Percutaneous Versus Open Pedicle Screw Fixation of Thoracic and Lumbar Fractures; Comparative Study at Zagazig University Hospitals

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ABSTRACT

BACKGROUND: Surgical treatment of thoracic and lumbar fractures 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.

OBJECTIVES: This work aims to evaluate the efficacy and safety of percutaneous versus open pedicle screw fixation in thoracolumbar fractures without neurological deficits clinically, radiologically, laboratory and surgically.

PATIENTS AND METHODS: A prospective study that took place at the neurotrauma unit of neurosurgery department at Zagazig University (from September 2014 till September 2016) and included 40 neurologically intact patients with thoracolumbar fractures (Only AOSpine type A); 20 patients have been treated by the minimally invasive percutaneous pedicle screw fixation technique and 20 patients have been treated by the conventional (open) technique with a follow up period of six months. The two groups were evaluated clinically (VAS, ODI and Odom's criteria), radiologically (angle of kyphosis, wedge %, pedicle violations, facet violations, canal compromise multifidus cross sectional area and multifidus/psoas signal intensity ratio in MRI), laboratory (Creatine phosphokinase level) and surgically (operative time, perioperative blood loss, infection, postoperative mobilization and hospital stay).

RESULTS: 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.

CONCLUSION: Percutaneous fixation is a valid, safe, and effective treatment for thoracolumbar fractures.

KEY WORDS: thoracic and lumbar fractures, percutaneous fixation, pedicle screws.
Introduction

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). 1

The ancient Egyptians gave us the first known record of spinal injury, the Edwin Smith Papyrus (2500-3000 Before Common Era, BCE). 2 It described different techniques for management of spinal trauma. 3

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. 4, 5

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. 6

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. Percutaneously pedicle screw has been increasingly used within last two decades. 7

In traditional open approaches, extensive midline exposure extends above and below the instrumented levels allowing lateral retraction of the soft tissues to visualize the pedicle screw entry points at the intersection of the transverse process and facet complexes. In addition, the open approach extends laterally to expose the transverse processes of the levels to be fused and requires wide retraction of the paraspinal muscles for extended periods of time. 8

Minimally Invasive Spine Surgery (MISS) is defined as any spinal surgery that specifically attempts to minimize tissue damage. MISS has sought to achieve the same surgical goals as standard open surgery while minimizing associated morbidity and recovery times. 9

Conventional open spine surgery has several reported limitations including extensive blood loss, post-operative muscle pain and infection risk. The paraspinal muscle dissection involved in open spine surgery can cause muscular denervation, increased intramuscular pressure, ischaemia, necrosis and revascularization injury resulting in muscle atrophy and scarring, often associated with prolonged post-operative pain and disability. 10

There is a trend towards MIS of the spine due to lower complication rates and approach-related morbidity, with minimal soft tissue trauma, reduced intra-operative blood loss/risk of transfusion, improved cosmesis, decreased post-operative pain and narcotic usage, shorter hospital stays with faster return to work and thus reduced overall health care costs. 10
Despite its wide use in traditional degenerative spine conditions, percutaneous screw fixation in trauma is novel. Furthermore, the reported benefits of minimally invasive surgery stated previously may be even more advantageous in the trauma setting as Verlann et al.\textsuperscript{11} found trauma patients may be more susceptible to increased operative blood loss and infection. Therefore, incorporating minimally invasive techniques would ultimately, minimize morbidity in patients with multitrauma.\textsuperscript{6}

**Patients and Methods**

A prospective study that took place at the neurotrauma unit of neurosurgery department at Zagazig University (from September 2014 till September 2016) and included 40 neurologically intact patients (according to the ASIA protocol\textsuperscript{12}) was utilized for neurologic assessment of patients that were all neurologically intact with thoracolumbar fractures (Only AOSpine type A\textsuperscript{13}; 20 patients have been treated by the minimally invasive percutaneous pedicle screw fixation technique and 20 patients have been treated by the conventional (open) technique with a follow up period of six months.  

**Exclusion criteria:**  
Fracture type: AOSpine classification of thoracolumbar fractures:  
- Type B (Distraction) and C (Rotation) thoracolumbar fractures.  
- Any patient with neurological deficits.  
- Age below 18 or above 75.  
- Patient generally unfit for surgery.  

The two groups were evaluated clinically (VAS\textsuperscript{14}, ODI\textsuperscript{15} and Odom's criteria\textsuperscript{16}), radiologically (angle of kyphosis, wedge %, pedicle violations, facet violations, multifidus cross sectional area and multifidus/psoas signal intensity ratio in follow up MRI), laboratory (Creatine phosphokinase level within 12-48 hrs. postoperatively) and surgically (operative time, perioperative blood loss, infection, postoperative mobilization and hospital stay).

**Statistical analysis:**  
All data were collected, tabulated and statistically analyzed using SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA), MedCalc 13 for windows (MedCalc Software bvba, Ostend, Belgium) and Microsoft Office Excel 2010 for windows (Microsoft Cor., Redmond, WA, USA). Continuous quantitative variables e.g. age were expressed as the mean ± SD & median (range), and categorical qualitative variables were expressed as absolute frequencies (number) & relative frequencies (percentage). Chi-square, Fisher exact, paired t-test, and Pearson's correlation coefficient were used when appropriate. McNemar's test was used for paired categorical data. Stuart–Maxwell test (different generalization of McNemar test) was used for testing marginal homogeneity in a square table with more than two rows/columns. All tests were two sided. P-value < 0.05 was considered statistically significant (S), p-value < 0.001 was
considered highly statistically significant (HS), and p-value ≥ 0.05 was considered statistically insignificant (NS).

