The Percutaneous Versus Open Pedicle Screw Fixation of Thoracolumbar Fracture AO Spine Type (A)

Islam Abdalla Mohamed Elsayed, Hossam Mohamed Khairy, Tarek ElHewala, Ahmed Mohamed Elshaer

Department of Orthopedic Surgery Department, Faculty of Medicine, Zagazig University, Egypt.

Email: eslammansi222@gmail.com

Article History: Received 10th June, Accepted 5th July, published online 10th July 2023

Abstract

Our study protocol was registered to institutional review board (IRB) in Zagazig University and approved at April 2023. we searched for eligible studies from 2002 to 2022 concerning the percutaneous pedicle screw fixation compared to traditional open pedicle screw fixation. systemic review was conducted to compare the percutaneous pedicle screw with traditional open pedicle screw in fixation of thoracolumbar fracture type A and meta-analysis was done according to the availability of randomized controlled trials using Review Manager software (RevMan version 5.4.1).

Keywords: Percutaneous, Open Pedicle Screw, Thoracolumbar Fracture

DOI: 10.53555/ecb/2023.12.Si12.276

Our study protocol was registered to institutional review board (IRB) in Zagazig University and approved at April 2023. we searched for eligible studies from 2002 to 2022 concerning the percutaneous pedicle screw fixation compared to traditional open pedicle screw fixation.

Study design: systemic review was conducted to compare the percutaneous pedicle screw with traditional open pedicle screw in fixation of thoracolumbar fracture type A and meta-analysis was done according to the availability of randomized controlled trials using Review Manager software (RevMan version 5.4.1).

Search strategy for identification of eligible studies:

A computerized research was performed in PubMed, Scopus databases, Web of science, Cochrane Library and Embase to identify the relevant literature published until December 2022.

The following terms were used for literature search:

- (spine fracture),
- (spinal fracture),
- (thoracolumbar fracture),
- (thoracolumbar fracture type A),
- (spine fixation),
- (spinal fixation),
- (fracture fixation),

- (pedicle Screw),
- (open pedicle screw fixation),
- (percutaneous pedicle screw fixation).

Criteria for considering studies for this review:

-Table (1): Inclusion and exclusion criteria:

	Inclusion criteria	**Exclusion criteria**
Patient	-Thoracolumbar fractures type A.	-Thoracolumbar fractures type B,C. -Cervical fractures.
	-Studies with spine traumatic fractures.	-Pathological fractures.
	-Studies without neurological deficits.	-Studies with neurological deficits.
Intervention	-Fixation surgery strategy for the treatment (open versus percutaneous).	-Conservative methods of the treatment.
	-Minimal follow up 1 year postoperatively.	-Follow up of less than 1 year post operatively.
Study design	-Prospective studies.	-Retrospective studies.
	-Randomized controlled trial studies.	-Case reports.
		-Review articles.

The functional results were evaluated according to:

Intra operative results such as: the operation length, incision size and blood loss.

Radiological evaluation such as:

- Kyphosis ⁄Cobb angle: (defined as the angle formed between a line drawn parallel to the superior endplate of 1 vertebra above the fracture and a line drawn parallel to the inferior endplate of the vertebra 1 level below the fracture **(1).**

Fig. (1): Illustration of Cobb angle. **(1).**

Anterior vertebral height ratio: (defined as the anterior body height of the fractured vertebra divided by the height of the adjacent intact vertebral body, can be calculated by the following formula = {2b / (a + c) × 100 (%)} where "a" is the height of normal superior vertebra, "b" is the height of the fractured vertebral body and "c" is the height of normal inferior vertebra **(2).**

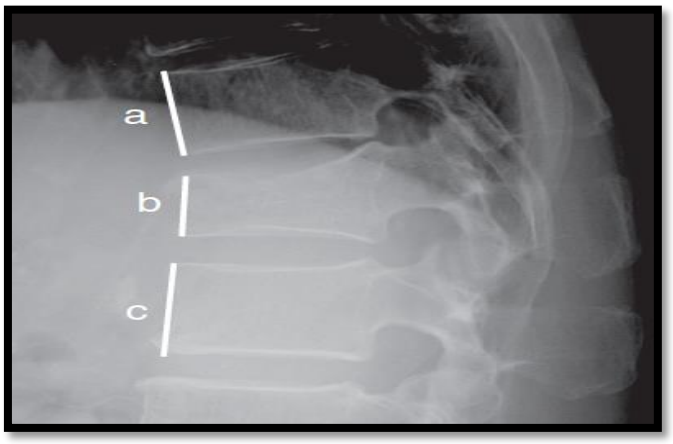


Fig. (2): Illustration of Anterior vertebral body height. **(2).**

- Functional outcome such as:

  - Visual analogue scale: (defined as a pain rating scale, the simplest VAS is a straight horizontal line of fixed length, usually 100 mm. The patient marks on the line the point that they feel represents their perception of their current state. The VAS score is determined by measuring in millimeters from the left-hand end of the line to the point that the patient marks **(3).**

-No pain (0–4 mm) -Mild pain (5-44 mm)
-Moderate pain (45–74 mm) -Severe pain (75–100 mm)

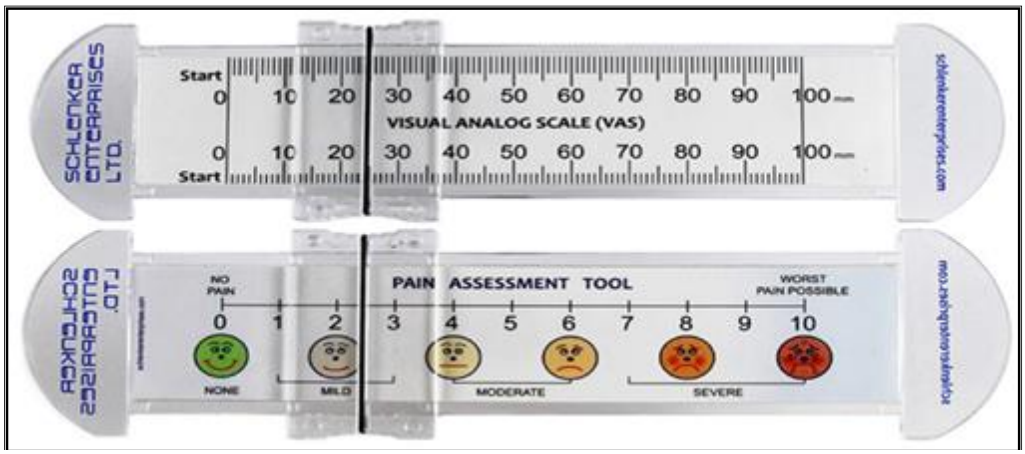


Fig. (3): Ruler method to access pain visual analogue scale and face pain rating scale. **(3).**

Data extraction:

A standardized data form was used to extract all data we evaluated. The information was collected from each study includes the first authorship, the publication year, the type of study, sample size,

the follow-up time, the characteristics of demographics, intraoperative complications, postoperative complications and results of patients.

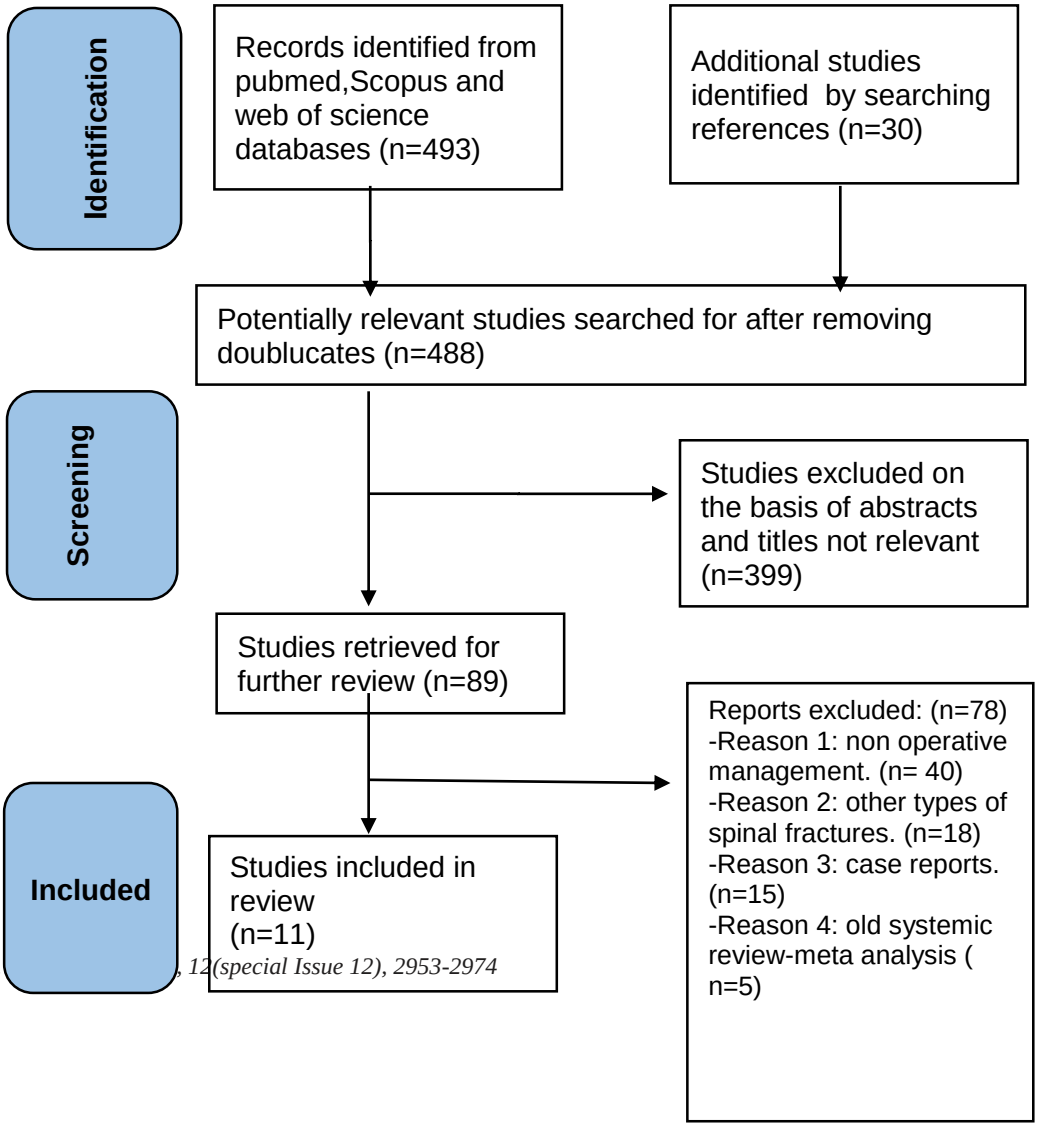
Statistical Analysis:
Analysis of data was done using Review Manager software (RevMan version 5.4.1).

