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Safety and efficacy of short percutaneous fixation in AO3 and AO4 lumbar fractures: a single-centre experience of 35 cases

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ABSTRACT

Introduction. Spinal fractures with subsequent bone fragment dislocation are among the injuries most feared by patients and physicians. The surgical strategy is tailored to the individual patient's characteristics and often consists of pedicle instrumentation with rod-screw systems. Short instrumentation has been associated with worse spinal correction and increased complications. However, recent studies have suggested similar results in terms of kyphosis correction and the maintenance of sagittal alignment compared to longer instrumentation.

Material and methods. This single-center retrospective study was conducted between January 2018 and April 2021. We included 35 single lumbar burst fractures AO Spine grade A3 or A4 with evidence of intra-canal fragments. Patients underwent minimally invasive percutaneous posterior lumbar instrumentation with pedicle screws. Patients received short segmental fixation involving only one level above and below the fractured vertebra.

Results. An immediate postoperative computed tomography (CT) scan demonstrated a significant reduction in vertebral kyphotic deformation (11.7° ± 1.6 vs 16.7° ± 5, $p<0.001$) and sagittal Cobb angle (9.8° ± 1.3 vs 11.7° ± 1.5, $p < 0.001$). The correction was slightly reduced but remained significant at 12 months for both kyphotic (12.3° ± 1.4, $p = 0.03$) and sagittal Cobb (10.3° ± ± 0.9, $p = 0.04$). Upper lumbar vertebrae showed even larger correction indices compared to lower lumbar segments. No implant failure or screws pullout was seen at the last follow-up.

Conclusions. Short spinal fixation is a safe and effective treatment of complete and incomplete burst fractures with posterior bone fragment dislocation. All included patients fared well and achieved good kyphotic correction with no perioperative or long-term complications.

Keywords: spine, trauma, short fixation, posterior fixation

Introduction

spinal fractures with subsequent bone fragment dislocation are among the injuries most feared by patients and physicians. Their consequences can be devastating, ranging from mild pain and discomfort to paralysis and death [1–3]. Incomplete and complete burst fractures affect millions of patients every year, accounting for c.10-20% of all spine fractures, with c.25% occurring at the lumbar level [1, 4].

Lumbar burst fractures result in spinal instability and possible nerve damage; they often require surgery to achieve sufficient decompression, vertebral height restoration, and

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stability while at the same time correcting and avoiding kyphosis and the onset of neurological deficits. Traditionally, posterior fixation with rod-screw systems has been widely used for the treatment of these fractures. More recently, the minimally invasive percutaneous pedicle screw placement technique has been advocated because it involves smaller incisions, less bleeding, less dissection of paraspinal muscle tissue, less pain, and rapid postoperative recovery [5, 6].

The length of spinal fixation is still a matter of debate, with some studies demonstrating a more favorable course with longer instrumentations [7–10], while recent studies have reported similar results in terms of kyphotic correction and long-term complications, but with the additional advantage of reduced operating time as well as a lower risk of screw malposition and related neurological complications observed with shorter constructs. Short-segment stabilization has also shown faster pain relief, less tissue destruction than long-segment, and good biomechanical stability [11–19].

This retrospective study analyzed the clinical and neuroradiological outcomes of patients undergoing a minimally invasive percutaneous short posterior vertebral fixation, with additional laminectomy in selected cases.

Material and methods

Ethical considerations

Ethical approval was not required for this study. All procedures were performed in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all participants.

Design of study

This was a single-center retrospective study conducted between January 2018 and April 2021 in patients treated for traumatic lumbar fractures with significant intracanal fragments at the Neurosurgery Unit, Vito Fazzi Hospital, Lecce, Italy. Of the 142 patients treated for spinal fractures during the period in question, 35 fulfilled our enrollment criteria and were included in the final analysis.

We included single lumbar burst fractures classified according to the AO Spine classification system [20] as grade A3 or A4. Neurological status was assessed using the American Spinal Injury Association International Standards for Neurological Classification of Spinal Cord Injury (AIS) [21]. Included patients shared normal or only slightly impaired neurological function (AIS grades D or E) and underwent short posterior instrumentation with percutaneous polyaxial pedicle screws insertion after exclusion of the need for anterior approaches assessed by means of the Load Sharing Score (LSS) [22].