**Ethical considerations:**
The whole procedure was explained in a simplified manner to the patient, stressing on certain points; Advantages and possible disadvantages of the technique.
That he can refuse to do the examination without any harm on him.
The outcome of the procedure will be used to help research purposes.
Then, a written informed consent was taken either from the patient or the one who can legally substitute him about the approval of doing the technique.

**Results:**
*The basic characteristics of the studied groups : (Tables 1, 2)*
Male was the predominant sex in the percutaneous fixation group (80%) while female was the predominant sex in open fixation group (55%).
Mean age in percutaneous fixation group was 40.10 years (range: 20-65 years) while was 35.95 (range: 18-72 years) in open fixation group. Fall from height was the predominant type of trauma in both groups (70%) while MVA occurred in 30% of patients. Associated injuries occurred in 35% of percutaneous fixation group versus 20% in open fixation group.
The most common AO type of fracture in both groups was A3 fracture where it constituted 25% of percutaneous fixation group versus 30% of open fixation group.
The most common level of fixation was L2 in percutaneous fixation group where 22.5% of 80 inserted screws were used while was L4 in open fixation group where 19.5% of 82 inserted screws were used.

**Table (1): Comparison between percutaneous fixation and open fixation as regard preoperative clinical evaluation.**

<table>
<thead>
<tr>
<th>Preoperative Clinical evaluation</th>
<th>Percutaneous fixation (N=20)</th>
<th>Open fixation (N=20)</th>
<th>Test</th>
<th>p-value (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Fracture (AO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A0</td>
<td>5  25%</td>
<td>5  25%</td>
<td></td>
<td>7.800  0.050</td>
</tr>
<tr>
<td>A1</td>
<td>0  0%</td>
<td>0  0%</td>
<td></td>
<td>(NS)</td>
</tr>
<tr>
<td>A2</td>
<td>2  10%</td>
<td>2  10%</td>
<td></td>
<td>0.784  0.661</td>
</tr>
<tr>
<td>A3</td>
<td>13  65%</td>
<td>7  35%</td>
<td></td>
<td>0.125  0.723</td>
</tr>
<tr>
<td>A4</td>
<td>0  0%</td>
<td>6  30%</td>
<td></td>
<td>0.000  1.000</td>
</tr>
<tr>
<td>Level of Fracture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D8</td>
<td>0  0%</td>
<td>1  5%</td>
<td></td>
<td>1.026  1.000</td>
</tr>
<tr>
<td>D12</td>
<td>3  15%</td>
<td>2  10%</td>
<td></td>
<td>0.229  1.000</td>
</tr>
<tr>
<td>L1</td>
<td>4  20%</td>
<td>2  10%</td>
<td></td>
<td>0.784  0.661</td>
</tr>
<tr>
<td>L2</td>
<td>4  20%</td>
<td>4  20%</td>
<td></td>
<td>0.000  1.000</td>
</tr>
<tr>
<td>L3</td>
<td>5  25%</td>
<td>6  30%</td>
<td></td>
<td>0.125  0.723</td>
</tr>
<tr>
<td>L4</td>
<td>4  20%</td>
<td>4  20%</td>
<td></td>
<td>0.000  1.000</td>
</tr>
<tr>
<td>L5</td>
<td>2  10%</td>
<td>2  10%</td>
<td></td>
<td>0.000  1.000</td>
</tr>
<tr>
<td>Neurological status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deficit</td>
<td>0  0%</td>
<td>0  0%</td>
<td></td>
<td>0.000  1.000</td>
</tr>
<tr>
<td>Intact</td>
<td>20 100%</td>
<td>20 100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Chi-square test. p<0.05 is significant. Sig.: Significance.

**Table (2): Comparison between percutaneous fixation and open fixation as regard operative data.**

<table>
<thead>
<tr>
<th>Operative data</th>
<th>Percutaneous fixation (N=20)</th>
<th>Open fixation (N=20)</th>
<th>Test</th>
<th>p-value (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of screws</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total=80 screws</td>
<td>N=20</td>
<td>N=20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>0  0%</td>
<td>2  2.4%</td>
<td></td>
<td>1.976  0.497</td>
</tr>
<tr>
<td>D9</td>
<td>0  0%</td>
<td>2  2.4%</td>
<td></td>
<td>1.976  0.497</td>
</tr>
<tr>
<td>D11</td>
<td>6  7.5%</td>
<td>4  4.9%</td>
<td></td>
<td>0.481  0.532</td>
</tr>
<tr>
<td>D12</td>
<td>8  10%</td>
<td>4  4.9%</td>
<td></td>
<td>1.549  0.213</td>
</tr>
<tr>
<td>L1</td>
<td>12 10.5%</td>
<td>12 14.6%</td>
<td></td>
<td>0.157  0.692</td>
</tr>
<tr>
<td>L2</td>
<td>18 22.5%</td>
<td>14 17.2%</td>
<td></td>
<td>0.752  0.386</td>
</tr>
<tr>
<td>L3</td>
<td>10 12.5%</td>
<td>12 14.6%</td>
<td></td>
<td>0.157  0.692</td>
</tr>
<tr>
<td>L4</td>
<td>12 15%</td>
<td>16 21.5%</td>
<td></td>
<td>0.577  0.448</td>
</tr>
<tr>
<td>L5</td>
<td>12 15%</td>
<td>12 14.6%</td>
<td></td>
<td>0.004  0.948</td>
</tr>
<tr>
<td>S1</td>
<td>4  5%</td>
<td>4  4.9%</td>
<td></td>
<td>0.001  0.001</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artech®</td>
<td>11 55%</td>
<td>0  0%</td>
<td></td>
<td>40.000&lt;0.001</td>
</tr>
<tr>
<td>Longitude®</td>
<td>7  35%</td>
<td>0  0%</td>
<td></td>
<td>(HS)</td>
</tr>
<tr>
<td>Sextant®</td>
<td>2  10%</td>
<td>0  0%</td>
<td></td>
<td>(HS)</td>
</tr>
<tr>
<td>Egifix®</td>
<td>0  0%</td>
<td>0  0%</td>
<td></td>
<td>(HS)</td>
</tr>
<tr>
<td>No. K wire use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>5  25%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>15 75%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Independent samples Student’s t-test. • Mann Whitney U test.
† Chi-square test. p<0.05 is significant. Sig.: Significance.
The Operative time: (Figure 1)
It was significantly shorter in percutaneous fixation group than open fixation group (Mean±SD: 54.65±11.51 vs 108.80±11.26 minutes, p<0.001).