Statistical package:
Data was collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 26. The quantitative data was presented as mean, standard deviations and ranges. Also qualitative variables was presented as number and percentages in case of systemic review.

Results

- **Literature search**:

The search strategy yielded 523 relevant articles, 35 articles were excluded after removing doublucates. 488 articles were retrieved, 399 of these articles were excluded on the basis of not relevant abstracts and titles. 89 articles were retrieved for further review, 78 of these articles were excluded according to inclusion and exclusion criteria. Process is shown in detail flow chart. At the end, a total of 11 studies met the inclusion criteria. All the included studies were comparing the percutaneous pedicle screw fixation with the open method in management of thoracolumbar fracture AO spine type (A).



Quality Assessment of the Included Studies:

All the included studies were clinical trial and prospective studies, which compare the percutaneous pedicle screw fixation with the open method in management of thoracolumbar fracture AO spine type (A).

Quality assessment of our included studies is done to exclude any risk of bias in results or conclusions in order to prevent of any underestimation or overestimation of the actual intervention effect.

Table (2): Quality Assessment of the Included Studies:

Study	Selection				Comparability	Outcome			Results
	Is the Case Definition Adequate?	Selection of Controls	Representativeness of the Cases	Definition of Controls	Comparability of Cases and Controls on the Basis of the Design or Analysis	Assessment of Outcome	Was follow-up long enough for outcomes to occur ?	Adequacy of follow-up of cohorts	Good\ Fair\ Poor
Vanek et al., 2014	*	*	*		*	*	*	*	(7*) Good
SHAIKH et al., 2021	*	*	*	*	*	*	*	*	(8*) Good
PISHNAMAZ et al., 2015	*	*	*	*		*	*	*	(7*) Good
Hong- wei et al., 2010	*	*	*			*	*	*	(6*) Fair
Patil et al., 2016	*	*	*	*		*	*	*	(7*) Good
Chao Lee et al., 2019	*	*	*			*	*	*	(6*) Fair
Tu et al., 2021	*	*	*			*	*	*	(6*) Fair
Kocis et al., 2020	*	*	*	*	*	*	*	*	(8*) Good
Lyu et al., 2016	*	*	*			*	*	*	(6*) Fair
Yang et al., 2018	*	*	*	*	*	*	*	*	(8*) Good
Lee et al., 2013	*	*	*	*	*	*	*	*	(8*) Good

Table (3): The extracted patient characteristics from the included studies:

Study	Fracture Type	Study type	Total No.	percutaneous group			open group			Duration of follow up (mon)
				Sex (M:F)	Age	Total	Sex (M:F)	Age	Total	
Vanek et al., 2014	Thoracolumbar fracture (A3.1–A3.3).	Prospective cohort	37		39.4 ± 16.9	18		45.6 ± 15.3	19	16
SHAIKH et al., 2021	Denis's two column vertebral column injury.	Prospective cohort	59	19:13	45.60 ± 15.71	32	20:07	48.21 ± 12.33	27	30
PISHNAMAZ et al., 2015	Thoracolumbar spine (T11 to L2) AO (Magerl) Classification.	Prospective cohort	72	13:16	53.1	29	22:21	50.4	43	24
Hong-wei et al., 2010	Type A thoracolumbar fractures AO type A.	Prospective cohort	38	13:04	41.6	17	18:03	45	21	24
Patil et al., 2016	Single level acute thoracolumbar and lumbar burst fracture (TLBF).	Prospective cohort	50	18:07	30.96 ± 5.2	25	20:05	29.76 ± 8.94	25	24
Chao Lee et al., 2019	Thoracolumbar and lumbar fractures.	Prospective cohort	32	07:06	42 ± 15	13	12:07	37±16	19	36
Tu et al., 2021	Thoracolumbar vertebral fracture by diagnosis and imaging, and classified as A1, A2, and B2 according to the AO classification of spinal fractures.	Prospective cohort	50	13:12	45.10 ± 6.40	25	15:10	42.60± 4.20	25	12
Kocis et al., 2020	Type A3 and A4 thoracolumbar fractures.	Prospective cohort	46	12:11	49.9	23	10:13	52.2	23	12
Lyu et al., 2016	Type A thoracolumbar fractures.	Prospective cohort	60	15:15	45.8 ± 7.8	30	12:18	43.7 ± 8.8	30	40
Yang et al., 2018	Thoracolumbar fractures received surgical treatment.	Prospective cohort	60	14:16	39.90 ± 9.89	30	17:13	41.45 ± 10.01	30	24
Lee et al., 2013	Short-segment posterior transpedicular screw fixation system for treatment of thoracolumbar burst fractures.	Prospective cohort	59	20:12	45.6 ± 15.7	32	19:08	48.2 ± 12.3	27	30

Summary of the Included Studies

1- Vanek et al., (4)

"Treatment of thoracolumbar trauma by short-segment percutaneous transpedicular screw instrumentation: prospective comparative study with a minimum 2-year follow-up."

Publication

Journal of Neurosurgery: Spine.

Study Design

A prospective cohort study.

Patients and Methods

Thirty-seven consecutive patients were enrolled in the study over a period of 16 months. Patients were included in the study if they experienced 1 thoracolumbar fracture (A3.1–A3.3, according to the AO/Magerl classification), had an absence of neurological deficits, had no other significant injuries, and were willing to participate. Eighteen patients were treated by short-segment, minimally invasive, percutaneous pedicle screw instrumentation. The control group was composed of 19 patients who were stabilized using a short-segment transpedicular construct, which was performed through a standard midline incision. The pain profile was assessed by a visual analog scale (VAS), and overall satisfaction by a simple 4-stage scale relating to performance of daily activities. Working ability and return to original occupation were also monitored. Radiographic follow-up was defined by the vertebral body index, vertebral body angle, and bisegmental Cobb angle. The accuracy of screw placement was examined using CT.

Results

The mean surgical duration in the percutaneous screw group was 53 ± 10 minutes, compared with 60 ± 9 minutes in the control group ($p = 0.032$). The percutaneous screw group had a significantly lower perioperative blood loss of 56 ± 17 ml, compared with 331 ± 149 ml in the control group ($p < 0.001$). Scores on the VAS in patients in the percutaneous screw group during the first 7 postoperative days were significantly lower than those in the control group ($p < 0.001$). There was no significant difference between groups in VBI, VBA, and Cobb angle values during follow-up. There was no significant difference in screw placement accuracy between the groups and no patients required surgical revision. There was no significant difference between groups in overall satisfaction at the 2 year follow-up ($p = 0.402$). Working ability was insignificantly better in the percutaneous screw group; previous working position was achieved in 17 patients in this group and in 12 cases in the control group ($p = 0.088$).

Conclusion

This study confirms that the percutaneous transpedicular screw technique represents a viable option in the treatment of preselected thoracolumbar fractures. A significant reduction in blood loss, postoperative pain, and surgical time were the main advantages associated with this minimally invasive technique. Clinical, functional, and radiological results were at least the same as those achieved using the open technique after a 2-year follow-up. The short-term benefits of the percutaneous transpedicular screw technique are apparent, and long-term results have to be studied in other well-designed studies evaluating the theoretical benefit of the percutaneous technique and assessing whether the results of the latter are as durable as the ones achieved by open surgery.

2- Shaikh et al., (5)

"Short Segment Pedicle Screw Fixation for Thoracolumbar Burst Fractures. Percutaneous without Fusion Versus Open Pedicle Screw Fixation with Posterolateral Fusion."

Publication

Pakistan Journal of Medical and Health Sciences.

Study Design

A prospective cohort study.

Patients and Methods

Between December 2019 and October 2021, fifty nine patients underwent short-segment pedicle screw fixation, 32 percutaneous pedicle screw fixation while 27 open. Each of the three follow-up examinations included radiographs to ensure that the spinal column had recovered to its pre-injury state. A lateral thoracolumbar radiograph was used to calculate the Cobb angle, vertebral wedge angle, and vertebral body compression ratio. In this study, patients' pain and function were assessed using the VAS, the Frankel grading system, and the Low Back Outcome Score (LBOS). Additionally, the volume of blood loss and the time required to finish the procedure were also noted.

