Three-dimensional assessment of pedicular screws in thoracic and lumbar fractures using free-hand technique: a single-surgeon experience

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Introduction
Several sophisticated image-guided modalities have been developed to improve the accuracy of screw placement; however, such modalities may increase healthcare costs and radiation exposure to the patient, and the clinical efficacy compared with traditional techniques may be questionable. Globally, the free-hand technique of pedicle screw placement was found to be a reliable and safe method with low rates of complications and to be potentially more cost-effective than other sophisticated techniques in treating several spinal disorders.
Aim
The aim of this work was to assess the accuracy and safety of free-hand pedicle screw placement in thoracic and lumbar fractures using minimal image exposure.
Materials and methods
This is a prospective radiographic review of thoracic and lumbar pedicle screws inserted in patients suffering from unstable fractures. All of the procedures were performed by a single consultant spine surgeon. Screws were inserted at one side and then intraoperative lateral imaging was used to check the level and verify the position of the screws. The same procedure was repeated on the other side. The vertebral bodies were divided into three equidistant horizontal zones (A, B, and C). Positioning of the screw tips was regarded as ideal when located in zones A and B. Multislice computed tomography was used to assess the accuracy.
Results
There were 669 pedicle screws inserted in 88 consecutive cases from T3 to L5, with a mean of 7.6 screws. The overall number of misplaced screws was nine (1.3%). Intraoperative revision was made in 16 (seven cases, 2.4%) screws. No intraoperative or immediate postoperative complication occurred due to screw placement.
Conclusion
Minimal revision rate was noticed, and only two lateral images were needed in most of the cases. This is quite important in developing countries, where an image intensifier serves more than one room.

Keywords:
fractures, lumbar, pedicle, screws, thoracic

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Introduction

There are several advantages in the use of pedicle screws for operative management of various conditions, including fractures. Besides the superior biomechanical properties over other instrumentation techniques, they provide three-column rigid fixation of the vertebra [1–5].

Even with these advantages, misplacement of pedicle screws may decrease fixation capabilities as well as increase the risk for soft tissue and neural injury [6–8].

Several anatomical and morphometric studies of thoracic pedicles have emphasized the complex anatomy and variability in size and orientation of the thoracic pedicle [9]. The intimate relation of the pedicle to the neural and vascular structures makes the potential complications from screw misplacement a serious concern [10]. Other complications are related to the pedicle screw placement technique, such as difficulty or inability in fitting the instrumentation to the pedicle, dural tears, pedicle fractures, and others [11].

Proper application of pedicle screw constructs requires an understanding of pedicle screw insertion techniques, pedicle morphometry, salvage options, and bone quality.

Recently, several advanced image-guided modalities have been developed to improve the accuracy of

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screw placement [12,13]. However, the cost-effectiveness and the hazards of radiation to both patient and operating room staff should not be underestimated [14]. Globally, the free-hand technique of pedicle screw placement was found to be a reliable and safe method with low rates of complications and to be potentially more cost-effective than other sophisticated techniques in treating spinal disorders [15].

Many spine surgeons utilize a lateral plain radiograph to intraoperatively assess the inclination of pedicle screw placement, and image-guided navigation is not commonly utilized worldwide. In our spinal unit, we use the free-hand technique for thoracic and lumbar pedicular fixation, with verification with two lateral views using the C-arm, with very low revision rates.

Aim

The aim of the present study was to assess a single-surgeon experience in pedicle screw placement accuracy in thoracic and lumbar fractures, and to record the rate of intraoperative screw revision using the free-hand technique.

Patients and methods

The authors performed a prospective radiographic review of thoracic and lumbar pedicle screws in 88 consecutive patients suffering from unstable thoracic and lumbar fractures. An informed consent was obtained from every patient. Ethics Committee had approved the protocol of the study. They were treated at our institute with posterior spinal instrumentation between March 2010 and May 2013. The procedures were performed by a single consultant spine surgeon (the first author). All pedicle screws were inserted by the free-hand method. The technique of pedicle screw placement of the thoracic and lumbar spine is described in detail elsewhere [16].