Figure (1): Error Bar chart shows comparison between percutaneous fixation and open fixation as regard operative time (min.); Bar represent mean; Y-error bar represent 95% confidence interval of mean.

The perioperative blood loss: (Figure 2) 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).

Figure (2): Error Bar chart shows comparison between percutaneous fixation and open fixation as regard amount of perioperative blood loss (ml); Bar represent mean; Y-error bar represent 95%

The postoperative clinical evaluation:
All patients were neurologically intact. VAS of pain was significantly lower in percutaneous fixation group than open fixation group (Mean±SD: 2.45±1.09 vs 4±1.21, p<0.001). 85% of percutaneous group had mild VAS of pain while only 20% in open group (p<0.001).

ODI was significantly lower in percutaneous fixation group than open fixation group (Mean±SD: 12±1.74 vs 29.95±10.01, p<0.001). 100% of percutaneous group had minimal ODI while only 20% in open group (p<0.001).

100% of percutaneous group had good Odom’s criteria while only 20% in open group (p<0.001).

Postoperative imaging evaluation:
Insignificant difference between both groups as regard accuracy of screw insertion where 85% of percutaneous fixation group had no pedicle violation versus 90% in open fixation group (p=0.598).

(Figure 3)
Facet violation: (Figure 3) In our study we found that 95% of percutaneous fixation group had no facet violation versus 85% in open fixation group (p=0.605).
Change in angle of kyphosis between pre and postoperative periods: (Figure 4)
A significant decrease in angle of kyphosis had occurred in both groups (p<0.001). Absolute decrease of angle of kyphosis in percutaneous fixation group was insignificantly higher than open group (Mean±SD: 6.86±4.17 vs 6.53±1.24, p=0.771). Relative decrease of angle of kyphosis in percutaneous fixation group was insignificantly higher than open group (Mean±SD: 29.06±13.36 vs 27.54±5.83 %, p=0.691).

Change in Wedge % between pre and postoperative periods: (Figure 4)
A significant increase in Wedge % had occurred in both groups (p=0.001). Absolute increase of Wedge % in percutaneous fixation group was insignificantly higher than open group (Mean±SD: 31.20±12.32 vs 25.20±9.88, p=0.101). Relative increase of Wedge % in percutaneous fixation group was insignificantly higher than open group (Mean±SD: 60.71±46.66 vs 51.60±33.17 %, p=0.361).

Change in canal compromise between pre and postoperative periods: (Figure 4)
A significant decrease in canal compromise had occurred in both groups (p=0.007 and <0.001 respectively). Absolute reduction of canal compromise in percutaneous fixation group was significantly lower than open group (Mean±SD: 6.55±1.94 vs 12±6.15, p=0.006). Relative reduction of canal compromise in percutaneous fixation group was insignificantly lower than open group (Mean±SD: 50.55±14.36 vs 57.25±5.39 %, p=0.361).
Change in CPK between pre and postoperative periods: (Table 3)

A significant elevation in CPK occurred in both groups (p<0.001). Insignificant difference between both groups as regard absolute elevation of CPK (Mean±SD: 445.75±214.48 vs 585.30±358.86, p=0.146).

Table (3): Comparison between percutaneous fixation and open fixation as regard change in CPK (U/L).

<table>
<thead>
<tr>
<th>CPK (U/L)</th>
<th>Percutaneous fixation (N=20)</th>
<th>Open fixation (N=20)</th>
<th>Test</th>
<th>p-value (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative</td>
<td>105.10 ± 81.28</td>
<td>196.80 ± 118.43</td>
<td>-2.611*</td>
<td>0.009 (S)</td>
</tr>
<tr>
<td>Postoperative</td>
<td>550.85 ± 251.75</td>
<td>782.10 ± 434.48</td>
<td>-2.059*</td>
<td>0.048 (S)</td>
</tr>
<tr>
<td>Test</td>
<td>-3.920†</td>
<td>7.294†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value (Sig.)</td>
<td>&lt;0.001 (HS)</td>
<td>&lt;0.001 (HS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute elevation</td>
<td>445.75 ± 214.48</td>
<td>585.30 ± 358.86</td>
<td>-1.493*</td>
<td>0.146 (NS)</td>
</tr>
</tbody>
</table>

* Independent samples Student's t-test.
† Mann Whitney U test.
§ Wilcoxon signed ranks test.
p< 0.05 is significant.
Sig.: Significance.