Results

Regional Cobb angle improved post operatively in both groups without any disparity when assessed the two groups, which was noticed till three months. Operative time and blood loss was less in the percutaneous group. LBOS and VAS markedly improved during early follow ups in the percutaneous group compare to the open group. Concluding follow up did not show significant difference between the two groups.

Conclusion

Open or percutaneous short-segment pedicle fixation with or without fusion is secure and efficient treatment option for thoracolumbar burst fractures. The percutaneous group alone resulted in a greater reduction in pain and improvement in functional ability than the open group during initial time period which substantially improve overall outcome in management of thoracolumbar Burst fractures.

3- Pishnamaz et al., (6)

"Open versus Percutaneous Stabilization of Thoracolumbar Spine Fractures: A Short-Term Functional and Radiological Follow-up."

Publication

Acta chirurgiae orthopaedicae et traumatologiae Čechoslovaca journal.

Study Design

A prospective cohort study.

Patients and Methods

This study was performed between 2010 and 2012 at a Level 1 trauma center. Patients treated either with an open or a percutaneous dorsal instrumentation for traumatic fractures of the thoracolumbar spine (T11 to L2) were included. Fracture morphology, screw positioning and clinical parameters were analyzed. Standardized questionnaires (VAS-spine-score; Oswestry-disability-score; SF-36) and follow up radiographs were performed.

Results

Overall 72 patients (29 percutaneous; 43 open) could be included. The surgical and the early postsurgical course were similar between both groups. Furthermore the operative approach had no influence on the functional and radiological outcome one year after surgery, but the questionnaires showed moderate impairments within both groups. Also both groups showed a significant loss of reduction after the first postoperative month ($p < 0.01$). Within the open group a significantly higher amount of fracture reduction ($p < 0.01$) and a significantly reduced intraoperative radiation exposure was seen (open 105.9 sec.; percutaneous 143.1 sec; $p < 0.05$); whereas the percutaneous approach was associated with significantly reduced intraoperative blood loss (open 2.2 g/dl; percutaneous 1.2 g/dl; $p < 0.001$).

Conclusion

The functional and the radiological outcome of both groups was comparable one year after trauma. Minor advantages of the percutaneous system was less blood loss, whereas the open approach was associated with a significantly higher amount of initial reduction and significantly less intraoperative radiation exposure.

Independent from the type of posterior fixation loss of reduction was already significant in the early postoperative course.

4- Hong-wei et al., (7)

"Percutaneous pedicle screw fixation through the pedicle of fractured vertebra in the treatment of type A thoracolumbar fractures using Sextant system: an analysis of 38 cases."

Publication

Chinese Journal of Traumatology.

Study Design

A prospective cohort study.

Patients and Methods

A total of 38 consecutive non-randomized patients with type A thoracolumbar fractures, which had been stabilized posteriorly from December 2006 to March 2009,were examined retrospectively more than 9 months after surgery. Twenty-one patients had been treated conventionally with open pedicle screw fixation (OPSF) and 17 patients received minimally invasive treatment with Sextant percutaneous pedicle screw fixation (SPPSF). As a method of evaluation, the incision size, the intraoperative and postoperative volume of blood loss, operation time, postoperative hospital stay, blood transfusion, the radiological assessment of the sagittal Cobb's angle, vertebral body angle and vertebral body height were recorded and compared.

Results

All patients were followed up for 8-24 months (average 11.6 months). There were significant differences in the incision size, surgical blood loss, surgical draining loss, operation time, hospital stay after operation, blood transfusion, the proportion of antalgic supplement and postoperative incisional VAS between the two groups ($P<0.05$). Mean preoperative kyphotic deformity was 16.0°and improved by 9.3° after surgery in OPSF group, but 15.2° and 10.3° respectively in SPPSF group. Mean preoperative angle of the fractured vertebral body was 15.9°and improved by 7.9° after surgery in OPSF group, but 14.9° and 6.6° respectively in SPPSF group. Mean anterior vertebral body height (% of normal) was 67.3% before surgery and 95.8% after surgery, but 69.1% and 90.1% respectively in SPPSF group. Mean posterior vertebral body height (% of normal) was 93.3% before surgery and 99.5% after surgery, but 88.9% and 93.3% respectively in SPPSF group. Among the patients whose 9-month follow-up films were available, 3.0° of kyphosis correction was lost in OPSF group, but 3.2°in SPPSF group. And 1.0° of the angle of the fractured vertebral body correction was lost in OPSF group, but 1.5° in SPPSF group. Then 3.0% of the anterior vertebral body height correction was lost in OPSF group, but 2.2% in SPPSF group. And 3.0% of the posterior vertebral body height correction was lost in OPSF group, but 2.5% in SPPSF group. The sagittal Cobb's angle, vertebral body angle and anterior height of the fractured vertebra were all significantly different in each group before and after operation ($P<0.05$).There were no significant differences in the postoperative sagittal Cobb's angle, vertebral body angle and the improvement of the vertebral body height and the kyphotic deformity correction between OPSF and SPPSF groups ($P>0.05$),but there was significant difference in the postoperative anterior height of the fractured vertebra between the two groups ($P<0.05$).

Conclusion

The percutaneous pedicle screw fixation through the pedicle of fractured vertebra using Sextant system is a good minimally-invasive surgical therapeutic choice for patients with type A thoracolumbar fracture except for that the SPPSF has a little insufficiency in resuming the anterior height of the fractured vertebra compared with OPSF.

5- Patil et al., (8)

"Comparative study between short segment open versus percutaneous pedicle screw fixation with indirect decompression in management of acute burst fracture of thoracolumbar and lumbar spine in adults."

Publication

Journal of Spine.

Study Design

A prospective cohort study.

Patients and Methods

The present prospective study was conducted at a tertiary care center in south Rajasthan (India) over a period of two years from October 2013 to October 2015. Adult (age 18-50 years) trauma patients, with acute single level burst fracture of thoraco-lumbar and lumbar spine. Patients with history of trauma more than 72 hours, multilevel spinal injury, fracture other than burst fracture, multi-organ trauma, vitally unstable patients and those not willing to participate were excluded from study. Indication for surgery included loss of ≥50% vertebral body height, angulation ≥300, kyphotic deformity ≥200, canal compromise ≥40%, intact pedicle and failure of at least 2 columns. All patients pre-operatively underwent complete clinico-radiological [X-ray, NCCT spine, MRI spine] examination. Patients were randomly subjected to OPSFD or PPSFD surgery. Titanium mono-axial pedicle screw-rod assembly was used. Decompression of the canal was achieved by distraction of the fracture vertebra. Post-operatively patients were advice brace, subjected for regular physiotherapy and followed up to 1 year. Data regarding intra-operative blood loss and duration of surgery, complications, neurological and radiological (restoration of anterior and posterior vertebral body height, change in sagittal Cobb′s angle and fracture body angle) improvement in comparison to pre-operative status at the time of last follow-up was collected and analyzed.

Results

Fifty patients (38 male, 12 female), age range 18-50 years (mean 30.36 ± 9.15 years) with TLICS score of >4 (5.2 ± 0.6) underwent posterior spinal instrumentation. Fall from height was the most common mode of injury in 34 (68%) patients followed by road traffic accidents in 10 (20%) patients. Seventy percent of patients sustain injury at level of thoraco-lumbar junction (T12-L1 level), and most common vertebra involved was L1. Statistical analysis of data showed no significant difference in the sagittal cobb′s angle, fracture vertebral body angle, anterior and posterior vertebral body height on pre-operative, immediate post-operative and final follow up of 1 year between the two surgical techniques. However, a statistically significant difference was observed between the two surgical techniques in corrected sagittal cobb′s angle (P-value=0.008). There is a significant difference in average surgical time, average surgical blood loss between two surgical groups (P=value < 0.001). There is also a significant difference in time spent in hospital and return to work between the two surgical groups, with favourable results for PPSF (P-value < 0.001). Complication like implant failure, superficial infection, and bed sore were common in OPSFL group (1, 4 and 3 patients respectively) then PPSF group (1, 1 and zero patients respectively).

Conclusion

Short segment PPSFD is fast, safe and effective method of treating acute single level TLBF.

6- Chao Lee et al., (9)

"Minimally invasive stabilization for thoracolumbar and lumbar fractures: a comparative study with short segment open screw constructs."

Publication

Journal of Spine Surgery.

Study Design

A prospective cohort study.

Patients and Methods

There were 13 patients in the percutaneous group and 19 in the open group. Primary outcomes were the correction of fracture angulation and percentage loss of reduction until fracture union. Patient demographics, fracture classification, perioperative data and complications were also collected.

Results

There was no significant difference in cohorts when comparing demographics and fracture classification. Operative time was 50 minutes less and haemoglobin drop was 9 g/L less in the percutaneous group. Radiation exposure was significantly higher in the percutaneous group. Pre-operatively, the mean kyphotic angle was 22° in the percutaneous and 16° in the open group. Both groups achieved similar on-table correction. On

immediate postoperative erect radiographs, the percutaneous group lost 15% of correction *vs*. 55% in the open group. At final follow-up, both groups had a further loss of position, but significantly higher in the open group (28% *vs*. 96%).

Conclusion

Combined polyaxial-monoaxial screw percutaneous constructs demonstrate favorable radiological and clinical outcomes for treatment of unstable thoracolumbar and lumbar fractures. Our study also demonstrates higher rates of radiological collapse in the open cohort.

7- Tu et al., (10)

"Effect of percutaneous minimally invasive pedicle screw internal fixation in the treatment of thoracolumbar vertebral fractures and its impact on quality of life."

Publication

Pakistan Journal of Medical Sciences.

Study Design

A prospective cohort study.