Surgical considerations

All of our procedures were performed under general anesthesia with the patient in the prone position using the standard posterior approach. The spine was exposed bilaterally in the usual manner. Pedicle screws were inserted into one side and then the image intensifier was used to check the level and verify the position of the screws on the lateral image. The same procedure was repeated on the other side.

Only intraoperative lateral imaging was used to assess the positioning of the pedicle screw tips within the vertebral bodies. Anteroposterior views were not routinely used.

Methods of assessment

Postoperative radiographs and multislice computed tomography (CT) were performed for better assessment.

Radiographic assessment

On the lateral film, the vertebral bodies were divided into three equidistant horizontal zones, which were designated as A, B, and C (Fig. 1). Screws were considered acceptable when they engaged the pedicle in the lateral view and unacceptable when the screw perforated the pedicle or violated the superior or inferior disc spaces. Positioning of the screw tips was regarded as ideal when located in zones A and B. Zone C was the least accepted (Fig. 2).

Computed tomography assessment

Multislice CT scans (axial, sagittal, coronal, and reconstruction) were examined to evaluate the position of the screws according to the classification of Learch *et al.* [17] and Wiesner *et al.* [18]. In this classification, there are four main categories for screw misplacement:

(1) Encroachment: If the pedicle cortex cannot be visualized.
(2) Minor penetration: When the screw trajectory is less than 3 mm outside the pedicular boundaries.
(3) Moderate penetration: When the screw trajectory is 3–6 mm outside the pedicular boundaries.
(4) Severe penetration: When the screw trajectory is more than 6 mm outside the pedicular boundaries.
    (a) Moreover, intraoperative revisions for unacceptable screws were noted.

Figure 1

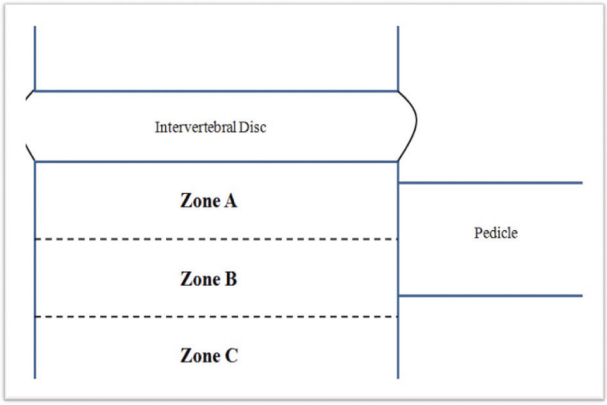


Illustration depicting stratification of vertebral body zones to assess the sagittal profile of pedicle screw placement.