Postoperative complications: (Table 4)

No patients in percutaneous fixation group had complications while one patients in open fixation group had superficial wound infection.

Postoperative mobilization and hospital stay: (Table 4)

Mobilization was significantly earlier in percutaneous fixation group than open fixation group (Mean±SD: 12 vs 24 hours, p<0.001).

Hospital stay was significantly shorter in percutaneous fixation group than open fixation.

| Table (4): Comparison between percutaneous fixation and open fixation as postoperative data |
|---------------------------------------------------------------|-------------------------------------|
| Postoperative data                                           | Percutaneous fixation (N=20) | Open fixation (N=20) | Test | p-value (Sig.) |
|                                                               | No % | No %   |      |               |
| Complications                                                |        |        |      |               |
| No complication                                             | 20   | 19     | 1.026†  | 1.000 (NS)   |
| Superficial wound infection                                 | 0    | 1      | 1.000 (NS) |
| Mobilization (hrs)                                           |       |        |      |               |
| Mean ± SD                                                   | 12 ± 0 | 24 ± 0 | -5.831†  | <0.001 (HS) |
| Median (Range)                                              | 12    | 24     |      |               |
| Hospital stay (hrs)                                         |       |        |      |               |
| Mean ± SD                                                   | 24 ± 0 | 48 ± 0 | -6.245†  | <0.001 (HS) |
| Median (Range)                                              | 24    | 48     |      |               |

* Mann Whitney U test.
† Chi square test.
p< 0.05 is significant.
Sig.: Significance.

Change in VAS of pain between postoperative period and follow up:

A significant decrease in VAS of pain had occurred in both groups where 55% of percutaneous fixation group was changed from mild VAS to no pain versus 0% in open fixation group (p<0.001).

Insignificant difference between both groups as regard absolute reduction of VAS of pain (Mean±SD: 2±1.02 vs 1.50±1.63, p=0.225), while relative reduction of VAS in percutaneous fixation group was significantly higher than open group (Mean±SD: 80.91±27.78 vs 22.25±62.84 %, p<0.001). In other words, mean relative reduction of VAS in percutaneous fixation group was four times mean relative reduction of VAS in open fixation group.
Change in ODI between postoperative period and follow up:
Insignificant decrease in ODI had occurred in both groups (p=0.317). Insignificant difference between both groups as regard absolute reduction of ODI (Mean±SD: 5.95±1.35 vs 7.70±3.97, p=0.352) while relative reduction of ODI in percutaneous fixation group was significantly higher than open group (Mean±SD: 49.82±10.55 vs 28.46±16.03 %, p<0.001). In other words, mean relative reduction of ODI in percutaneous fixation group was about one and half times mean relative reduction of ODI in open fixation group.

Change in Odom's criteria between postoperative period and follow up:
A significant improvement in Odom's criteria occurred in open group only where 65% was changed from fair to good Odom's criteria (p<0.001).

Change in Multifidus CSA between preoperative and follow up periods: (Figure 4,5,6)
A significant decrease in multifidus CSA had occurred in both group (p<0.001). Absolute reduction of multifidus CSA in percutaneous fixation group was significantly lower than open group (Mean±SD: 90.03±11.32 vs 344.79±48.15 mm², p<0.001). Relative reduction of multifidus CSA in percutaneous fixation group was significantly lower than open group (Mean±SD: 6.77±0.98 vs 27.70±4.22 %, p<0.001). In other words, mean relative reduction of multifidus CSA in open fixation group was about five times mean relative reduction of multifidus CSA in percutaneous fixation group.

Change in M/P intensity between preoperative and follow up periods: (Figure 4,5,6)
A significant increase in M/P intensity had occurred in both groups (p<0.001). Absolute increase of M/P intensity in percutaneous fixation group was significantly lower than open group (Mean±SD: 0.24±0.05 vs 0.57±0.12, p<0.001). Relative increase of M/P intensity in percutaneous fixation group was significantly lower than open group (Mean±SD: 7.30±1.53 vs 16.74±4.78 %, p<0.001). In other words, mean relative increase in M/P intensity in open fixation group was about double mean relative increase in M/P intensity in percutaneous fixation group.
Figure (5): Little back muscle damage after percutaneous fixation.

Figure (6): Marked back muscle damage after open fixation.

Regarding the K wireless technique of percutaneous fixation:
K wire was used in 75% of percutaneous fixation group. Insignificant difference between patients in whom K wire was not used and patients in whom K wire was used as regard operative time (Mean±SD: 49±14.64 vs 56.53±10.17 minutes, p=0.175) and total amount of perioperative blood loss (Mean±SD: 52.20±12.53 vs 41.13±5.47 ml, p=0.120).

Discussion
The posterior approach to the thoracolumbar spine has been the most commonly used access to the spine since the 1950s. The exposure is straightforward but the collateral damage to the muscle is not negligible. 17-20

Magerl introduced pedicle screw procedure with percutaneous method in 197721. In recent years, there has been a trend toward minimally invasive techniques in spinal surgery, including percutaneous pedicle screw fixation of the thoracic and lumbar spine. 22 Despite its wide use in traditional degenerative spine conditions, percutaneous screw fixation in trauma is novel23. This study compared the benefits and functional outcome of two different modalities of posterior pedicle screw fixation for thoracolumbar fractures in patients without neurological deficits; the conventional (open) and the percutaneous techniques.