Patients and Methods

Fifty patients with thoracolumbar vertebral fracture admitted to our hospital from January 2015 to December 2018 were selected and divided into two groups according to different treatment regimens. The observation group was treated with minimally invasive percutaneous pedicle screw internal fixation, while the control group was treated with traditional posterior approach open pedicle screw internal fixation. The surgery time, incision length, intraoperative blood loss, postoperative drainage, hospitalization time, ambulation time, fracture healing time and postoperative VAS scores were compared between the two groups. In addition, the cobb angle, the sagittal plane index, and the anterior vertebral height were compared between the two groups before and after surgery, as were the Oswestry Disability Index (ODI) at 1d, 3 months, and 6 months postoperatively.

Results

The surgery time, incision length, postoperative pain level, postoperative drainage and intraoperative blood loss of the observation group were less than those of the control group ($P<0.05$). The postoperative Cobb angle of the two groups decreased, the sagittal plane index as well as the anterior vertebral height increased ($P<0.05$). The Oswestry index of the observation group was better than that of the control group at one day and three months postoperatively, with a statistical significance between the two groups ($P<0.05$). The complication rate of the observation group was significantly lower than that of the control group ($P<0.05$).

Conclusion

Percutaneous minimally invasive pedicle screw internal fixation is safer than the traditional open pedicle screw internal fixation, and it is more worthy of clinical promotion.

8- Kocis et al., (11)

"Percutaneous versus open pedicle screw fixation for treatment of type A thoracolumbar fractures."

Publication

European Journal of Trauma and Emergency Surgery.

Study Design

A prospective cohort study.

Patients and Methods

A prospective analysis was made to evaluate consecutive 46 patients with type A3 and A4 thoracolumbar fractures. Patients were divided into a percutaneous pedicle screw fixation group (PPSF) and an open pedicle screw fixation group (OPSF). The mean age of patients in PPSF group (12 men, 11 woman) was 49.9 years and in OPSF group (10 men, 13 women) 52.2 years. For the purpose of evaluation, the radiological assessment of the bisegmental Cobb angle, the loss of correction, the volume of blood loss, operation time, cumulative radiation time and dose were recorded and compared.

Results

All patients were followed up for 12 months. There were no significant differences between OPSF and PPSF in the Cobb angle preoperative and postoperative angle and the loss of bisegmental correction. In PPSF group, the mean preoperative Cobb angle was 10.9° and improved by 4.5° postoperatively, and in OPSF group the preoperative angle was 12.1° and postoperatively improved by 3.8°. Significant differences between OPSF and PPSF were found in the mean cumulative radiation time, radiation dose and operation time. PPSF group also had a significantly lower perioperative blood loss.

Conclusion

Both open and percutaneous short-segment pedicle fixation were safe and effective methods to treat thoracolumbar burst fractures. Percutaneous fixation without fusion seems to be suitable for type A3 and A4 fractures.

9- Lyu et al., (12)

"A comparison of three different surgical procedures in the treatment of type A thoracolumbar fractures: a randomized controlled trial."

Publication

International Orthopaedics journal.

Study Design

A prospective cohort study.

Patients and Methods

Between September 2012 and January 2015, a total of 90 patients with type A thoracolumbar fractures were randomly assigned into three groups of 30 each. Patients in group A, B, and C were treated with three level percutaneous fixation, two-level percutaneous fixation, and three-level open fixation, respectively. Blood loss, duration of surgery, VAS scores, Cobb angles, and anterior height ratios of fractured vertebrae were collected for statistical analysis.

Results

The average follow-up was 17.7 months. Postoperative Cobb angles were significantly corrected and anterior height ratios of fractured vertebrae were well restored in all three groups ($p < 0.01$). Back pain was efficiently relieved according to VAS score change ($p< 0.01$). There were significant differences in values of blood loss and post-operative VAS scores (at three months) between group A and group C ($p <0.01$). No significant difference concerning post-operative anterior height ratios of fractured vertebrae, Cobb angles and correction losses was observed between group A and group B ($p=0.580, 0.840, 0.215$, respectively).

Conclusion

Percutaneous fixation not only provides the same reduction effect as open fixation, but also has an advantage of causing less operation related trauma which is beneficial to post-operative rehabilitation. The efficacy of three-level percutaneous fixation and two-level percutaneous fixation in the treatment of type A thoracolumbar fractures is not significantly different.

10-Yang et al., (13)

"Comparison of clinical results between novel percutaneous pedicle screw and traditional open pedicle screw fixation for thoracolumbar fractures without neurological deficit."

Publication

International Orthopaedics journal.

Study Design

A prospective cohort study.

Patients and Methods

Sixty adult patients with single thoracolumbar fracture between June 2014 and June 2016 were recruited in this study, randomly divided into open fixation group (group A) or minimally invasive percutaneous fixation group (group B). Clinical and surgical evaluation including surgery time, blood losses, radiation times, hospital stay, and complication were performed. The two groups of patients with pre-operative and last

follow-up anterior height ratio of fracture vertebral, Cobb angle of fracture vertebral, and VAS score of back pain were compared.

Results

All patients completed valid follow-ups, with an average time period of 15.4 months (12–26 months). Group B achieved much better results in time of operation, intra-operative blood loss, and length of stay than group A ($P < 0.05$). Group A was significantly better than group B in the times of radiation ($P < 0.05$). The VAS score was significantly lower in group B than in group A at three days after the operation ($P < 0.05$). There were no significant differences between the two groups in the anterior height ratio of fracture vertebral, Cobb angle, and VAS score in the last follow-up ($P > 0.05$). No injured nerve or other severe complications occurred in both groups; one of the patients from group A had back and loin pain lasting for about one month, which resolved after analgesia and functional training. There was no significant difference between the two groups in incidence of complications.

Conclusion

Novel percutaneous pedicle screws with angle reset function can achieve the same effect as traditional open pedicle screw fixation in the treatment of thoracolumbar fractures without nerve injuries. Percutaneous minimally invasive pedicle screw fixation has the characteristics of shorter operative time, less bleeding, and less pain, but it needs more radiation times.

11- Lee et al., (14)

"Percutaneous short-segment pedicle screw placement without fusion in the treatment of thoracolumbar burst fractures: is it effective?: comparative study with open short-segment pedicle screw fixation with posterolateral fusion."

Publication

Acta Neurochirurgica journal.

Study Design

A prospective cohort study.

Patients and Methods

This study included 59 patients, who underwent either percutaneous (n =32) or open (n =27) short-segment pedicle screw fixation for stabilization of thoracolumbar burst fractures between December 2003 and October 2009. Radiographs were obtained before surgery, immediately after surgery, and at the final follow-up for assessment of the restoration of the spinal column. For radiologic parameters, Cobb angle, vertebral wedge angle, and vertebral body compression ratio were assessed on a lateral thoracolumbar radiograph. For patient's pain and functional assessment, the visual analogue scale (VAS), the Frankel grading system, and Low Back Outcome Score (LBOS) were measured. Operation time, and the amount of intraoperative bleeding loss were also evaluated.

Results

In both groups, regional kyphosis (Cobb angle) showed significant improvement immediately after surgery, which was maintained until the last follow up, compared with preoperative regional kyphosis. Postoperative correction loss showed no significant difference between the two groups at the final follow-up. In the percutaneous surgery group, there were significant declines of intraoperative blood loss, and operation time compared with the open surgery group. Clinical results showed that the percutaneous surgery group had a lower VAS score and a better LBOS at three months and six months after surgery; however, the outcomes were similar in the last follow-up.

Conclusion

Both open and percutaneous short-segment pedicle fixation were safe and effective for treatment of thoracolumbar burst fractures. Although both groups showed favorable clinical and radiologic outcomes at the final follow-up, PPSF without bone graft provided earlier pain relief and functional improvement, compared with open TPSF with posterolateral bony fusion. Despite several shortcomings in this study, the result suggests that ongoing use of PPSF is recommended for the treatment of thoracolumbar burst fractures.

Meta-analysis results

Our meta-analysis results from the included studies include :

Operative data :

- ✓ Blood loss.
- ✓ Operative time.
- ✓ Incision length.
- ✓ Radiation exposure.

Radiological data :

- ✓ Kyphosis angle.
- ✓ Anterior vertebral height ratio.

Functional outcome :

- ✓ Visual analogue scale.

