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Original article

Posterior percutaneous reduction and fixation of thoraco-lumbar burst fractures

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ABSTRACT

Background: Treatment of A3 thoraco-lumbar and lumbar spinal fractures nowadays remains a controversial issue. Percutaneous techniques are becoming very popular in the last few years to reduce the approach-related morbidity associated with conventional techniques.
Hypothesis: Purpose of the study was to analyze the clinical and radiological outcome of patients who underwent percutaneous posterior fixation without fusion for the treatment of thoraco-lumbar and lumbar A3 fractures.
Materials and methods: Sixty-three patients, having sustained a single-level thoraco-lumbar fracture, underwent short segment percutaneous instrumentation and were retrospectively analyzed. sagittal index (SI) was calculated in all patients. Clinical and functional outcome were evaluated by Visual Analog Scale (VAS), Oswestry Disability Index (ODI) and Short Form General Health Status (SF-36).
Results: Average operative blood loss was 82 mL (50–320). Mean pre-operative SI in the thoraco-lumbar segment was 13.3° decreased to 5.8° in the immediate postoperative with a mean deformity correction of 7.5. Mean pre-operative SI in the lumbar segment was 16.5° decreased to 11.3° in the immediate postoperative with a mean deformity correction of 5.2. Not statistically significant correction loss was registered at 1-year minimum follow-up. Constant clinical conditions improvement in the examined patients was observed.
Conclusion: Percutaneous pedicle screw fixation for A3 thoraco-lumbar and lumbar spinal fractures is a reliable and safe procedure.
Level of evidence: Level IV. Retrospective study.

1. Introduction

Treatment of thoraco-lumbar and lumbar burst or A3 fractures according to Magerl Classification [1], without neurologic injury, is, nowadays, a controversial issue. Evidence-based guidelines for the treatment of traumatic fractures of the thoracic and lumbar spine are lacking and the scientific evidence is largely based on retrospective case-series [2]. Wood et al. demonstrated that treatment of patients with a stable thoraco-lumbar fracture and normal findings on the neurological examination provided no major long-term advantage compared with non-operative treatment. Disadvantages of non-operative management are related to early or late complications as residual kyphosis, pressure sores, prolonged recumbence, deep vein thrombosis [3]. Today, there is a growing consensus that post-traumatic kyphotic deformity or vertebral fracture's non-union are responsible for persistent back pain and inability to return to normal daily activity [4,5]. Theoretical rationale for operative management is to obtain an immediate mechanical stability, a reduction of deformity and to restore good sagittal alignment of the spine [6]. The advantages of surgical versus conservative treatment are a better clinical outcome, reduction of deformity and earlier patient mobilization [3]. Open posterior short segment pedicle instrumentation is largely accepted for the treatment of thoraco-lumbar and lumbar fractures [5,6]. Nevertheless, disadvantages of extensive exposure typical of conventional surgery are largely recognized. Minimally invasive vertebral cement augmentation techniques such as vertebroplasty or kyphoplasty offer the patient the alternative treatment to prolonged bed rest or major spine surgery with relatively low risk and reportedly high clinical success rates [7]. In addition to vertebral augmentation performed with bone cement alone, the past

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decade has also seen the development of other percutaneous systems using supplemental intracorporeal devices. One of the first systems described in this category was the vertebral body stent (VBS) introduced in the year 2002 [8]. In the last few years, few studies [9–11] on the safeness and validity of the percutaneous pedicle screw instrumentation for thoraco-lumbar fractures have been published [2,12]. Purpose of our study was to analyse the clinical and radiological outcome of patients who underwent percutaneous posterior fixation without fusion for the treatment of thoraco-lumbar and lumbar A3 fractures [8]. In the last few years, few studies [9–11] on the safeness and validity of the percutaneous pedicle screw instrumentation for thoraco-lumbar fractures have been published [2,12]. Purpose of our study was to analyse the clinical and radiological outcome of patients who underwent percutaneous posterior fixation without fusion for the treatment of thoraco-lumbar and lumbar A3 fractures.

