractures. A significant reduction in blood loss, post operative pain and surgical time were the main advantages associated with this minimally invasive technique. (2).

In this study, the operative time 48 min ranging from minimum 25 min to 70 min. Long operation time was in early cases because we used to do screw tracts one by one taking a lot of images on C-arm, later we started making 2 tracks at the same time which did shorten the time of surgery.

(2) Reported that mean surgical time in pedicle screw group was 53 minutes plus or minus 10 minutes.

(3) reported in percutaneous pedicle screw fixation that mean operating time, the average operative time was 78 minutes ranging from (62min. – 117 min.).

Minimally invasive posterior stabilization lead to lower blood loss and less operating time, in comparison to the open technique (4)

In this study, no practical blood loss only 5-8 ml.

In this study, the hospital stay was 9.08 days. The long duration stay in some cases was due to ICU admission, associated injury and compound fractures. The shortest hospital stay was 3 days after surgery in cases with only fracture spine and the longest was 34 days

(5) reported in percutaneous pedicle screw fixation that the mean hospital stay duration was 15 days ± 4 days. (6) reported that the mean hospital stay duration was 10.2 days.

In this study, we had 2 mal-placed screws. They both preached the lateral cortex of the pedicle but no canal encroachment or nerve injury postoperative in clinical and radiological assessment. The patient has

neither pain nor limitation of movement or daily activity and the fracture was fully united. We did not have any other intra-operative or postoperative complication.

(11), Reported that minimally invasive transpedicular fixation is an accurate, reliable and safe method to treat a variety of spinal disorders including thoracic and lumbar spine fracture. **494/502 (98%)** pedicle screws were found to have good or excellent position; one screw had to be revised due to medial position with neurological deficit.

4. Discussion:

The aim of **Endoscopic discectomy** study was to evaluate the new modality of endoscopic discectomy & its effectiveness in addressing the various aspects in the surgical treatment of lumbar disc herniation.

The study encompassed 20 patients operated upon by endoscopic techniques.

The age on admission ranged from 24 to 56 years with a mean age of 40 yrs, the greatest incidence being in the third and fourth decades.

Twenty patients were included in the study. Fifteen cases were males and five cases were females with preponderance of males over females with a ratio of 3:1.

Sciatica and back pain were the main symptoms in the study, present in all cases. Sciatica was the predominant symptom in 90% of the cases.

Back signs were among the commonest preoperative findings. Paravertebral muscle spasm was present in 80% of the cases. Local tenderness was present in 75% of the cases. Limited back mobility was present in 95% of the cases and scoliosis was encountered in 5% of the cases.

Straight leg raising was positive in 100% of the cases.

The level of the prolapsed disc was L4-5 in 55% of the cases and L5-S1 in 45% of the cases.

Hypoesthesia of the L5 dermatome was present in 50% of the cases, in the S1 dermatome in 40% of the cases and in the L4 dermatome in 5% of the cases.

MRI lumbosacral spine and Plain X-ray was done for all the cases (100%). CT lumbosacral spine was done for 3 cases (15%). Narrowing of the disc space of the affected level was evident on plain X-ray in 88% of the cases and straightening of the lumbar spine was evident in 98%. Caudal migration of the prolapsed disc was evident on MRI in 20% while cranial migration was evident in 0 % of the cases.

Patients were operated upon by endoscopic microdiscectomy using both, the sequential dilators & tubular retractor of the MED system in 9 cases and the coned multi-portal retractor of Destandau in 11 cases.

General anesthesia was employed in all cases, although we believe that spinal anesthesia would be favorable too.

The patients were placed in the prone position with the abdomen free and the spine flexed. The same low midline (maximum 2 cm) skin incision was done as in the literature.

In this series, there were no double level discs, but it is believed that endoscopic removal of two adjacent disc levels is possible from the same skin and fascial incision.

The advantages of the endoscopic technique are:

- 1) a smaller skin incision,
- 2) a muscle-splitting rather than subperiosteal approach to the lamina,
- 3) less postoperative pain,
- 4) earlier hospital discharge,
- and 5) quicker return to employment.

After exposure has been obtained with the tubular endoscopic system, the endoscopic techniques for ligamentum flavum removal, discectomy, and foraminotomy are easily obtained by experts.