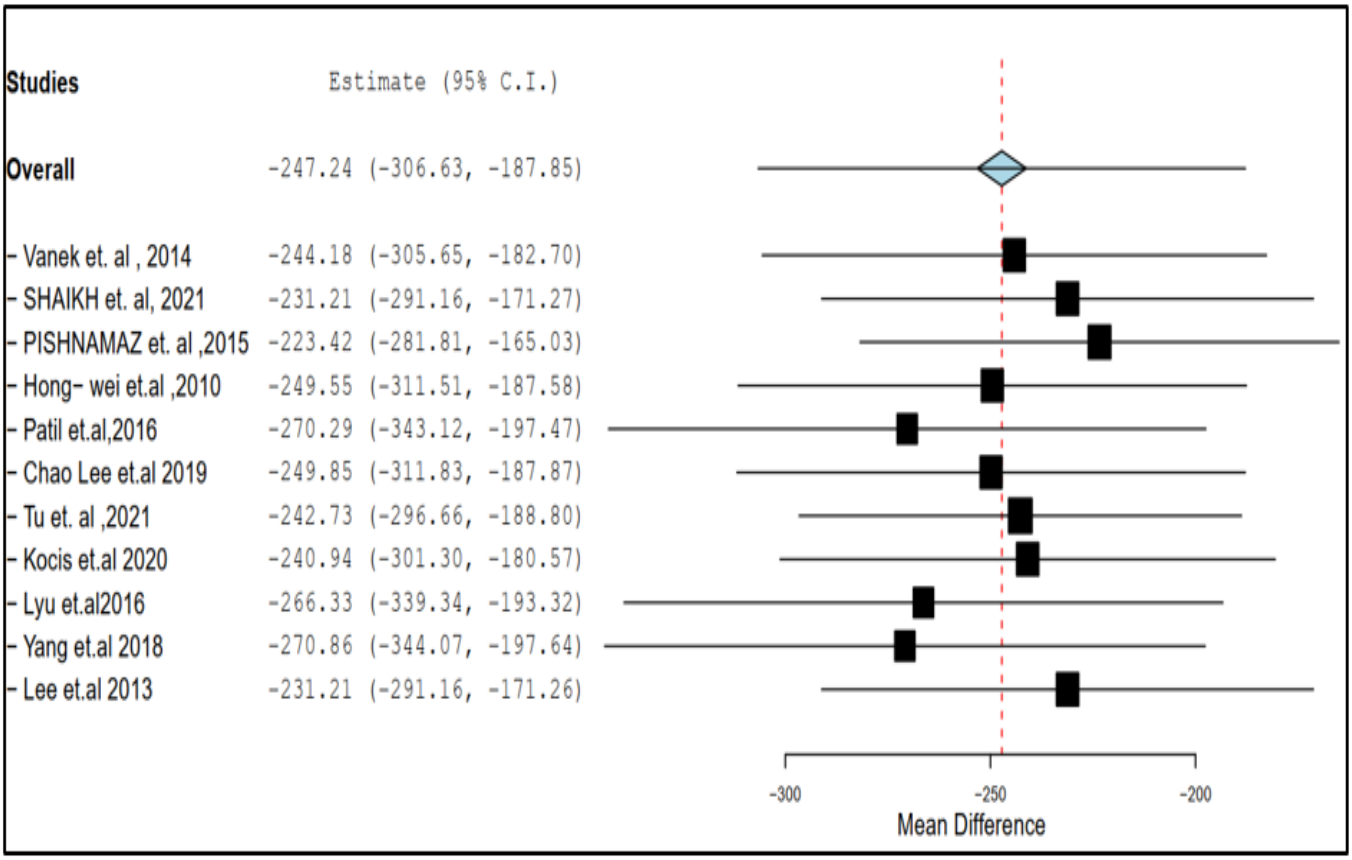
Table (4): The extracted meta-analysis results from the included studies:

Study	Year	percutaneous group							Open Group						
		Blood loss (ml)	Operative time (min)	Radiation exposure (sec.)	Incision length (cm)	Anterior Vertebral height ratio	Kyphosis angle	Visual analogue scale	Blood loss (ml)	Operative time (min)	Radiation exposure (sec.)	Incision length (cm)	Anterior Vertebral height ratio	Kyphosis angle	Visual analogue scale
Vanek et al., 2014	2014	56 ± 17	53 ± 10			67 ± 12	−14.4 ± 6.5		331 ± 149	60 ± 9			68 ± 12	−13.5 ± 5.5	
SHAIKH et al., 2021	2021	262.55± 86.91	83.22± 26.11				15.84± 8.26	2.90±1.52	684.33± 239.90	154.91± 39.20				16.74± 7.62	4.02± 1.33
PISHNAMAZ et al., 2015	2015	500±50	114.3	143.1				4.5±2.9	1000±300	110.1	105.9				4.9± 2.1
Hong-wei et al., 2010	2010	83.5± 51.8	97.1± 15.3		0.94± 0.09		15.2±0.9	1.5±0.9	304.8± 209.1	161.0± 72.5		1.18± 0.28		16±9.3	2.2± 0.8
Patil et al., 2016	2016	85 ± 20	69.76 ± 11.76		8.4 ± 1.321	62 ± 0.286	26.36 ± 4.29		150 ± 35	103.48 ± 12.25		13.96 ± 1.274	69 ± 0.311	29.08 ± 8.30	
Chao Lee et al., 2019	2019	82± 22	138± 38				22		300± 205	189± 43				16	
Tu et al., 2021	2021	18.2± 24.6	44.1± 8.6		1.7±0.6	62.5± 10.5	15.7±5.7	2.6± 0.4	268.3± 45.7	66.7± 17.4		12.6± 3.5		16.8± 6.0	3.1± 0.5
Kocis et al., 2020	2020	29	49.7	29			− 10.9		328.7	52	17.3			− 12.1	
Lyu et al., 2016	2016	100.7 ± 18.9	72.1 ± 12.5			65.1 ± 9.3	16.7 ± 5.5	2.2 ± 0.5	202.1 ± 42.0	77.8 ± 8.2					3.3 ± 0.5
Yang et al., 2018	2018	63.75 ± 13.46	51.55 ± 7.10	11.93 ± 2.49		67.20 ± 8.40	26.20 ± 6.19	0.95 ± 0.69	125.01 ± 19.87	96.60 ± 8.844	4.40 ± 1.50		62.35 ± 8.28	23.95 ± 7.14	1.25 ± 0.72
Lee et al., 2013	2013	262.5± 86.9 ml	83.2± 26.1				15.8± 8.2	2.9± 1.5	684.3± 239.9	154.9± 39.2				16.7± 7.6	4.0± 1.3

A) Operative data :

1- (Blood loss) :

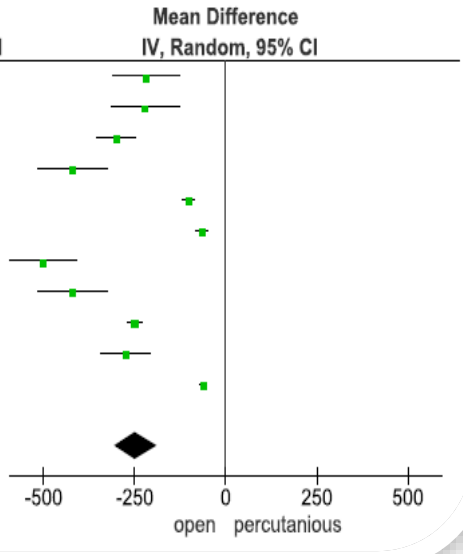
We included 11 studies that comparing blood loss between the percutaneous and open technique. There was high heterogeneity ***(Chi² = 559,61, df = 10(P < 0.00001); I² = 98%)***. The pooled data demonstrated a high significant statistical difference in blood loss ***(mean difference MD = -247,24,***



Study or Subgroup	percutanious Mean	SD	Total	open Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Chao Lee et.al 2019	82	22	13	300	205	19	8.2%	-218.00 [-310.95, -125.05]
Hong- wei et.al ,2010	83.5	51.8	17	304.8	209.1	21	8.2%	-221.30 [-314.06, -128.54]
Kocis et.al 2020	29	6.06	23	328.7	129.91	23	9.5%	-299.70 [-352.85, -246.55]
Lee et.al 2013	262.5	86.9	32	684.3	239.9	27	8.1%	-421.80 [-517.17, -326.43]
Lyu et.al2016	100.7	18.9	30	202.1	42	30	10.2%	-101.40 [-117.88, -84.92]
Patil et.al,2016	85	20	25	150	35	25	10.2%	-65.00 [-80.80, -49.20]
PISHNAMAZ et. al ,2015	500	50	29	1,000	300	43	8.2%	-500.00 [-591.50, -408.50]
SHAIKH et. al, 2021	262.55	86.91	32	684.33	239.9	27	8.1%	-421.78 [-517.15, -326.41]
Tu et. al ,2021	18.2	24.6	25	268.3	45.7	25	10.1%	-250.10 [-270.44, -229.76]
Vanek et. al , 2014	56	17	18	331	149	19	9.0%	-275.00 [-342.46, -207.54]
Yang et.al 2018	63.75	13.46	30	125.01	19.87	30	10.2%	-61.26 [-69.85, -52.67]
Total (95% CI)			**274**			**289**	**100.0%**	**-247.24 [-306.63, -187.85]**