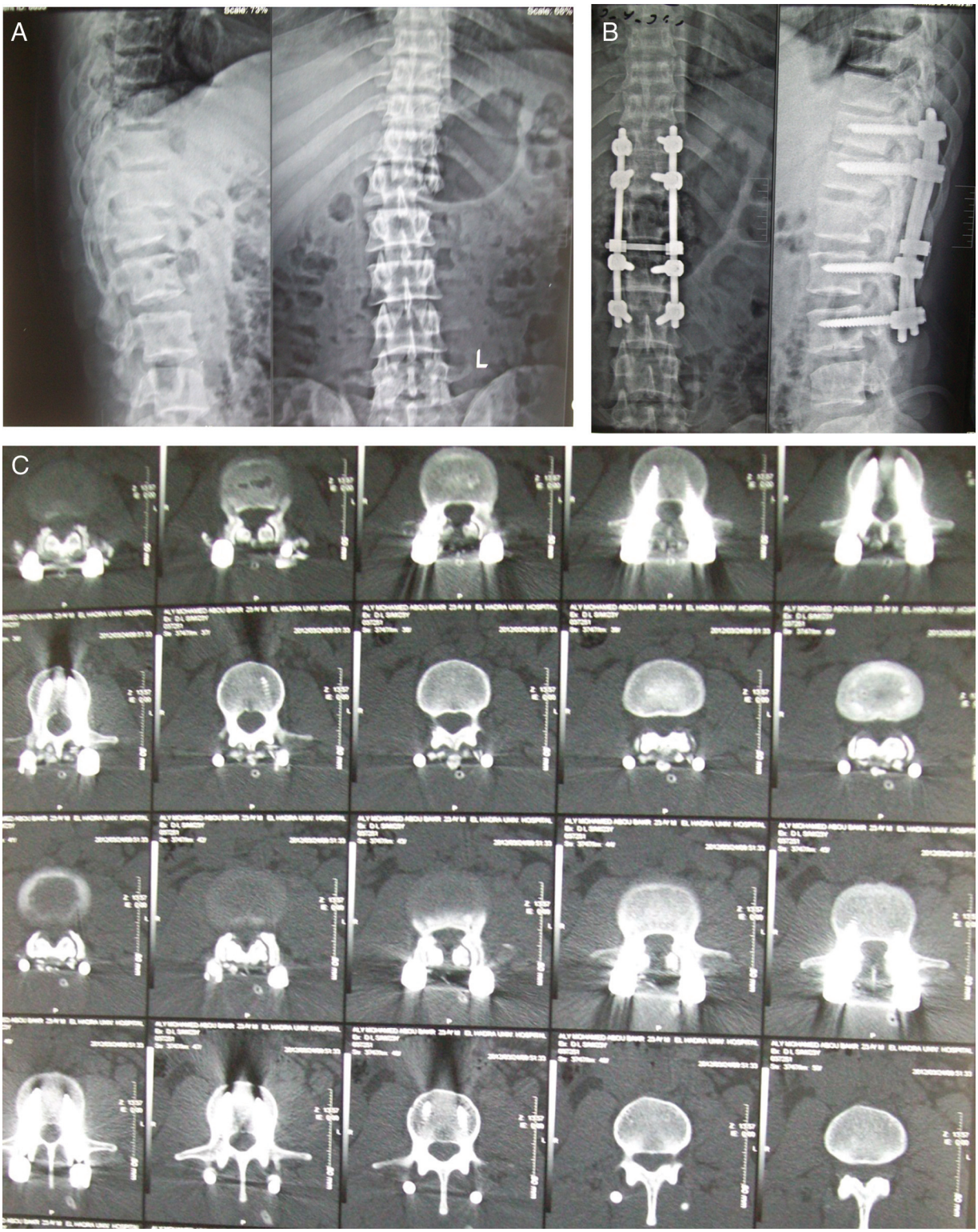
(b) Additionally, the presence of any intraoperative and postoperative complications was also assessed.

Statistical analysis was performed using SPSS, version 14 (SPSS Inc., Chicago, Illinois, USA).

Results

There were 56 (63.6%) male and 32 (36.3%) female patients, with a mean age of 30.3±11.7 (range: 15–66) years.

Figure 2



(a) Radiograph of a 47-year-old man with unstable fracture subluxation T12–L1. (b) Immediate postoperative radiograph of the same patient after long segment posterior instrumentation showing perfect correction and screw positioning. Note the screw tips at zones A and B. No intraoperative revision was made for any of the screws. (c) Immediate postoperative computed tomography showing excellent screw position.

Three types of instrumentation were carried out:
(1) Long segment fixation (two above and two below the fracture).
(2) Short segment fixation (one above and one below the fracture).
(3) Short intermediate segment fixation (one above and one below the fracture, and in the fractured vertebra).

The level most frequently operated upon was L1 (40 case), followed by T12 (32 cases), L2, L3, and L4 (four cases each), and T3, T9, T10, and T11 (one case each).

There were 669 pedicle screws inserted in 88 consecutive cases from T3 to L5, with a mean of 7.6 (range: 4–9) screws inserted per patient. Pedicle screw placement into zone A was 400 (59.7%) screws and that in zone B was 227 (34%) screws, whereas screw insertion into zone C involved 42 (6.2%) screws.

According to postoperative CT, the overall number of misplaced screws was nine (1.3%), and they were distributed as follows:

(1) Two intradiscal (T10, T11).
(2) Four with encroachment (T11, T12, and L1).
(3) Three with minor penetration (T11, T12).

No revision was done in any of them, and there was no clinical complication. Otherwise, postoperative multislice CT confirmed perfect screw positioning in the remaining screws.

On the other hand, intraoperative revision was made in 16 (seven cases, 2.4%) screws. One of them was due to inferior entry into L2, and the remaining because of superior intradiscal violation, namely in L4 and L1 (two screws in each), and in T11, T12, and L3 (one screw each). Of the 16 screws, eight were revised because of wrong level (L1 instead of T12 in four cases).