2. Materials and methods

Since May 2005 to March 2009, 63 patients have undergone short posterior percutaneous instrumented fixation for single level traumatic type A3 fracture of thoraco-lumbar/lumbar spine, at our institution. Three patients were lost to follow-up and were excluded from the study. Sixty patients, 38 males and 22 females, with an average age of 51.2 (range 20–65) were analysed in a retrospective way. In all cases, Pathfinder system (Zimmer-Abbot Spine Austin Texas) was implanted using 4 pedicle screws, one level above and one below the fractured vertebra (Fig. 1a, b). Inclusion criteria were: single-level A3 fracture, age ranged between 18 and 65 years, no neurological involvement and fracture level between T11 and L5 (Table 1). Exclusion criteria were: pathological or osteoporotic fracture, multilevel fracture, previous surgery at site of fracture. Instrumented levels ranged from T10 to S1.

Patients were in prone position on a radiolucent operating table. First step is to localize the entry points into the pedicles on a two-dimensional plane. A series of 4 sequential dilators are then used to dilate and expand the musculature and fascia. After the largest dilator is in place, the 3 inner dilators are removed, leaving the outer largest dilator along with the guide wire in place. At this point, the constructed extender sleeve attached to the canulated polyaxial screw is inserted as a single construct using the fitted canulated screwdriver. Then, a titanium rod was inserted through the caudal skin incision, was bluntly advanced through the muscle and was engaged to the poliaxial canulated screws. In some cases, correction on the sagittal plane in distraction or compression way were performed.

Table 1
Table showing the demographic data of the study's population.

Demographic data	
Sex	
Male	38
Female	22
Mechanism of injury	
Fall from height	22
Car injury	21
Motor vehicle accident	17
Politrauma	15
BMI (kg/m^2)	
16–18.50	2
18.51–24.99	27
25–29.99	25
30–34.99	6
Type of fracture	
A3.1	28
A3.2	8
A3.3	24
Level of fracture	
T11	5
T12	17
L1	17
L2	8
L3	9
L4	3
L5	1

Thirty-five of sixty patients underwent two second surgery in order to remove the instrumentation percutaneously after fracture healing while the other twenty-five patients refused a second surgical procedure. Of the 35 patients who accepted hardware, removal underwent thin-cut CT scans (2.5 mm contiguous, non-overlapping images, reconstructed at 2 mm intervals in order to obtain sagittal and coronal reformats) of the pertinent spinal levels to evaluate screw positioning and fracture healing. Radiological follow-up of the other 25 patients was performed with only plane X-ray exams avoiding unnecessary or excessive radiation dose exposure correlated to computed tomography, therefore pedicles screw positioning was not analyzed.

Image interpretation was performed by three independent observers (two senior spinal surgeons and a senior radiologist). Evaluation of screw placement was performed according to Youkilis' criteria: grade 1, screws were not counted as violations, because they replaced the pedicular cortex without extending beyond it. Grade 2 violations were defined as screws that extended less than 2 mm beyond the pedicular cortex, whereas grade 3 violations were defined as screws found to be more than 2 mm outside of the cortical margin [13]. Sagittal index (SI) in accordance to Farcy' s criteria [14] was calculated in all 60 patients, with a dedicated software (Kodak DirectView Picture Archiving and Communication System), in the pre-operative and postoperative time.

Clinical and functional outcome were evaluated, in all patients, by Visual Analog Scale (VAS), Oswestry Disability Index (ODI) and Short Form General Health Status (SF-36) at regular intervals (pre-operative, 15 days, 1 month, 3 months, 6 months, 12 months and every year postoperative). Patients were divided in two groups respect to the pre-operative SI value: a group A with a SI value between $10^\circ \leq 15^\circ$, patients of this group were carefully selected patients in which surgical treatment was presented as an alternative to best rest and cast immobilization considering their high functional daily-life request and a group B with a SI value $> 15^\circ$. Clinical outcome and kyphosis correction of the 2 groups was compared at a one-year minimum follow-up. The data of all consecutive patients treated since May 2005 to March 2009 were included in this study and analyzed in a retrospective fashion.