As regard **percutaneous fixation**:

This study is a prospective study of **30** consecutive patients in Al-azhar university hospitals, to assess percutaneous spine fixation in thoracolumbar fractures.

Minimally invasive stabilization of selected spine fracture appears to be safe technique with low complication rate and high patient satisfaction. Minimally invasive stabilization reduces hospitalization and allows a fast functional recovery improving the quality of life. **(12)**

(13) reported that open surgical technique that thoraco-lumbar spine fixation following trauma is associated with prolonged surgical time, significant blood loss, increased infection rate and approach related soft tissue and muscle destruction. In addition, patients are often afflicted with significant pain despite successful surgical recovery.

Open approach for thoracolumbar spine fixation following trauma requires extensive tissue dissection to expose the bony structures of the spine and for pedicle screw fixation. Consecutively, paravertebral muscles are denervated and dissection leads to muscle and soft tissue ischemia, significant postoperative pain, long recovery times and potentially contributing to some cases of failed fracture stabilization **(14)**.

(15) analyzed postoperative MRI and trunk muscle strength following lumbar surgery in 80 patients. They determined that damage to the low back muscles was directly related to the muscle retraction time during surgery. The incidence of low back pain was also significantly higher in those who had long muscle retraction times. These conclusions support the

studies of (16) who examined the effects of retractor pressure on the paraspinal muscles during lumbar surgery. They found that muscle injury, as demonstrated by elevated serum levels of creatine phosphokinase MM isoenzyme, is directly related to the retraction pressure and duration.

In addition conventional approach to the spine is associated with extensive blood loss, risk of wound infection and prolonged hospitalization, as well conventional extensive surgical approach in polytrauma, ICU and geriatric patient may increase their morbidity and prolong hospital stay (17).

The percutaneous system eliminates the need for a large midline incision and significant paraspinous muscle dissection. Both the pedicle screws and the precontoured rod or plate are placed through stab incisions. The paraspinous muscles are bluntly split rather than divided, leading to potentially shorter periods of hospitalization and recovery. Blood loss and tissue trauma are minimized. An ideal lateral-to-medial screw trajectory is much more easily accomplished as significant paraspinous tissue retraction is avoided (18).

Compared with conventional open surgeries the clinical outcomes of minimally invasive surgery have indicated that the procedure is at least equally effective. Moreover, recovery time, pain, time required to return to work after surgery are reduced for minimally invasive spine surgery. (13)

For polytraumatized or septic patients suffering from critical illness. The minimally invasive percutaneous stabilization of the spine might be the right concept to minimize such approach-related morbidity and secondary iatrogenic soft tissue trauma. (15)

Percutaneous fixation enables earlier mobilization, especially for ICU and geriatric patients which might contribute to improved outcome regarding pulmonary or thromboembolic complications, and even decubitus ulcers (19).

Compared with conventional open spine surgeries, percutaneous fixation for thoraco-lumbar fractures are associated with minimal soft tissue disruption, minimal blood loss, reduced infection rate and less operative time in most cases, particularly in poly trauma patients or those with significant medical co morbidities, complex open spine surgery may not be possible. Unlike open surgery, percutaneous instrumentation can provide spinal stabilization of thoraco-lumbar injuries with a decreased peri operative morbidity rate. (13).

This study is a prospective study of 30 consecutive patients started from June 2011 to february2014 in Cairo University hospital. The age varied from 20 to 47 years with mean age 27.8 years.

Our study included 18 males (60%) and 12 female (40%).

(20) reported fifteen consecutive patients underwent placement of percutaneous Sextant insertion during Jan 2004 to Jun 2005.

There were ten men and five women, with ages ranged from 28 to 60 years.

In this study the mechanisms of injury were fall from height 10patients 33.3% and motor car injury 20 patients 66.7%. The types of fractures were wedge or burst fractures. There were 22 patients with single level fracture 6 patients had D12, 10 patients had L1, 5 patients had L2, 4 patients had L3, 3 patient had L4. Two patients had 2 adjacent levels fracture, one patient had D12-L1and one patient had L2-3; they all were fixed one level above and one level below.

(20) reported that all his patients had compression fractures. All patients had a single level fixation, of which one was at L3, ten were at L4 and four were at L5 (20).