Regarding the preoperative neurological status, 20 had incomplete paraplegia, 10 had complete paraplegia, and 58 were neurologically free.

No intraoperative or immediate postoperative complication occurred due to screw placement. Only one case had postoperative deterioration of the neurological status, but it was not related to screw placement. He was a 36-year-old male patient, with burst L1, incomplete paraplegia, with a sizable retropulsed fragment. After posterior decompression, the cord was found to stretched, and the fragment was hammered and reduced back into position. Postoperatively, the neurological status showed deteriorated motor weakness in the dermatomes L2 down to L4. The patient had defaulted follow-up.

Discussion

There are several methods of pedicle screw placement to enhance the accuracy and safety of pedicle screw application and decrease the potential of complications, such as intraoperative fluoroscopy, computer-guided navigation systems, and intraosseous endoscopy [12,13]. However, these modalities are time-consuming, expensive, may require preoperative CT scans, involve a significant learning curve, and are not widely available, especially in developing countries [19,20].

Although pedicle screw fixation is a well-established technique for the lumbar spine, screw placement in the thoracic spine is more challenging because of the smaller pedicle size and more complex three-dimensional (3D) anatomy [11]. Screw misplacement especially in the thoracic spine can endanger neural and vascular structures [10,11]. Thoracic screws perforate the cortical margins of the pedicle at a rate ranging from 16 to 54%, creating the potential for hemorrhage, nerve root injury, or spinal cord injury. Moreover, long pedicle screws endanger adjacent structures such as the aorta and the pleural cavity [7].

The free-hand pedicle screw technique has been well described and one inserts the pedicle screws based on the anatomical landmarks and the tactile feel of probing the pedicles. Kim *et al.* [9,12] report a low complication rate with this technique. It should be noticed that the accuracy of screw position remains primarily a function of surgical skill together with experience and is associated with a steep learning curve [20].

Although we believe that many spine surgeons in Egypt use this strategy for placement of pedicle screws, we are unaware about similar publications. Our prevalence of misplaced screws was minimal (1.2%). This means that the accuracy is ~99%.

The reason behind dividing the vertebral bodies into three zones is that we think that the upper two zones are perfect for screw placement, although zone C is also feasible. It has been shown by others that screws adjacent to the superior endplate (zone A) provide the best overall segmental rigidity. Screws placed in the mid-portion of the vertebral body may provide

good lateral torsion. However, there are several factors that can affect the pedicle screw stability, including the sagittal and coronal inclination, the depth of screw insertion, and bone quality [16]. In our series screws in zone A and zone B represented the majority of cases (about 96%).

Recently, Allam *et al.* [21] published an article comparing the free-hand technique with 3D-based navigation techniques. The accuracy rate in his work was 89.8% in the free-hand group compared with 98% in the generic 3D navigated group, which is less than our results [21].

An important issue should be added, which is the screws violating the medial cortex in our patient. It is not routine practice to perform CT in the postoperative period; therefore, although this complication may occur, most of the time it is not discovered.

We feel that our study had some strengths. It assessed a single-surgeon experience at a single institute, with relatively sufficient patients and screws numbers (88 patients, 669 screws). It should be noted, however, that we understand that our policy may not be accepted by some spine surgeons who insist on obtaining intra-operative anteroposterior views to achieve maximum accuracy. Once again, we believe that pedicular screw placement remains an experienced surgical skill after a long learning curve.

Conclusion

Free-hand technique with minimal image exposure is an effective method in pedicular screw placement in thoracic and lumbar fractures. Minimal revision rate was noticed, and only two lateral images were needed in most of the cases. This is quite important in developing countries, where an image intensifier serves more than one room.

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Conflicts of interest
There are no conflicts of interest.

References

1 Liljenqvist U, Hackenberg L, Link T, Halm H. Pullout strength of pedicle screws versus pedicle and laminar hooks in the thoracic spine. Acta Orthop Belg 2001; 67:157–163.

2 Roy-Camille R, Saillant G, Mazel C. Plating of thoracic, thoracolumbar, and lumbar injuries with pedicle screw plates. Orthop Clin North Am 1986;17:147–159.