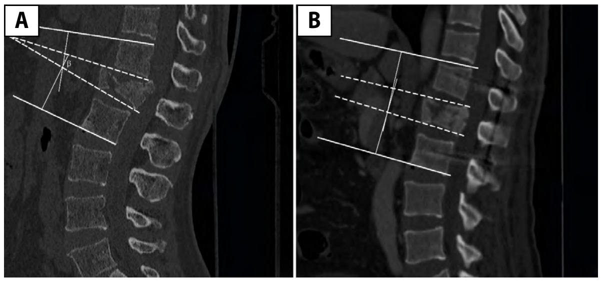

Figure 1. Example of sagittal measurement of kyphotic deformation following burst fracture. L1 AO A4 fracture before (**A**) and after (**B**) vertebral instrumentation. Dotted lines define vertebral kyphotic deformation angle (alpha – α), whereas solid lines define sagittal Cobb angle (beta – β)

Patients were included if their LSS score was > 7. Posterior wall failure and an intracanal fragment causing a reduction of at least 15% of the vertebral canal diameter were two of the inclusion criteria. Pedicle screws were interconnected to posterior rods to exert a lordotic force to restore the vertebral height and correct the spinal kyphosis. No screws were placed in the affected vertebrae.

Patients were excluded if they presented with severe neurological deficits (AIS grades A, B, or C), multilevel vertebral fractures, osteoporotic or pathological fractures, or a previous history of lumbar spine instrumentation.

Clinical and radiological evaluation

Demographic data, as well as clinical details and the entity of neurological impairment, were carefully recorded after patient admission. Data relevant to the study was retrieved from medical records. Patients were clinically followed up at one, eight, and 12 months.

Upon hospital admission, patients received baseline computed tomography (CT) and magnetic resonance imaging (MRI). The key radiological features included in the final analysis were the vertebral height and deformity of the spine before and after surgery, as well as the long-term implant integration and integrity. Figures 1 and 2 depict the pre-operative diagnostic workout and the calculation of spinal canal compression and peri-operative angular radiological outcomes.

Spinal alignment was assessed using the regional kyphosis angle between the upper plate of the overlying vertebra and the lower plate of the vertebra underlying the fracture (here named the sagittal Cobb angle) and the kyphotic deformation of the fractured vertebra, measured as the angle between the upper plate and the lower plate of the injured vertebra (Fig. 1). The average mid-sagittal canal diameter for the two adjacent vertebrae, one above and one below the fractured vertebra, was considered to be the normal mid-sagittal diameter of the fractured vertebra. The percentage of spinal canal compromise at presentation was calculated using the method described by Hashimoto et al. [23] set out in Figure 2.

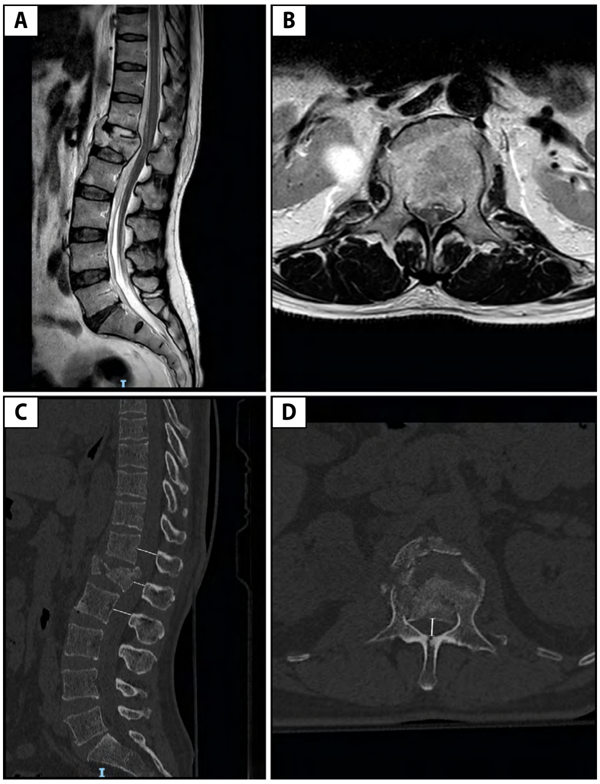

Figure 2. Pre-operative radiological evaluation. All included patients received pre-operative magnetic resonance (MRI, panels **A**, **B**) and computed tomography imaging (CT, panels **C** and **D**). Extent of maximal spinal canal compression has been systematically evaluated on CT images. Maximal reduction in canal diameter was defined as distance from posterior aspect of bone fragment and anterior wall of posterior arch on a midsagittal location, as shown in panel **D**. This measure was compared to mean canal diameter measured at upper and lower levels (as depicted in panel **C**). All measures were performed on axial CT slices. See text for further details

All patients received an additional CT scan within six days after surgery. Two independent neuroradiologists used sagittal, coronal, and axial slices with bone windows to detect screw positioning, angular changes, and early complications. Long-term follow-up was conducted using plain 2-projection X-rays at 8- and 12-month follow-ups to address late kyphotic correction angles and the occurrence of complications (Fig. 3).