Regarding the Operative time:
It was significantly shorter in percutaneous fixation group than open fixation group. 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:
In a series of 76 patients, Schmidt et al. (2007)\(^{24}\) reported an average operative time of 47 minutes. Merom et al. (2009)\(^{25}\) 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). Ni et al. (2010)\(^{26}\) reported an average operative time of 70 minutes for short-segment fixation. Silva et al. (2013)\(^{27}\) reported a mean operative time of 81 minutes (Min 69, Max 95 min).

Elsawaf et al. (2016)\(^{28}\) reported mean operative time of 115 minutes (range 60–220 minutes) for percutaneous group vs 189 minutes (range 110–310 minutes) for the open group.

Regarding the perioperative blood loss:
Total amount of perioperative blood loss was significantly lower in percutaneous fixation group than open fixation group. 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. (2007)\(^{29}\) reported statistically lower blood loss in trauma cases after internal fixation was implanted percutaneously than when implanted during an open procedure. Schmidt et al. (2007)\(^{24}\) described a series of 76 percutaneous long-segment fixation cases for the thoracic spine. Blood transfusion was needed only in three cases; these were all cases where an additional anterior procedure also had to be performed. Merom et al. (2009)\(^{25}\) reported an average blood loss of 50 mL less in the percutaneous group than in the open group (range 200 to 500 mL). Silva et al. (2013)\(^{27}\) evaluated the efficacy and safety of percutaneous pedicle fixation in 23 patients with thoracolumbar fractures without neurologic compromise. They reported a mean volume of intraoperative blood loss of 85ml (75 Min and Max 155 ml).

Elsawaf et al. (2016)\(^{28}\) reported that no one case needed blood transfusions in the percutaneous fixation group. With average blood loss of 880cc in the open group. Twenty patients received 1 unit packed red blood cells in the open technique.
Regarding the postoperative clinical evaluation:
All patients were neurologically intact.
VAS of pain and ODI were significantly lower in percutaneous fixation group than open fixation group.
100% of percutaneous group had good Odom's criteria while only 20% in open group (p<0.001).
These better results in the clinical outcome of the percutaneous fixation group (in the early postoperative period) 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.

Regarding postoperative imaging evaluation:
Insignificant difference between both groups as regard accuracy of screw insertion where 85% of percutaneous fixation group had no pedicle violation versus 90% in open fixation group (p=0.598).
These results are in agreement with:
Wiesner et al. (2000) reported that in a series of 408 screws implanted percutaneously, 6.6% (27 screws) had pedicle wall violations, with two cases needing an open revision procedure because of neurological problems. They observed that many of these misplaced screws (11 of 27) occurred in the sacrum.
Ringel et al (2006) looked at the position of 488 screws: the placement was good in 87% of cases, acceptable in 10% and unacceptable in 3%. Nine of the screws had to be repositioned, with two being at the origin of nerve root pain.
Pelegri et al. (2008) reported a 3.8% rate of misplacement out of 50 screws; in one case, an open revision had to be performed because of neurological problems.
Korovessis et al. (2008) reported that out of 180 screws implanted percutaneously for fracture fixation, three were placed too medially, but these had no clinical consequences and they occurred early in his learning process.
Ni et al. (2010) found that 6.7% of 104 screws implanted were misplaced, but there were no neurological complications.
Elsawaf et al. (2016) reported that:
In the percutaneous group, 392 screws were inserted in the seventy-two patients of that group; 325 screws (83%) were classified as satisfactory, 67 screw as accepted and no screw was classified as non-accepted regarding their classification. In the open group, however, 658 screws were inserted in the ninety-four patients of that group; 490 screws were satisfactory
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(75%), 154 screws were acceptable and 14 screws were classified as nonaccepted and showed violation of the pedicle cortex more than 3 mm, but only 6 of them needed revision surgery.

In summary, these studies show that percutaneous pedicle screw targeting with fluoroscopy guidance, when using proper technique, leads to comparable pedicle wall violations to the standard open technique. This correlates well to the safety of the percutaneous technique. We should mention here that adequate knowledge of fluoroscopic landmarks and long surgeon learning curve are essentials, otherwise, we put the neural tissue at great risks.

**Facet violation:**

In our study, we found that 95% of percutaneous fixation group had no facet violation versus 85% in open fixation group (p=0.605).

*These results are in disagreement with:*

Park et al. (2011)\(^34\) investigated the incidence and relating factors of facet joint violations by percutaneous pedicle screws. The incidence of the violations was 50% (46/92) of all patients and 31.5% (58/184) of all screws, which were significantly higher than the previously reported rates with the traditional open procedure (50% vs. 23.5% of all patients, p < 001; 31.5% vs. 15.2% of all screws, p < 001). The violations occurred approximately 3.3 times more frequently at the most cranial pedicle screws.

Their data raised a concern about the higher incidence of cranial facet joint violations by percutaneously placed pedicle screws than that previously reported rates by traditionally instrumented screws.

Jones-Quaidoo et al. (2013)\(^35\) concluded that the use of a percutaneous method to insert pedicle screws results in a statistically significantly higher incidence of facet joint violation, even if only proximal screws are considered. They recommended further studies to determine if this leads to a higher incidence of symptomatic adjacent-level disease.

*We could explain this disagreement by the fact that in the year 2015 – 2016, the cumulated data of surgeons have increased side to side to their awareness of the possibility of facet violations by percutaneously placed pedicle screws; so most spine surgeons avoid this complication. Another point here is the free hand technique of open pedicle screw insertion that sometimes require removal of a part of the superior facet to identify the pedicle entry point leaving it violated.*

*We agree with the final conclusion of Park et al. (2011)\(^34\) that facet violation should be considered by*
all spine surgeons especially the cranial facet violations that should be avoided when performing either of the two techniques.