In this study preoperative radiological investigation requested where plain X- ray films and CT scan. Magnetic resonance imaging (MRI) was not requested because none of our patients had any neurological affection, the indication of surgery is unstable fracture according to Denis classification. The sagittal and transverse cuts of CT with the inverted cortical sign of fragment rotation were important key to show the posterior longitudinal ligament integrity.

In this study the average pre-operative **local kyphosis (lateral Cobb's angle)** was 19.2°, the pre-operative **vertebral body angle** was 22.95° and the pre-operative **wedge index** was 0.68. Average **pre-operative canal compromise** was 20.3% ranging from 21% to 66%. The highest canal compromise was at L2 with 66%. At D12 the highest canal compromise 50% and at L1 highest canal compromise 61%.

(6) reported average pre-operative **local kyphosis** was 27°, the average pre-operative vertebral body angle was 23, the average pre-operative **wedge index** was 0.7, and the average pre-operative canal compromise was 26%.

(21) reported that mean preoperative local kyphosis was 16.0 degree and improved by 9.3 degree after surgery. Mean preoperative VBA of fractured vertebrae was 15.9 degree and improved by 7.9 degree after surgery.

(22) reported that burst fractures having the following percentage of canal compression are at significant risk of neurological involvement:

- At D11 and D12 with 35% or more.
- At L1 with 45% or more.
- At L2 and below 55% or more.

The difference in opinion may be explained by the following:

- The cord compression is not the sole mechanism of cord injury in spinal fractures. Other mechanisms of cord injury are not accounted for in CT assessment of canal compromise.

- Pre-operative CT assessment of canal compromise does not assess the compromise at the time of accident or transport.

In this study the indication for percutaneous fixation is unstable wedge or burst fractures, no neurological deficits and. **Exclusion** criteria were canal encroachment must be less than 67% because higher grades are associated with posterior longitudinal ligament injury and rupture of annulus, Gains classification must be less than 7 and also L5 fracture was excluded.

In this study L5 fracture was excluded from the surgery because the difficulty to insert S1 screw percutaneously and the rod or plate will stop by high L5-S1 facet joint.

(20) operated on patients whom had unstable compression fractures (20).

(6) reported the indication for surgery was unstable wedge and burst fractures. Patients with verified neurological affection were excluded from the study (6).

In this study, the operation was done 3 days after the trauma.

(6) reported that percutaneous fixation in first five days enables better fragment reduction.

Conclusion:

Conclusion For Endoscopic Discectomy:

The decision to perform the discectomy by the various endoscopic systems available may be left to the surgeon as the indications and patient selection criteria are similar with other surgical modalities.

Endoscopic discectomy may be considered as an alternative option to either micro- or standard discectomy in appropriately trained and experienced hands for appropriately selected patients.

So careful preoperative patient evaluation/selection and correct indications for surgical intervention are of utmost importance in the management of patients with lumbar disc herniation and sciatica.

However endoscopic discectomy has a steep learning curve and is certainly performed more efficiently by neurosurgeons familiar with endoscopic techniques. It is with no doubt that the more popular use of endoscopy in the various surgical interventions, and noticeably in neurosurgery, endoscopic lumbar discectomy is a technique that requires training and guidance in order to reach the skill of performing efficiently. We believe that a specific skill in endoscopic approaches is the best basis from which to begin.

Endoscopic discectomy has a number of advantages along with its efficiency equal to that of microsurgical discectomy.

Advantages of this low invasive surgery of intervertebral discs hernia include the reduced time and volume of surgical intervention, shortening of the length of patient's stay, a decrease in postoperative administration of narcotic analgesics, and improvement of postoperative outcomes.

Lastly, further results are awaited including larger patient series.

Conclusion for Percutaneous Fixation:

From our study we can conclude the following:

Percutaneous spine fixation is a safe technique follows these same principles of open procedures, allowing the surgeon to perform biomechanically sound internal spinal fixation with minimal tissue trauma and represents a good alternative option for treatment of unstable thoraco-lumbar wedge and burst fractures with no neurological affection.

It has the advantage of short time surgery, no blood loss, no muscle damage results in less postoperative pain than traditional open procedures, moreover, short hospital stay, earlier mobilization, a faster return to work and the rate of complications is low.

Clinical and functional results are better or comparable to traditional open procedures.