Heterogeneity: Tau² = 8965.91; Chi² = 559.61, df = 10 (P < 0.00001); I² = 98%

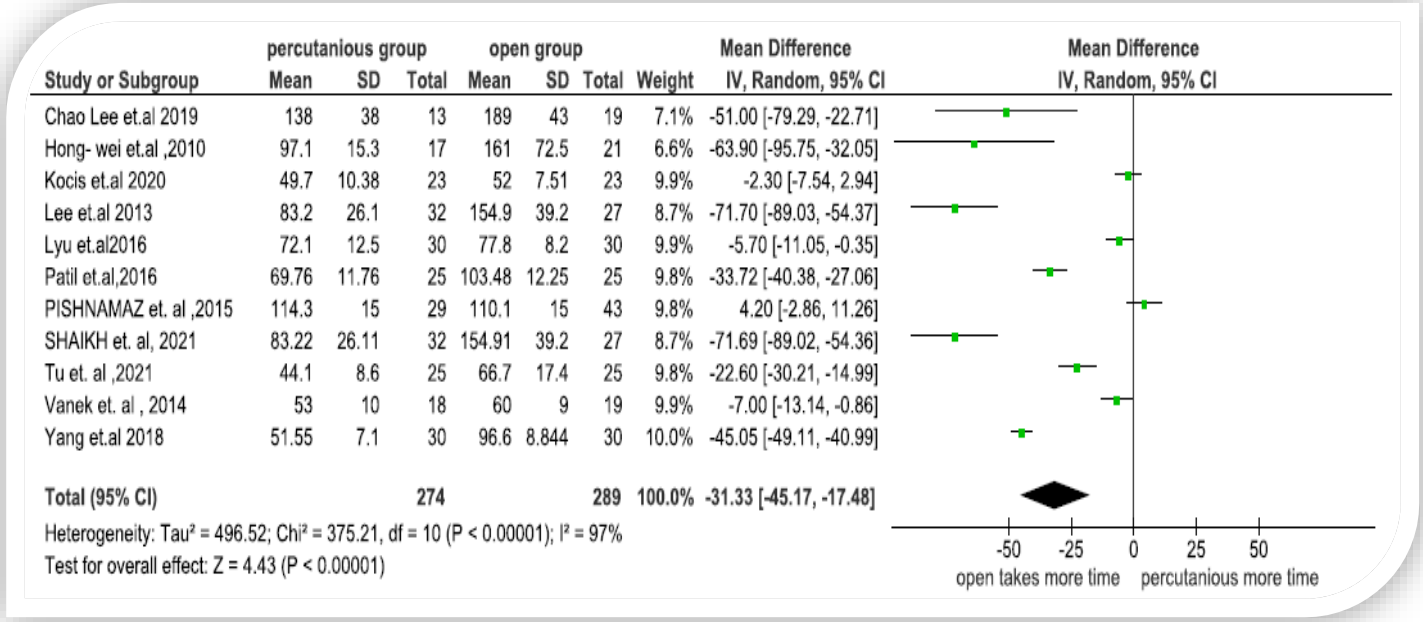
Test for overall effect: Z = 8.16 (P < 0.00001)



confidence interval CI = -306,63 to -187,85, P value <0.00001) that indicating percutaneous fixation had less blood loss than open fixation.

2- (Operative time) :

We included 11 studies that comparing operative time between the percutaneous and open technique. There was high heterogeneity ***(Chi² = 375,21, df = 10(P < 0.00001); I² = 97%)***. The pooled data demonstrated a high significant statistical difference in operative time ***(mean difference MD = -31,33, confidence interval CI = -45,17 to -17,48, P value <0.00001)*** that indicating percutaneous fixation had less operative time than open fixation.



Sensitivity analysis for blood loss was done by leave-one-out method to avoid the extreme results of a single paper from affecting the overall effect, but it was found that no bias affecting the overall effect.

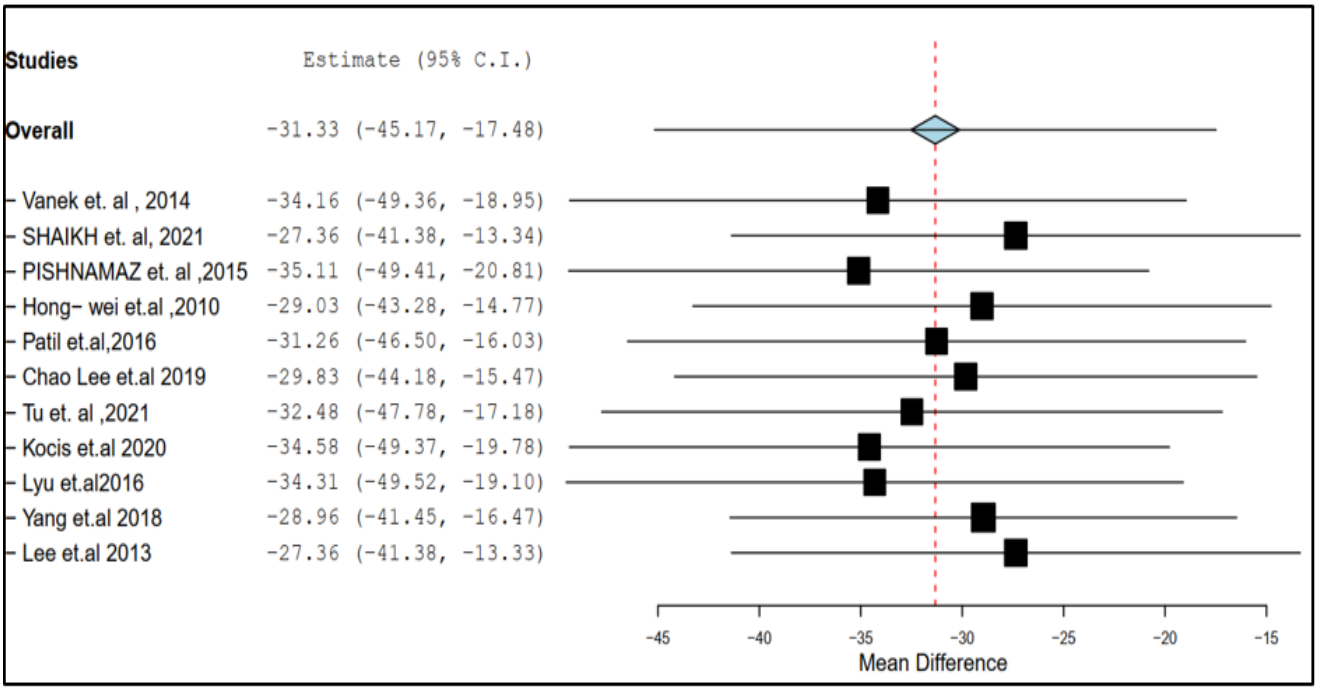


Fig. (4): The sensitivity analysis for operative time.

3- (Incision length) :

We included 3 studies that comparing incision length between the percutaneous and open technique. There was high heterogeneity ***(Chi² = 420,48, df = 2(P < 0.00001); I² = 100%)***. The pooled data demonstrated a high significant statistical difference in incision length ***(mean difference MD = -5,53, confidence interval CI = -10,98 to -0,08, P value = 0,05)*** that indicating percutaneous fixation had less incision length than open fixation.

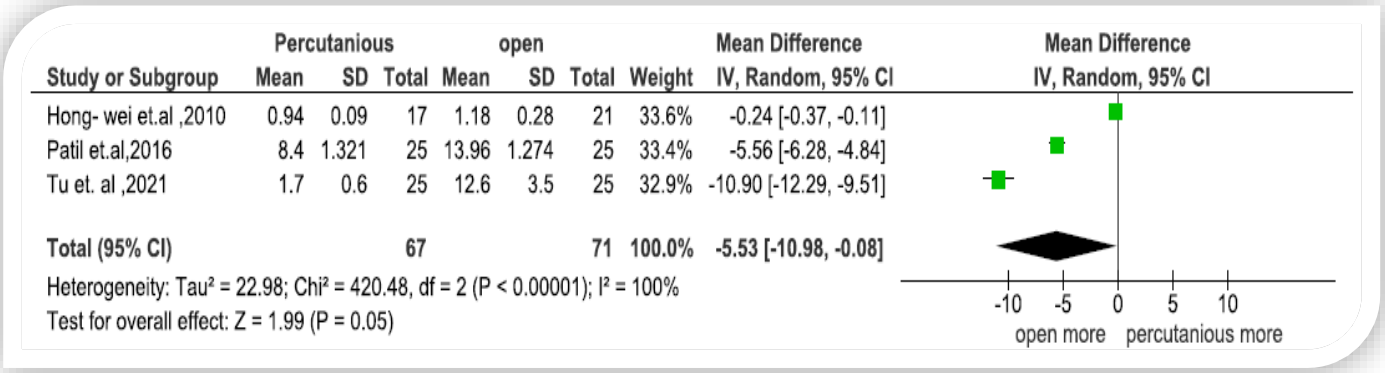


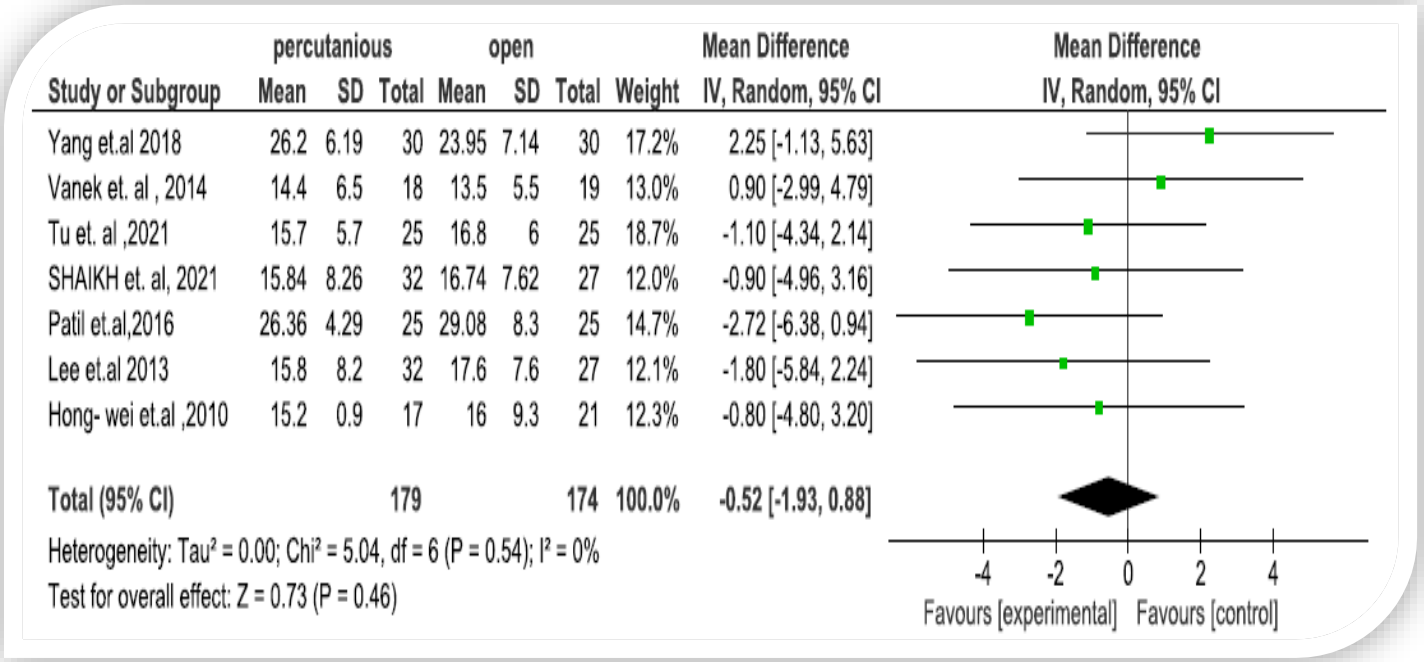
Fig. (5): The forest plot for incision length in cm.