**Angle of kyphosis** in percutaneous fixation group was insignificantly smaller than open fixation group.

**Change in angle of kyphosis between pre and postoperative periods:**
A significant decrease in angle of kyphosis had occurred in both groups (p<0.001).

These results agree with:
- Silva et al. (2013)\(^{27}\) reported that preoperative Cobb's angle averaged 16.9° (5.3°-31.7°), postoperatively it was 4.9°, which represents an improvement of about 86%.
- Elsawaf et al. (2016)\(^{28}\) reported that: 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.
- Vanek et al. (2014)\(^{36}\), Wang et al. (2014)\(^{37}\), Dong et al. (2013)\(^{38}\), Lee et al. (2013)\(^{39}\), Grossbach et al. (2013)\(^{40}\) and Jiang et al. (2012)\(^{41}\) concluded that there were no significant differences between the two approaches in regards to local kyphosis angle. McAnany et al. (2016)\(^{42}\) conducted a meta-analysis of those six studies and reported the point estimate for the effect size was 0.335, in favor of the open group; however, this difference was not statistically significant (p = 0.356).

**Wedge %** in percutaneous fixation group was significantly larger than open fixation group.

**Change in Wedge % between pre and postoperative periods:**
A significant increase in Wedge % had occurred in both groups (p=0.001).

These results agree with:
- Silva et al. (2013)\(^{27}\) reported that the percentage of mean preoperative reduction of the vertebral body height was 39.8% (31.6% to 61.6%) and 10.3% postoperatively, representing an improvement of about 29.5%.
- Vanek et al. (2014)\(^{36}\), Wang et al. (2014)\(^{37}\), Dong et al. (2013)\(^{38}\), Lee et al. (2013)\(^{39}\), and Jiang et al. (2012)\(^{41}\) concluded that there were no significant differences between the two approaches in regards to restoration of VBH. McAnany et al. (2016)\(^{42}\) conducted a meta-analysis of those five studies and reported the means and standard deviations for VBH. The point estimate for the effect size was -0.107, which was in favor of the percutaneous group, though not statistically significant (p =0.773).
Canal compromise in percutaneous fixation group was insignificantly smaller than open fixation group. Change in canal compromise between pre and postoperative periods:
A significant decrease in canal compromise had occurred in both groups (p=0.007 and <0.001 respectively).

These results agree with:
Silva et al. (2013)\(^27\) reported that the percentage of compression of the spinal canal was 28.5% (8.4 to 53.8) and postoperatively, it was 10.8%.
Elsawaf et al. (2016)\(^28\) did decompression either open or minimally invasive when needed. The Improvement of the transverse diameter of the spinal cord at the level of maximal compression was shown in both groups but was more significant and obviously in group (open) than in group (percutaneous).

In summary, these results indicate that percutaneous fixation of thoracolumbar fractures results in equivalent biomechanics and consequently clinical outcomes as the open group. In other words, the percutaneous and open techniques did not result in significant differences in the curative effect or radiologic measurement data and that both approaches achieve a good curative effect.

Regarding postoperative CPK:

Postoperative CPK was significantly lower in percutaneous fixation group than open fixation group. Change in CPK between pre and postoperative periods:
A significant elevation in CPK occurred in both groups (p<0.001).
This could be explained by lack of muscle splitting, dissection to expose landmarks and muscle retraction that significantly decreases the muscle fiber damage in the percutaneous technique.

These results are in agreement with:
In a clinical study of degenerative diseases, Kim et al. (2005)\(^43\) found that patients operated with an open procedure took more postoperative pain killers, had higher muscle enzyme levels on the first and seventh day, and had significantly more muscle atrophy visible on MRI.
In a preclinical sheep study, Lehmann et al. (2008)\(^44\) found that muscle enzyme levels did not increase as much when the screws were placed percutaneously versus open (P < 0.05); this was independent of the operative time.
Kumbhare et al. (2008)\(^45\) found that the selection of total CK was considered prudent for clinical applicability given the low cost and wide availability of measurement, in comparison to CK isoenzymes, or other tissue proteins (eg, Tn, MHC),
which are only measurable in specialty settings, typically at greater cost. They found no advantage in using CK/MM. They found also moderate validity was obtained for peak circulating CK concentration as a measure of muscle trauma in spinal decompression surgery. The findings support the use of lumbar surgery as a model for further testing of this objective approach to muscle injury estimation.

**Regarding postoperative complications:**
No patients in percutaneous fixation group had complications while one patient in open fixation group had **superficial wound infection**. This could be related to the less exposure and tissue manipulation with lack of cauterization in the percutaneous technique. **These results are in agreement with:**

*Schmidt et al. (2007)*\(^{24}\) had no infections in 76 patients, but one revision was performed for paravertebral haematoma.

*Merom et al. (2009)*\(^{25}\) observed only one superficial infection in ten cases of open fixation and no infections in ten cases of percutaneous fixation.

*Palmisani et al. (2009)*\(^{16}\) had one infection that required instrumentation removal out of 64 percutaneous fixation cases.

*Ni et al. (2010)*\(^{26}\) reported one superficial infection out of 36 patients having percutaneous fixation; the infection was treated with antibiotics alone.