3. Statistics

Statistical analysis was conducted using paired *t* test for continuous variables as SI value and Chi^2 test verified with Fisher's exact test for non-parametric data as Oswestry Disability Index and SF-36 data and Visual Analog Scale. Significance was established for $P < 0.05$. The tests were carried out with SPSS software (SPSS Inc, Chicago, IL).

4. Results

Among the screws, 240 were implanted in 60 consecutive patients. Average surgical time was 67 minutes (range, 50–96 min). Average intra-operative blood loss was 82 mL (range 50–320 mL). The median length of hospital stay after surgery was 4.9 days (range 3–7). All patients were successfully mobilized at first postoperative day. Placement of the 140 pedicle screws was analyzed in 35 patients who underwent second surgery. Screw placement was

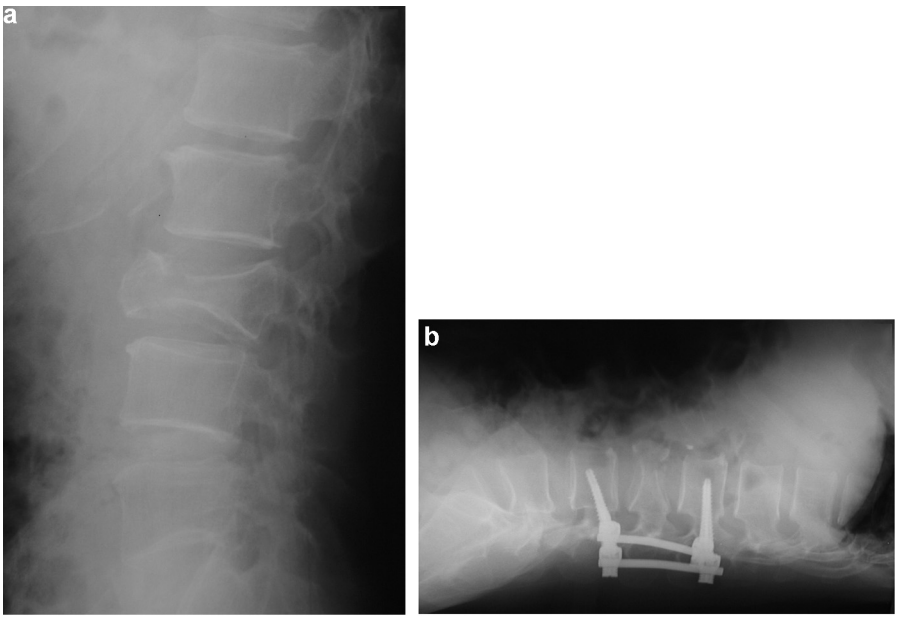

Fig. 1. a: pre-operative lateral X-ray showing L 3 A3.3 fracture; b: a six-month lateral X-ray showing percutaneous short pedicle fixation with four screws (one level above and below the vertebral fracture) and restoration of the sagittal index.

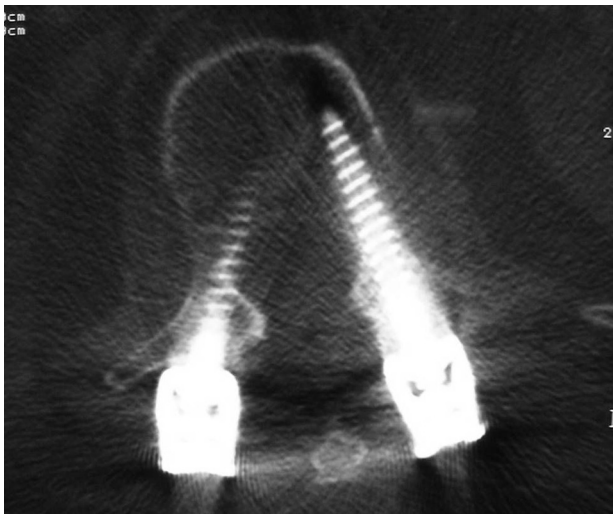

Fig. 2. Right screw encroached the medial pedicle cortex of L1 at axial CT scan. It was evaluated as "acceptable" placement according to Youkilis' criteria.