Statistical analysis

Categorical variables are reported as absolute numbers and percentages, whereas continuous variables are reported as the median and interquartile range (IQR). The Kolmogorov-Smirnov and Skewness tests were used to assess the normality of the distribution of continuous variables. Between-group differences evaluation and unadjusted univariate analyses were performed using the t-test or Mann-Whitney U-test in accordance with normality and the Chi-square or Fisher's exact test, where appropriate. The results of all tests are presented as p-values and statistical significance was set as a probability value of 0.05 (95% confidence interval). Statistical analysis was performed using STATA Statistical Software 2015: Release 14 (StataCorp LLP, College Station, TX, USA).

Results

Overall characteristics

A total of 35 patients (23 males and 12 females) fulfilled the inclusion criteria for this study. The mean age at presentation was 51.4 years (range 12.8–80.8). Road accidents were the most common cause of lumbar trauma (n = 19, 54%), followed by falls (n = 16, 46%).

All enrolled patients suffered moderate to severe lumbar pain and tenderness to compression of spinous processes. In

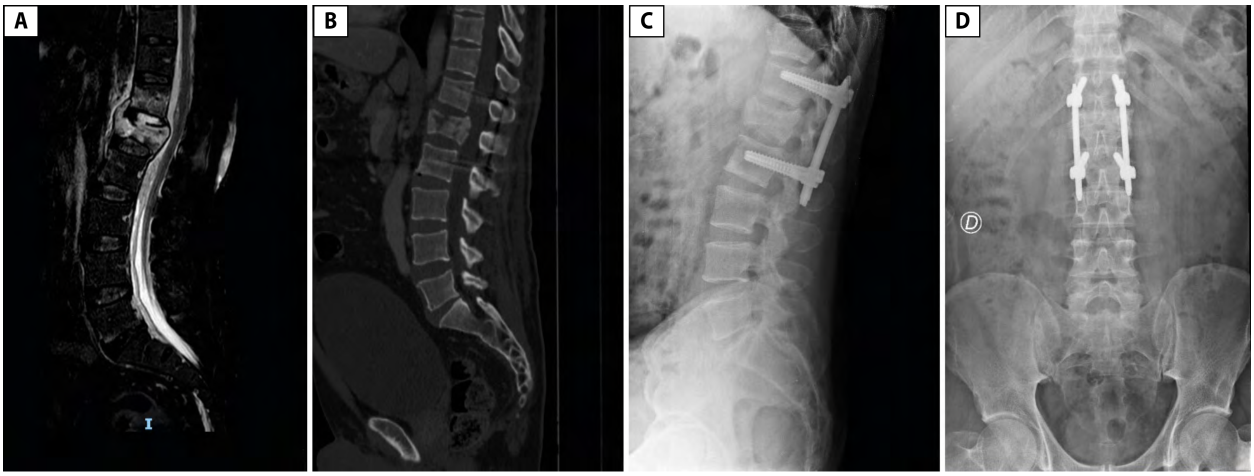

Figure 3. Follow-up of radiographical changes after short spinal instrumentation in a 56-year-old man with an AO A4 L1 fracture due to a road accident. **A**. Preoperative STIR MRI imaging; **B**. Immediate postoperative CT scan; **C**. 12 months later, lateral X-ray follow-up; **D**. 12-month anteroposterior X-ray follow-up

six cases, the pain was irradiated with a radicular pattern to the inferior limbs. Five patients showed mild sensory deficits with a radicular distribution. Only two patients showed initial neurological deficits (motor weakness and sphincteric dysfunction) and were classified as AIS grade D.

The most affected level was L1 (62.8%), followed by L2 (25.7%), L3 (5.7%), L4 and L5 (2.8% each). See Table 1 for a summary of demographic and lesion characteristics. We observed a mean post-traumatic vertebral kyphotic deformation of 16.7° ± 5 and a mean sagittal Cobb angle of 11.7° ± 1.5. This value was slightly inferior for L1-L2 lumbar vertebrae (10.3° ± 2.3). The vertebral canal impaction ranged from 15-73% with a mean of 36.5% ± 12.5%. Baseline MRI demonstrated initial radiological signs of damage to the conus medullaris in 11 cases (31%), corresponding to patients with L1 or L2 fractures with severe dislocation of posterior fragments (mean canal compression of 49% ± 15).