B) Radiological data :

1- (Kyphosis angle) :

We included 7 studies that comparing kyphosis angle between the percutaneous and open technique. There was significant homogeneity ***(Chi² = 5,04, df = 6(P = 0,54); I² = 0%)***. The pooled data demonstrated insignificant statistical difference in kyphosis angle between the percutaneous and open technique. ***(mean difference MD = -0,52, confidence interval CI = -1,93 to 0,88, P value = 0,46)***.

C) Functional outcome :



- (Visual analogue scale) :

We included 7 studies that comparing visual analogue scale between the percutaneous and open technique. There was substantial heterogeneity ***(Chi² = 19,44, df = 6(P = 0.003); I² = 69%)***. The pooled data demonstrated a high significant statistical difference in visual analogue scale ***(mean difference MD = -0,74, confidence interval CI = -1,05 to -0,43, P value <0.00001)*** that indicating percutaneous fixation had good clinical results of VAS than open fixation.

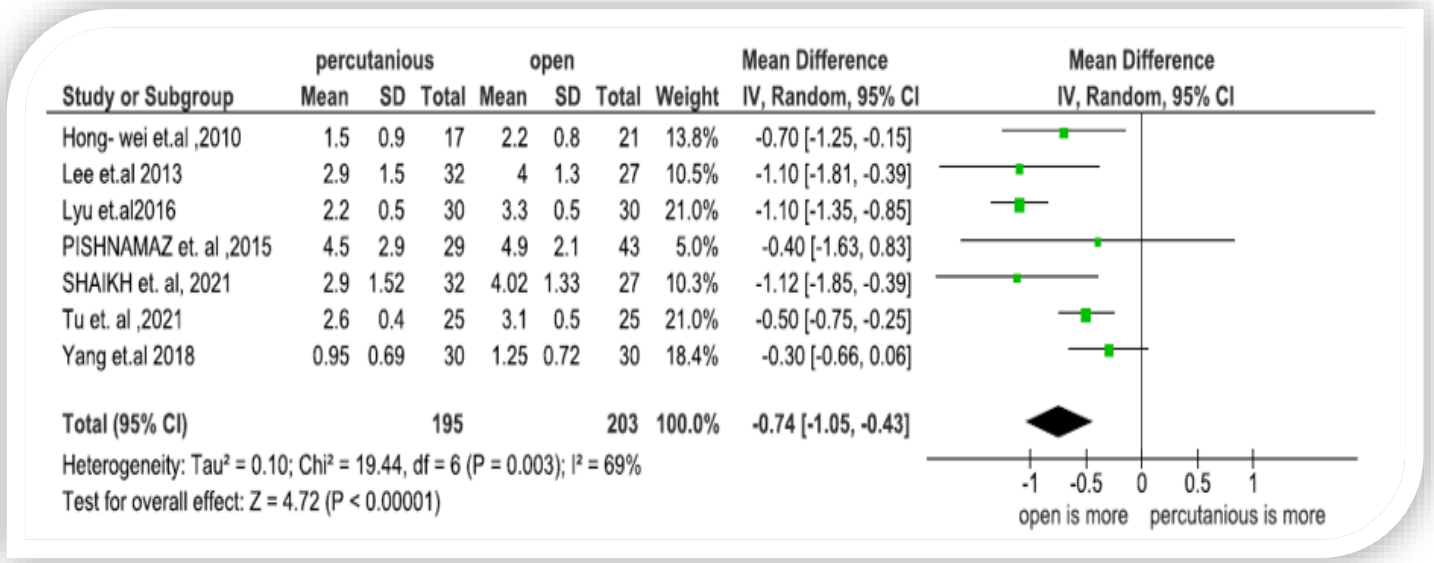


Fig. (6): The forest plot for visual analogue scale.

Spine fractures account for a large portion of musculoskeletal injuries worldwide. Approximately 75% to 90% of spinal fractures occur in the thoracic and lumbar spine, with most of these occurring at the thoracolumbar junction (T10-L2). **(15).**

Surgical treatment has demonstrated better clinical and radiological results than conservative treatment. It allows for immediate stabilization of the spine, restoration of sagittal alignment, and the possibility of spinal canal decompression. It entails both open and minimally invasive percutaneous procedures. **(16).**

Regardless of the technique, pedicle screw fixation has allowed for more stable constructs, earlier mobilization, and better deformity correction through the use of three column spinal fixation. **(17).**

Pedicle procedure for thoracolumbar fractures was first introduced by *Roy Camille* in 1963. Use of pedicle screws with conventional open surgery had been a recognized method for treatment of non-stable vertebral fractures. Magerl introduced pedicle screw procedure with percutaneous method in 1977. Percutaneous pedicle screw has been increasingly used within last two decades. **(18).**

The aim of this study is to emphasize the comparability of the percutaneous pedicle screw fixation to traditional open pedicle screw fixation and to clarify if the percutaneous pedicle screw fixation has better outcome than traditional open pedicle screw fixation in management of thoracolumbar fracture AO spine type (A).

This study utilized AO Spine classification of thoracolumbar (TL) fractures that is based on computed tomographic (CT) scan, an imaging tool widely available at most trauma centers in various countries. **(19).**

Our meta-analysis was performed after data extraction process. After application of inclusion and exclusion criteria, we reached to eligible prospective eleven studies included in our review from 2002 to 2022 to compare the percutaneous pedicle screw fixation with traditional open method. After analyzing the included studies we had pooled the available data to define the appropriate method of fixation.

A- Regarding Operative Data:

1) Blood loss:

By comparing the pooled data from the eligible 11 studies between the two groups with regard to blood loss during operation, the overall effect was found to be significant towards the open technique as it had more blood loss than percutaneous method where $p < 0.0001$ where it is statistically significant. But the pooled

data from these different studies showed high heterogeneity and this may be due to the different protocols and strategies used in management in these patients.

This could be explained by the small stabbing incisions, lack of extensive soft tissue dissection and the reduced need for drains postoperatively in the percutaneous technique. All these factors minimize the need for transfusions and decrease morbidity and economic burdens.

These results are in agreement with:

Wild et al., (20) reported statistically lower blood loss in trauma cases after internal fixation implanted percutaneously than when implanted during an open procedure.

Youssef et al., (21) conducted a study compared two groups of 40 injured patients treated with either percutaneous or open fixation. Total amount of perioperative blood loss was significantly lower in percutaneous fixation group than open fixation group (Mean ± SD: 43.90 ± 8.90 vs 384.45 ± 30.58 ml, $p<0.001$).

2) **Operative time:**

By comparing the pooled data from the eligible 11 studies between the two groups with regard to the time taken during operation, the overall effect was found to be significant towards the open technique as it had more time than percutaneous method where $p < 0.0001$ where it is statistically significant. But the pooled data from these different studies showed high heterogeneity and this may be due to the different protocols and strategies used in management in these patients.

This could be explained on basis of extensive muscle and periosteal dissection, retraction, more time for hemostasis and excess time expenditure to identify anatomical landmarks for proper screw entry point in the open technique. All these causes of long operative time are absent in the percutaneous technique. Fluoroscopy throughout the percutaneous approach also facilitates the identification of ideal landmarks for screw insertion.

These results are in agreement with:

Merom et al., (22) reported that with short-segment fixation, the operative time for percutaneous fixation (73 to 85 minutes) was slightly less than for open fixation (78 to 102 minutes).

Elsawaf et al., (23) conducted a prospective study of a total of hundred and sixty-six patients with unstable thoracolumbar fractures (72 patients for percutaneous fixation) and (94 patients for open fixation). The mean operative time was 115 minutes (range 60–220 minutes) for percutaneous group vs 189 minutes (range 110–310 minutes) for the open group.

3) **Incision length:**

Our analysis showed statistical insignificant data about incision length between both groups that reported only by 3 different studies.

B- Regarding Radiological Data:

1) Kyphosis angle:

By comparing the pooled data from eligible 7 studies, the percutaneous technique did not result in significant statistical differences in the correction of kyphotic deformity in comparison with the open technique where $p > 0.05$ where it is statistically insignificant and that both approaches achieve a good curative effect and there was significant homogeneity between these 7 studies.

These results agree with:

Elsawaf et al., (23) found that there was no significant difference in the correction of kyphotic deformity in both groups. In group I (percutaneous), Cobb angle was changed from a mean of 17.4°±7.1 preoperatively to a mean of 5°±8.6 postoperatively. In group II (open group), the Cobb angle showed also significant improvement from a mean of 20.8°±6.5 preoperatively to a mean of 3.1°±5.3 at the final follow-up visit postoperatively.