considered good (grade 1) in 95.72% (134/140) and acceptable (grade 2) in 4.28% (6/140) that encroached the pedicular cortex (Fig. 2). There is no neurological root injury or irritation due to screw misplacement (Table 2). There is no correlation between the instrumented level and screw misplacement ($P > 0.05$). Median pre-operative SI in the thoraco-lumbar spine was 13.3 degree (range 8–26) decreased to 5.8 (range 0–18) in the immediate postoperative with a mean deformity correction of 7.5 degree ($P < 0.001$). In the lumbar spine, median pre-operative SI was 16.5 degree (range 0–24) decreased to 11.3 (range 4–16) in the immediate postoperative with a mean deformity correction of 5.2 degree ($P = 0.001$). At a 1-year minimum follow-up, the mean SI was 8.0 degree (range 0–22) in the thoraco-lumbar spine with a correction loss of 2.2 degrees ($P > 0.05$) while SI in the lumbar spine was 14.8 (range 2–23) whit a correction loss of 3.5 degree ($P > 0.05$). The SI improvement was more significant in the thoraco-lumbar junction, in the lumbar spine a not statistically significant ($P > 0.05$) correction loss at 12 months after surgery were found (Table 3).

Clinical and functional results showed a great decrease of the VAS score, in the first 15 days, followed by a large progressive decrease until the first 3 months follow-up. A non-statistical increase in the VAS score ($P > 0.05$) was registered at 6 months follow-up, grew steadily at 12 months minimum follow-up. Oswestry Disability Index and SF-36 showed a different trend with a progressive and constant clinical conditions improvement of the examined patients (Figs. 3–5a, b). Patients were divided in two groups A and B, considering the pre-operative SI. Group A included 39 patients with a pre-operative SI between 10° and 15°; group B included 21 patients with a pre-operative SI major than 15°. The 2 groups were compared taking into account the VAS score,

Table 2
Table showing location and direction of screw misplacement.

Screw placement	Number of screw	Number of patient
Good	134 (95.72%)	30
Acceptable	6 (4.28)%	5
Not acceptable	0 (0%)	0
Location of misplacement		
T11	1	1
T12	1	1
L1	2	1
L2	1	1
L3	1	1
Direction of misplacement		
Medial	4	3
Lateral	2	2

Table 3
Table showing the postoperative sagittal index changes of the treated levels in the thoraco-lumbar (TL) and lumbar spine.

Sagittal index	T-L (T11-L1)	Lumbar (L2-L5)
Preoperative	13.3	16.5
Postoperative	5.8	11.3
Post-reduction change	7.5	5.2
	$P < 0.001$	$P = 0.001$
6 months	7.9	14.5
12 months	8	14.8
One-year correction loss	2.2	3.5
	$P > 0.05$	$P > 0.05$

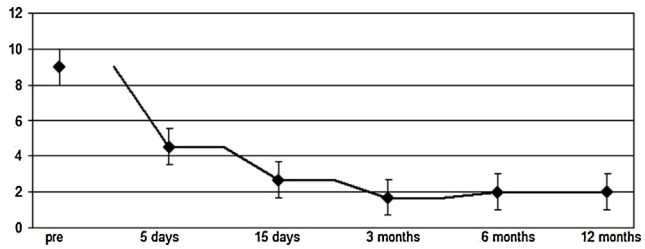

Fig. 3. Results Visual Analog Scale score after a 12-month minimum follow-up; patients $n = 60$, $P = 0.001$.

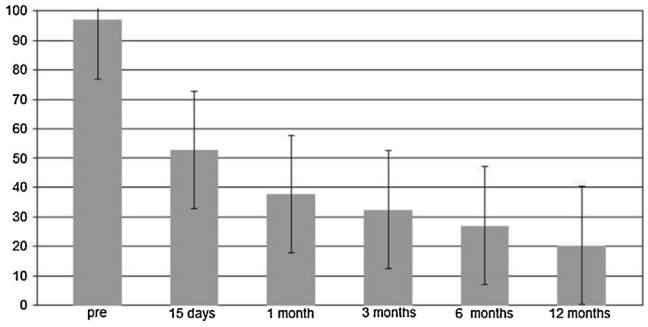

Fig. 4. Results of the Oswestry Disability Index after a 12-month minimum follow-up; patients $n = 60$, $P = 0.001$.