*Elsawaf et al. (2016)*\(^{28}\) reported that: In the percutaneous group, only one patient had deep infection and collection of pus. In the open group, thirteen patients had superficial infection treated by simple dressings. Five patients had deep infection, 3 of them needed operative debridement but none with hardware removal. Two cases of unintended durotomy occurred beneath a laminar fracture.

**Regarding postoperative mobilization and hospital stay:**

*Mobilization* was significantly earlier in percutaneous fixation group than open fixation group. *Hospital stay* was significantly shorter in percutaneous fixation group than open fixation. The early mobilization and decreased hospital stay in the percutaneous group is directly correlated with the better recovery and functional outcome. Also, the lack of drains and decreased complication rate contribute to this. **These results are in agreement with:**

In the *Merom et al. (2009)*\(^{25}\) study, patients treated with percutaneous fixation were able to walk one or two days after the surgery; those treated with open fixation had to wait three or four days before they could walk.
Elsawaf et al. (2016)\textsuperscript{28} reported that: In the percutaneous group, hospital stay ranged from 33 to 87 hours postoperatively. In the open group, it ranged from 96 to 220 hours postoperatively; with a mean of 166 hours. Others have reported clearly shorter hospital stays after percutaneous surgery than after open surgery for trauma indications\textsuperscript{12,20}.

**Regarding follow-up clinical evaluation:**

VAS of pain was significantly lower in percutaneous fixation group than open fixation group.

**Change in VAS of pain between postoperative period and follow up:**

A significant decrease in VAS of pain had occurred in both groups where 55\% of percutaneous fixation group was changed from mild VAS to no pain versus 0\% in open fixation group (p<0.001).

**ODI** was significantly lower in percutaneous fixation group than open fixation group.

**Change in ODI between postoperative period and follow up:**

Insignificant decrease in ODI had occurred in both groups (p=0.317). 100\% of percutaneous group had good Odom's criteria while 85\% in open group (p=0.231).

**Change in Odom's criteria between postoperative period and follow up:**

A significant improvement in Odom's criteria occurred in open group only where 65\% was changed from fair to good Odom's criteria (p<0.001).

**These results are in agreement with:**

Lee et al. (2012)\textsuperscript{47} “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), and the average improvement of Oswestry Disability Index was 36.2 (from 71.2 to 35.0) at the last visit (p<0.05). The clinical success rate according to Odom’s criteria was 88.2\%.

Silva et al. (2013)\textsuperscript{27} reported that the mean follow-up was seven months (3 months Min, Max, 14 months) with an average ODI of 18\% (excellent).

Elsawaf et al. (2016)\textsuperscript{28} Found 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.

In group II (open fixation): regarding pain at the fracture site; preoperatively, the degree of pain was 8.2 ±3.6 according to visual analogue scale. It changed to a mean of 5.7 ±3.5 two weeks postoperatively and to a mean of 4.4±7.4 at the final follow-up.

The comparable follow up improvement in the clinical outcome of the percutaneous group in
relation to the standard open group is a marker of adequacy of the percutaneous technique. We infer that the early postoperative results are likely the result of early recovery of back muscle pain and function in the percutaneous group and that the extent of paraspinal muscle dissection continues to define the early clinical outcomes between the two groups that approach each other at follow up. We can infer also that the extent of paraspinal muscle injury was positively correlated with postoperative back muscle performance.

**Regarding the follow-up imaging evaluation:**

- **Multifidus CSA** was significantly larger in percutaneous fixation group than open fixation group.

- **Change in Multifidus CSA between preoperative and follow up periods:**
  A significant decrease in multifidus CSA had occurred in both groups (p<0.001).

- **M/P signal intensity ratio** in percutaneous fixation group was significantly lower than open fixation group.

- **Change in M/P intensity between preoperative and follow up periods:**
  A significant increase in M/P intensity had occurred in both groups (p<0.001).

These results ascertain that muscle preservation is a hallmark of the percutaneous pedicle screw fixation away from the extensive muscle splitting, dissection and retraction that are evident in the standard open pedicle screw fixation. The multifidus is still retaining most of its bulk as evidenced by the minimal reduction of its cross-sectional area in postoperative MRI. It is still also retaining its signal intensity with little fibrous tissue when its signal is rationed to healthy psoas muscle at the multifidus/psoas index. This should be correlated to the better functional outcome of back muscle function.

**These results are in agreement with:**

In a clinical study of degenerative diseases, *Kim et al. (2005)* found that patients operated with an open procedure took more postoperative pain killers, had higher muscle enzyme levels on the first and seventh day, and had significantly more muscle atrophy visible on MRI. Postoperative muscle strength was better preserved in the group receiving percutaneous fixation. They used the same parameters as we used in our study to evaluate muscle injury radiologically:

**Multifidus Muscle Cross-sectional Area**

They found that there is significant decrease in the cross-sectional area of multifidus muscle in the open group. In the open group, the cross-sectional area of multifidus muscle was 1137.2 ± 240.7 mm² and 792.1
± 261.9 mm² on preoperative and follow-up MRI, respectively (P = 0.003, Wilcoxon signed ranks test). In contrast, the results in the percutaneous group showed no statistical difference between preoperative and follow-up MRI. In the percutaneous group, the cross-sectional area of multifidus muscle was 1321.9 ± 366.0 mm² and 1273.3 ± 302.1 mm² on preoperative and follow-up MRI, respectively (P = 0.484, Wilcoxon signed ranks test). This completely agrees with our study.