Youssef et al., (21) study compared two groups of 40 injured patients treated with either percutaneous or open fixation found that A significant decrease in angle of kyphosis had occurred in both groups ($p<0.001$).

2) **Anterior vertebral height ratio:**

Our analysis showed statistical insignificant data about anterior vertebral height between both groups that reported only by 3 different studies.

C- Regarding Functional outcome:

- **Visual analogue scale (VAS):**

By comparing the pooled data from eligible 7 studies between the two groups with regard to visual analogue scale, the overall effect was found to be significant towards the open technique as take much more visual analogue scale than percutaneous method where $p < 0.0001$ where it is statistically significant and there was substantial heterogeneity between these 7 studies.

We had better results in the clinical outcome of the pain with the percutaneous method than the open method and it is directly related to the small stabbing incisions, lack of cauterization and minimal soft tissue handling with absent iatrogenic injury to the muscles, ligaments, bone, and facet capsules. This decreases the need for analgesia postoperatively with better functional outcome.

These results are in agreement with:

Lee et al., (14) found that "Excellent" or "good" clinical results were obtained in 15 patients (88.2%). The average improvement of visual analogue scale was 5.2 points (from 9.3 to 4.1).

Elsawaf et al., (23) observed that in group I (Percutaneous group); Pain at the fracture site improved from a mean VAS of 7.8±3.7 preoperatively to a mean of 4.2±8.1 two weeks postoperatively. This was improved to a mean VAS of 1.9±5.4 at final follow-up.

Study Limitations:

It is known that meta-analyses require detailed and explained mechanisms for determining which studies to include or exclude. These eligibility criteria are explained by a combination of relevance and considerations of bias and are typically decided before the search for the studies. Although of this, our study did not provide sufficient data about the comparison aspects between the percutaneous and open approaches such as:

- ***Mechanism of trauma.***
- ***Associated injuries.***
- ***Other radiological measurements as (rate of screw malposition).***
- ***Hospital stay.***
- ***Postoperative complications as (risk of wound infection).***

The investigators must overcome these limitations in upcoming studies, this can be achieved by organizing well randomized controlled studies including large number of patients to get strong evidence of the benefits of both techniques, and develop treatment guidelines for thoracolumbar fracture AO spine type A.

Conclusion

Surgical treatment of thoracic and lumbar fractures allows for immediate stabilization of the spine, restoration of sagittal alignment.

Regardless of the technique, pedicle screw fixation has allowed for more stable constructs, earlier mobilization, and better deformity correction through the use of three column spinal fixation.

The percutaneous pedicle fixation technique presents clinical, radiological, and functional results that are significantly better than the conventional open pedicle screw fixation.

Percutaneous pedicle screw fixation, assisted by fluoroscopy, proved to be a technique with a high accuracy and reliability, with results comparable to those reported in studies with the classical open pedicle screw fixation regarding the deformity correction, but superior with regard to blood loss, postoperative rehabilitation, and return to the activities of daily living.

The results of this study show percutaneous fixation is a valid, safe, and effective treatment for thoracolumbar fractures.

References

1. Curfs, I., Grimm, B., van der Linde, M., Willems, P., & van Hemert, W. (2016): Radiological prediction of posttraumatic kyphosis after thoracolumbar fracture. The Open Orthopaedics Journal, 10, 135.
2. Qasem, K. M., Suzuki, A., Yamada, K., Hoshino, M., Tsujio, T., Takahashi, S., & Nakamura, H. (2014): Discriminating imaging findings of acute osteoporotic vertebral fracture: a prospective multicenter cohort study. Journal of Orthopaedic Surgery and Research, 9(1), 1-7.
3. Siebenga, J., Leferink, V. J. M., Segers, M. J. M., Elzinga, M. J., Bakker, F. C., Ten, D. H., ... & Patka, P. (2008): A prospective cohort study comparing the VAS spine score and Roland–Morris disability questionnaire in patients with a type A traumatic thoracolumbar spinal fracture. European spine journal, 17, 1096-1100.
4. Vanek, P., Bradac, O., Konopkova, R., de Lacy, P., Lacman, J., & Benes,V. (2014): Treatment of thoracolumbar trauma by short-segment percutaneous transpedicular screw instrumentation: prospective comparative study with a minimum 2-year follow-up: Clinical article. Journal of Neurosurgery: Spine, 20(2), 150-156.
5. Shaikh MA, Mehmood K, Shah I. (2021): Short Segment Pedicle Screw Fixation for Thoracolumbar Burst Fractures. Percutaneous without Fusion Versus Open Pedicle Screw Fixation with Posterolateral Fusion.
6. Pishnamaz M, Oikonomidis S, Knobe M, Horst K, Pape HC, Kobbe P. (2015) : Open versus percutaneous stabilization of thoracolumbar spine fractures: a short-term functional and radiological follow-up. Acta Chir Orthop Traumatol Cech. 2015 Jan 1;82(4):274-81.
7. Hong-wei, Wang, Li CQ, Zhou Y, Zhang ZF, Wang J, Chu TW. (2010): Percutaneous pedicle screw fixation through the pedicle of fractured vertebra in the treatment of type A thoracolumbar fractures using Sextant system: an analysis of 38 cases. Chinese Journal of Traumatology. 2010 Jun 1;13(03):137-45.
8. Patil RP, Joshi V, Pamecha C, Kumar P, Bisnoi UP. (2016): Comparative study between short segment open versus percutaneous pedicle screw fixation with indirect decompression in management of acute burst fracture of thoracolumbar and lumbar spine with minimal neurological deficit in adults. J Spine. 2016;5(339):2.
9. Chao, Lee Y, Selby M, Zotti M, Roy D, Freeman B. (2019): Minimally invasive stabilization for thoracolumbar and lumbar fractures: a comparative study with short segment open Schanz screw constructs. Journal of Spine Surgery. 2019 Mar;5(1):13.
10. Tu P, Yan CC, Hao JX, Cao S, Jiang C. (2022): Effect of percutaneous minimally invasive pedicle screw internal fixation in the treatment of thoracolumbar vertebral fractures and its impact on quality of life. Pakistan Journal of Medical Sciences. 2022 Jan;38(1):100.
11. Kocis J, Kelbl M, Kocis T, Návrat T. (2020): Percutaneous versus open pedicle screw fixation for treatment of type A thoracolumbar fractures. European Journal of Trauma and Emergency Surgery. 2020 Feb;46:147-52.
12. Lyu J, Chen K, Tang Z, Chen Y, Li M, Zhang Q. (2016): A comparison of three different surgical procedures in the treatment of type A thoracolumbar fractures: a randomized controlled trial. International orthopaedics. 2016 Jun;40:1233-8.
13. Yang M, Zhao Q, Hao D, Chang Z, Liu S, Yin X. (2018): Comparison of clinical results between novel percutaneous pedicle screw and traditional open pedicle screw fixation for thoracolumbar fractures without neurological deficit. International orthopaedics. 2019 Jul 4;43:1749-54.
14. Lee, J. K., Jang, J. W., Kim, T. W., Kim, T. S., Kim, S. H., & Moon, S. J. (2013): Percutaneous short-segment pedicle screw placement without fusion in the treatment of thoracolumbar burst fractures: is it effective? comparative study with open short-segment pedicle screw fixation with posterolateral fusion. Acta neurochirurgica, 155(12), 2305-2312.
15. Patel, A. A., & Vaccaro, A. R. (2010): Thoracolumbar spine trauma classification. Journal of the American Academy of Orthopaedic Surgeons, 18(2), 63-71.
16. Silva, L. M. P. D., Coutinho, P. M. S. L. C., Maia, R. F. F., Pereira, B. J. S., Silva, M. J. S. V. D., & Varanda, P. M. S. (2013): Percutaneous pedicle fixation of thoracolumbar vertebral fractures without neurological deficits. Coluna/Columna, 12(3), 238-241.
17. Park, D. K., Thomas, A. O., Clair, S. S., & Bawa, M. (2014): Percutaneous lumbar and thoracic pedicle screws: a trauma experience. Clinical Spine Surgery, 27(3), 154-161.
18. Chaichana, K. L., la Garza-Ramos, R. D., Sciubba, D. M., Gokaslan, Z. L., & Baaj, A. A. (2012): Minimally invasive percutaneous pedicle screw fixation for thoracolumbar spine fractures: Case report and review of literature. J Trauma Treat, 1(134), 2167-1222.
19. Vaccaro AR, Oner C, Kepler CK (2013): AOSpine thoracolumbar spine injury classification system: fracture description, neurological status and key modifiers. Spine (Phila Pa 1976) 38:2028–2037.

20. Wild MH, Glees M, Plieschnegger C, Wenda K. (2007): Five-year follow-up examination after purely minimally invasive posterior stabilization of thoracolumbar fractures: a comparison of minimally invasive percutaneously and conventionally open treated patients. Archives of orthopaedic and trauma surgery. 2007 Jul;127:335-43.
21. Youssef, E. M. E., et al., (2016): "Percutaneous versus open pedicle screw fixation of thoracic and lumbar fractures; Comparative study at Zagazig University Hospitals." British Journal of Science 14.2 (2016): 1-26.
22. Merom, L., Raz, N., Hamud, C., Weisz, I., & Hanani, A. (2009): Minimally invasive burst fracture fixation in the thoracolumbar region. Orthopedics, 32(4).
23. Elsawaf, A. M. (2016): 330 Outcome of Percutaneous Versus Open Posterior Spinal Fixation in Thoracolumbar Fractures. Neurosurgery, 63, 196- 196.