Radiographic outcomes

An immediate (obtained within six days) postoperative CT scan demonstrated a significant reduction in vertebral kyphotic deformation (11.7° ± 1.6 vs 16.7° ± 5, $p < 0.001$) and sagittal Cobb angle (9.8° ± 1.3 vs 11.7° ± 1.5, $p < 0.001$). The correction resulting from posterior instrumentation was sustained over time, although slightly decreased, and remained significant at the 12-month follow-up for both kyphotic deformation (12.3° ± 1.4, $p = 0.03$) and Cobb angle (10.3° ± 0.9, $p = 0.04$). The overall radiological outcomes are set out in Table 2. We performed a subgroup analysis including only L1-L2 fractures (n = 31, 88% of the entire series). In this subgroup, the extent of the correction was larger than that observed in the entire series (3.4° ± 1.9; $p < 0.001$ relative to the pre-operative values) and was well sustained at the final follow-up (4.5° ± 2; $p < 0.001$). Patients requiring laminectomy shared a mean 52% ± 10% reduction in vertebral canal diameter. After surgery, these patients gained significant dural sac decompression. At the final follow-up, we did not experience implant failure or screws pullout.

Table 1. Baseline characteristics of patients included in this study

Overall population		Patients (n = 35)
Demographics	Age	51.4 ± 19.7
	Age > 50	21 (60)
	Male	23 (65.1)
	Female	12 (34.2)
Fractures AO grade	AO A3	17 (48.5)
	AO A4	18 (51.3))
Aetiology	Road accident	19 (54)
	Fall	16 (46)
Location	L1	22 (62.8)
	L2	9 (25.7)
	L3	2 (5.7)
	L4	1 (2.8)
	L5	1 (2.8)
Intracanal fragment	Severe (> 25%)	17 (48)
	Moderate (< 25%)	18 (52)
	Mean canal compression	36% ± 17
	Mean compression in severe	52% ± 10
Damage	Conus medullaris	11 (31)
Symptoms	Lumbar pain	35 (100)
	Irradiated pain	6 (17.1)
	Sensory disturbances	5 (14.2)
	Motor weakness	2 (5.7)
	Sphincteric dysfunction	2 (5.7)
Clinical outcome at last follow up	Improved	32 (91.4)
	Stable	3 (8.5)
	Worse	0 (0)
Surgery	Short posterior fixation	35 (100)
	cement augmented	10 (28)
	+ laminectomy	17 (48.5)
	Mean hospital stay (d)	5 ± 2.5

Continuous variables are expressed as mean ± standard deviation or median [range], whereas dichotomic variables are expressed as frequency (%); d — days; AO — AO spine classification of thoracolumbar fractures

Table 2. Radiological changes after short lumbar posterior fixation

Timepoint	Vertebral kyphotic deformation (n = 35)	Sagittal Cobb angle (n = 35)	Sagittal Cobb angle - upper lumbar (L1-L2, n = 31)
Pre-operative	16.7° ± 5	11.7° ± 1.5	10.3° ± 2.3
Postoperative	11.7° ± 1.6	9.8° ± 1.3	3.4° ± 1.9
p-value	< 0.001	< 0.001	< 0.001
Pre-operative	16.7° ± 5	11.7° ± 1.5	10.3° ± 2.3
12-month follow up	12.3° ± 1.4	10.3° ± 0.9	4.5° ± 2
p-value	0.03	0.04	< 0.001

Continuous variables are expressed as mean ± standard deviation

Clinical outcomes

Twelve months after surgery, we recorded a 91.4% improvement in presenting symptoms (Tab. 1). Lumbar pain without leg irradiation was consistently the first symptom to recede following posterior instrumentation. Pain irradiating to the lower limbs and segmentary motor weakness started to improve later during the follow-up and had completely resolved at eight months. Sensory and sphincteric disturbances had a slower course. Sensory disturbances showed complete resolution only at the final follow-up in three cases while remaining stable in two patients. Similarly, patients presenting with sphincteric disturbances did not achieve any improvement at the final follow-up.

Discussion

Surgery is the mainstay of treatment for the correction of lumbar burst fractures with neurological deficits. Over recent decades, posterior decompression with pedicle screw fixation has played an increasing role, overcoming the limitations of laminar hooks and allowing for good rigid fixation [24]. The advantages of posterior instrumentation include immediate spinal canal decompression, intracanal fragments identification, and ligamentotaxis [25]. However, the differences between long and short posterior instrumentation are not obvious [26, 27].