The main drawbacks of this technique are the high learning curve and radiation exposure to all Surgeons, nursing staff and surly the patient, this harmful effect of radiation can be decreased as much as we can by using the recent modality in screw insertion by 3D CT navigation.

We feel that our findings can be used as background information for future assessing the efficacy of minimal invasive procedures for thoraco-lumbar surgery.

References

1. Brayda-Bruno M, Cinnella P (2000) Posterior endoscopic discectomy (and other procedures). *Eur Spine J*; 9 Suppl 1: S24–S29.
2. Petr Vanek, Ondre Bradac, Renata Konopkova, et al: journal of neurosurgery. spine, volume 75 issue 2, pp 162-167, 2014.
3. Wen-Fei, Huang, YI-Xing et al: journal of spinal disorders and techniques, volume 23, issue 8, pp 530-537, December 2010.
4. Micheal H., Wild, Markus Glees, et al: Archives of orthopedics and trauma surgery, volume 127 issue 5. Pp 335-343, July 2008.
5. Wild MH, Glees M, Plieschnegger C, et al.: five year follow up examination after purely minimally invasive posterior stabilization of

- thoracolumbar fractures; A comparison of minimally invasive percutaneous and conventionally open treated patients. *Arch orthopedic trauma surg*; 127: 335-43, 2007.
6. Oliver I Schmidt, Sergej Strasser, et al: Role of early minimally invasive spine fixation in acute thoracic and lumbar spine trauma, *IJO*, October-december;41-4, 2007.
 7. *Mixter WJ, Barr JS*: Rupture of the intervertebral disc with involvement of the spinal canal. *N Engl J Med* 5-1:210-214, 1934.
 8. *Caspar W*: A new surgical procedure for lumbar disc herniation causing less tissue damage through a microsurgical approach. *Adv Neurosurg* 4:74-81, 1977.
 9. *Ascher PW, Heppner F*: C0 in neurosurgery. *Neurosurg Rev* 7:123-133, 1984.
 10. *Choy OS*: *Percutaneous laser disc decompression (PLOD)*: Twelve years' experience with 752 procedures in 518 patients. *J Clin Laser Med Surg* 16:325—331, 1998.
 11. Timo Micheal H., Andreas B., Rainer M., et al: *European spine journal*, volume 22, issue 3, pp 495-502, march 2013.
 12. Alessandro G., Michele C., Simone C., et al: *European spine journal*, volume 22, pp 965-971, November 2013.
 13. Lior M., Raz N., Hamud C., et al: *orthopedics* volume 32, issue 4, April 2009.
 14. Sihvonen T, Herno A, Paljivarvi L, et al: Local denervation atrophy of paraspinal muscles in postoperative failed back syndrome. *Spine*; 18: 575-81, 1993.
 15. Gejo R, Matsui H, Kawaguchi Y, et al: Serial changes in trunk muscle performance after posterior lumbar surgery. *Spine*; 24 (10): 1023-8, 1999.
 16. Kawaguchi, Grobe D and Seemann D et al: stable dorsal function of lumbar spine, in Kehrp, Weidner., eds *cervical spine*. Austria: Springer-verlag, 9: 217-221, 2000.
 17. Rechtine GR, Bono PL, Cahill D, et al: Postoperative wound infection after instrumentation of thoracic and lumbar fractures. *J Orthop Trauma* 2001;15: 566-9, 2001.
 18. Kevin T. Foley, M. D., Sanjay K, et al: Percutaneous pedicle screw fixation of the lumbar spine, *Neurosurg. Focus / Volume 10 / April*, 2001.
 19. Rampersaud Y Fisher C, Wilsey J, Arnold PM: Regarding a New Algorithm for the Treatment of Thoracolumbar Injuries: A Multicenter Reliability Study. Submitted to *Journal of Spinal Disorders and Techniques*, 2006.
 20. Prafulla Kumar and Sahoo M Ch, *Percutaneous Pedicle Screw and Rod Insertion for Fracture of the Lumbar Spine*; 2005.
 21. Hong- Wei W., Chang-qing L., Yue Z., et al: *chinese journal of traumatology (English edition)* volume 13(3) pp, 137-145, june 2010.
 22. Hashimoto T., Kaneda K. and Abumi K: Relationship traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. *Spine* 13: 1268, 1988.

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