3 Suk SI, Kim WJ, Lee SM, Kim JH, Chung ER. Thoracic pedicle screw fixation in spinal deformities: are they really safe? Spine (Phila Pa 1976) 2001; 26:2049–2057.

4 Suk SI, Lee CK, Kim WJ, Chung YJ, Park YB. Segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis. Spine (Phila Pa 1976) 1995; 20:1399–1405.

5 Upendra BN, Meena D, Chowdhury B, Ahmad A, Jayaswal A. Outcome-based classification for assessment of thoracic pedicular screw placement. Spine (Phila Pa 1976) 2008; 33:384–390.

6 Ebraheim NA, Jabaly G, Xu R, Yeasting RA. Anatomic relations of the thoracic pedicle to the adjacent neural structures. Spine (Phila Pa 1976) 1997; 22:1553–1557.

7 Vaccaro AR, Rizzolo SJ, Balderston RA, Allardyce TJ, Garfin SR, Dolinskas C, An HS. Placement of pedicle screws in the thoracic spine. Part II: an anatomical and radiographic assessment. J Bone Joint Surg Am 1995; 77:1200–1206.

8 Parent S, Labelle H, Skalli W, De Guise J. Thoracic pedicle morphometry in vertebrae from scoliotic spines. Spine (Phila Pa 1976) 2004; 29:239–248.

9 Kim YJ, Lenke LG, Bridwell KH, Cho YS, Riew KD. Free hand pedicle screw placement in the thoracic spine: is it safe? Spine (Phila Pa 1976) 2004; 29:333–342.

10 Kuklo TR, Potter BK, Polly DW Jr, Lenke LG. Monaxial versus multiaxial thoracic pedicle screws in the correction of adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 2005; 30:2113–2120.

11 Simmons JW, Andersson GB, Russell GS, Hadjipaviou AG. A prospective study of 342 patients using transpedicular fixation instrumentation for lumbosacral spine arthrodesis. J Spinal Disord 1998; 11:367–374.

12 Kim KD, Johnson JP, Bloch BS, Masciopinto JE. Computer-assisted thoracic pedicle screw placement: an in vitro feasibility study. Spine (Phila Pa 1976) 2001; 26:360–364.

13 Stauber MH, Bassett GS. Pedicle screw placement with intraosseous endoscopy. Spine (Phila Pa 1976). 1994; 19:57–61.

14 Jones DP, Robertson PA, Lunt B, Jackson SA. Radiation exposure during fluoroscopically assisted pedicle screw insertion in the lumbar spine. Spine (Phila Pa 1976) 2000; 25:1538–1541.

15 Samartzis D, Boco T, O'Toole JE, Fessler RG. Comparison of image-guidance to conventional in vivo application of thoracic and lumbar pedicle screws: a meta-analysis. San Diego, CA: Annual Meeting of the Congress of Neurological Surgeons; 2007.

16 Sasso RC, Cotler HB, Reuben JD. Posterior fixation of thoracic and lumbar spine fractures using DC plates and pedicle screws. Spine (Phila Pa 1976) 1991; 16(Suppl): S134–S139.

17 Learch TJ, Massie JB, Pathria MN, Ahlgren BA, Garfin SR. Assessment of pedicle screw placement utilizing conventional radiography and computed tomography: a proposed systematic approach to improve accuracy of interpretation. Spine (Phila Pa 1976) 2004; 29:767–773.

18 Wiesner L, Kothe R, Ruther W. Anatomic evaluation of two different techniques for the percutaneous insertion of pedicle screws in the lumbar spine. Spine (Phila Pa 1976) 1999; 24:1599–1603.

19 Choi WW, Green BA, Levi AD. Computer assisted fluoroscopic targeting system for pedicle screw insertion. Neurosurgery 2000; 47:872–878.

20 Foley KT, Simon DA, Rampersaud YR. Virtual fluoroscopy: computer-assisted fluoroscopic navigation. Spine (Phila Pa 1976) 2001; 26:347–351.

21 Allam Y, Silbermann J, Riese F, Greiner-Perth R. Computer tomography assessment of pedicle screw placement in thoracic spine: comparison between free hand and a generic 3D-based navigation techniques. Eur Spine J 2013; 22:648–653.