Traditionally, pedicle screws were only inserted above and below the injured vertebral body. Although this surgical procedure is known to save the segmental motion of the vertebral body, poor surgical outcomes such as spinal non-union, implant failure, and increased kyphosis have been reported [28, 29]. Longer posterior instrumentation, on the contrary, is generally perceived as achieving a better distribution of biomechanical stress across the fused metamers and ensuing complications [27]. However, the notion of poorer surgical outcomes obtained with short instrumentation has been recently questioned [27], and recent works have reported similar results in terms of kyphosis correction, maintenance of sagittal alignment, and complications rate attained by both surgical strategies [11]. Moreover, we must remember that the biomechanical needs of a lumbar burst fracture are mainly relevant only in the first year after the traumatic event. Once spinal fixation has been achieved, long constructs exert a toll in terms of spinal stiffness and patient compliance [27].

This study presents our experience with short instrumentation of burst lumbar fractures using polyaxial screws. Some authors have advocated a slightly better outcome in patients implanted with monoaxial screws in terms of restoration of vertebral height [30]. However, the same study observed similar vertebral kyphotic angles (N.B. named Cobb angle in the original publication), admitting a prominent role played by the rods in achieving a good kyphosis correction.

In accordance with previous reports [11–19], we observed good immediate correction of the kyphosis resulting from vertebral fracture. Specifically, we recorded a satisfactory correction of kyphotic deformation at the level of the fractured vertebra and a reduction of the sagittal kyphotic Cobb angle. The reported immediate postoperative value of 9.8° ± 1.3 for sagittal Cobb angle refers to the whole series. Owing to the physiological lordosis of lower lumbar levels (L3–L5), burst fractures at these levels contributed to most of the overall kyphotic deformation.

We, therefore, performed a subgroup analysis including only L1–L2 fractures (88% of the entire series) and found an even larger correction index at this level. The extent of the correction is comparable to that shown in reports of posterior fixation with the inclusion of the fractured level [11] and fixation followed by anterolateral fusion (about 3° immediate post-op) [27]. It has been traditionally argued [8] that, despite immediate satisfactory results, in the long term, there could be loss of correction and fixation failure due to the four-pedicle screw fixation (being a double plane fixation) inducing simultaneous quadrilateral and suspension effects [16]. We did observe a slight decrease in the correction of both kyphotic angles; however, this correction was still significantly sustained at the 12-month follow-up and was attested at 4.5°. We note that Todeschi et al. reported an 8.5° sagittal Cobb angle at 24 months following short posterior fixation + anterolateral fusion [27].

In addition to this, we did not observe screws pullout or implant failure, although the relatively short follow-up might have been insufficient to detect late complications or further loss of correction. Importantly, no intraoperative complications, CSF leaks, screw malpositions, or implant pullouts were recorded at the final follow-up. Although patients with severe neurological deficits were excluded from this series, we observed a good rate of resolution of presenting symptoms, except for three cases with L1 burst and conus medullaris damage, whose symptoms remained stable at the final follow-up.

Limitations

The limitations of this study include its retrospective design, the lack of a control group, and the relatively short follow-up. Due to our strict inclusion and exclusion criteria, the number of cases meeting our requirements was relatively small. Further investigations are therefore necessary to evaluate longer follow-ups and determine the long-term efficacy of these interventions in treating lumbar burst fractures.

Conclusions

Given the aforementioned limitations, this experience with short instrumentation of complete and incomplete lumbar fractures suggests that limiting spinal instrumentation to one level above and below is a safe and effective treatment. Patients experience an almost global resolution of symptoms, while no peri-operative complications, late implant failure, or screws pullouts were recorded. All our included patients fared well.

These results suggest that short instrumentation might not be inferior to longer lumbar spine fixation, although further, larger studies are needed to confirm this.

Article information

Data availability statement: *The authors confirm that the data supporting the findings of this study is available within the article, figures, and tables.*

Ethics statement: *All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.*

The ethical review process and approval by our ethics committee were not required for the present study because it is a retrospective study on patients that required a life-saving intervention. Furthermore, the research data analysis does not affect the participants and their medical care.

Authors' contributions: *Conceptualization: PDD, AM; Data collection: PDD, RP, DC, MR, AM; Statistical analysis: PDD; Manuscript drafting: PDD, RP; Revision and final approval: MR, AM.*

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