**T2-Weighted Signal Intensity of Multifidus Muscle**

They found no significant increase in signal intensity ratios of multifidus to psoas muscle in either the percutaneous or the open group. In the open group, signal intensity ratio of multifidus to psoas muscle was 3.4±1.1 and 3.5 ± 1.6 on preoperative and follow-up MRI, respectively (P > 0.05, Wilcoxon signed ranks test). In the percutaneous group, signal intensity ratio of multifidus to psoas muscle was 3.7±0.8 and 3.7±1.6 on preoperative and follow-up MRI, respectively (P > 0.05, Wilcoxon signed ranks test). This is slightly different from our study as it all depends on the quality of the MRI images, the power of the MRI machine and the sensitivity in detecting traces of fibrous tissue signal intensity changes.

In a cadaver study, Regev et al. (2009) found that the multifidus motor nerve was injured in 20% of cases when screws were implanted percutaneously versus 80% when the screws were implanted during an open procedure (P < 0.0001).

**Regarding the K wireless technique of percutaneous fixation:**

The most common technique for placement of percutaneous pedicle screws utilizes K-wires to help guide cannulated taps and screws. Although K-wires serve as useful guides for cannulated screws, they have several limitations, including wire bending and breakage, and pullout leading to increased procedural time and potentially increased fluoroscopy use. In addition, K-wire migration may lead to neurological, vascular, or visceral injury, especially in patients with poor bone quality.

**In our study:**

K wire was used in 75% of percutaneous fixation group. Insignificant difference between patients in whom K wire was not used and patients in whom K wire was used as regard operative time, and total amount of perioperative blood loss.

**These results are in agreement with Spitz et al. (2015)** whom conducted a prospective case series of percutaneous pedicle screw placement (100 screws in 28 patients) using a K-wireless system.
demonstrating that percutaneous pedicle screws can be placed safely without the use of K-wires with a relatively low overall breach rate of 3.3% and a clinically significant breach rate of 1.1%. Screw placement and fluoroscopy times were reduced when compared with other published series.

But in our study, we verified the safety of the k-wireless technique in only a small sample (5 cases out of 20 cases of percutaneous fixation) that is only 20 screws. We didn't find any increased complication rate in this small group. The operative time although being slightly shortened, it didn't yield a significant difference. The same insignificant difference exists with regard to the perioperative blood loss. In our study, we didn't evaluate the fluoroscopy time and didn't quantify the radiation exposure. We think that this novel technique should be evaluated furtherly on a wider scale.

At the end of our discussion, we should revise the meta-analytic studies the deal with our topic.

To our knowledge, no systematic review or meta-analysis has evaluated comparative studies of the open versus percutaneous approach for thoracolumbar trauma except for the following one.

McAnany et al. (2016)\textsuperscript{42} conducted a major systematic literature review and meta-analysis of studies published in from January 1980 to June 2014 aiming at evaluating the differences in outcome variables between percutaneous and open pedicle screws for traumatic thoracolumbar fractures.

They revised the systematic reviews of PubMed, Cochrane, and Embase. The variables of interest included postoperative visual analog scale (VAS) pain score, kyphosis angle, and vertebral body height (VBH), as well as intraoperative blood loss and operative time.

Six studies were found to meet their inclusion criteria and were included in the meta-analysis: Vanek et al. (2014)\textsuperscript{36}, Wang et al. (2014)\textsuperscript{37}, Dong et al. (2013)\textsuperscript{38}, Lee et al. (2013)\textsuperscript{39}, Grossbach et al. (2013)\textsuperscript{40} and Jiang et al. (2012)\textsuperscript{41} Five studies reported postoperative VAS scores\textsuperscript{35, 30-33} Similarly, five studies reported postoperative vertebral body height (VBH).\textsuperscript{35, 30-33} Six studies reported information on operative time, blood loss, and postoperative kyphosis angle.\textsuperscript{30-35}

The results of this meta-analysis are:

The combined effect size was found to be in favor of percutaneous fixation for blood loss and operative time (p < 0.05); however, there were no differences in vertebral body height (VBH), kyphosis angle, or VAS scores between open and percutaneous fixation. All of the
studies demonstrated relative homogeneity, with I² < 25. So, this meta-analysis clarifies that patients with thoracolumbar fractures can be effectively managed with percutaneous or open pedicle screw placement. There are no differences in VBH, kyphosis angle, or VAS between the two groups. Blood loss and operative time were decreased in the percutaneous group, which may represent a potential benefit, particularly in the polytraumatized patient. All variables in this study demonstrated near-perfect homogeneity, and the effect is likely close to the true effect.

These results are in agreement with our study in all included variables.

Conclusion
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.

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Tethering of the thoracic and lumbar vertebral fractures by cervical screws through the skin: A comparative study of the open technique

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Abstract: The incidence of vertebral fractures, particularly thoracic and lumbar fractures, is high worldwide. This study aims to compare the results of two techniques of thoracic and lumbar vertebral fractures treatment by cervical screws through the skin with those of the open technique. The study was conducted in the Trauma Unit, Department of Neurosurgery, Zagazig University Hospital, Egypt, from September 2014 to September 2016. A total of 40 patients with thoracic and lumbar vertebral fractures were included. Twenty patients were treated with cervical screws through the skin, while the other 20 patients were treated with the open technique. The results showed that the skin technique reduces the risk of bleeding during surgery, pain, and infection compared to the open technique. It also reduces the risk of nerve root entrapment and muscle atrophy. The study concluded that the skin technique is a safe and effective method for the treatment of thoracic and lumbar vertebral fractures.

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