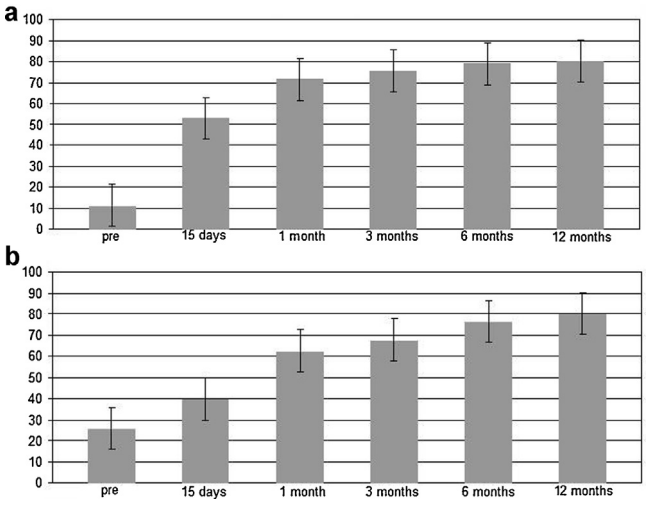

Fig. 5. a, b: results of the SF-36 Physical and Mental Component after a 12-month minimum follow-up; patients $n = 60$, $P = 0.001$.

Table 4
Table showing the correlation between pre-operative sagittal index and clinical outcome at 1-year minimum follow-up.

	Preoperative SI $10 \leq 15^\circ$ 39 patients		Preoperative SI $> 15^\circ$ 21 patients	
VAS 12 months	1.8 $P = 0.003$		4.25	
ODI 12 months	12% $P = 0.002$		38%	
SF-36 12 months	PCS 83.2% $P = 0.002$	MCS 79.9% $P = 0.005$	PCS 73.5%	MCS 68.8%

ODI and SF-36 values at 12 months minimum follow-up. Group A patients showed an average VAS score at 12 months minimum follow-up of 1.8 (range 0.5–2.5), instead, group B patients of 4.25 (range 1.4–6.2) $P = 0.003$. Average ODI value in group A was 12% (range 5%–17%), and 38% (range 17%–45%) in group B, $P = 0.002$. Average SF-36 (physical component) was 83.2% (range 67.5%–95.4%) in group A; and 73.5% (range 57.6%–85.3%) in group B, $P = 0.002$. Same trend showed the mental component with median value of 79.9% (range 63.2%–83.5%) in group A and of 68.8% (range 53.2%–75.6%) in group B, $P = 0.005$. The clinical and functional outcome values at 12 months minimum follow-up showed a statistically significant difference in the 2 groups, so the pre-operative SI could play an important role in the postoperative clinical outcome (Table 4). Median pre-operative SI in group A, was 12.5 degree (range 10–15) decreased to 7.2 (range 4–11) in the immediate postoperative with a mean deformity correction of 5.3 degree ($P = 0.003$). Median pre-operative SI in group B was 18.7 degree (range 16–24) decreased to 11.7 (range 10–19) in the immediate postoperative with a mean deformity correction of 7 degree ($P = 0.004$). At a 1-year minimum follow-up, the mean SI in group A was 9.3 degree (range 10–15) with a correction loss of 2.1 degrees ($P > 0.05$) and of 15.4 degree (range 13–22) in the group B with a correction loss of 3.7 (> 0.05). One patient returned to clinic at 6 weeks with a superficial dehiscence that was treated conservatively with routine wound care and a 10-day course of oral antibiotics. One patient presented a deep wound infection after 1 month. Revision surgery was necessary to remove the internal fixator and a conservative treatment with a custom made brace was performed. At 48 months maximum follow-up, no hardware failure was observed. One hardware failure was registered at five years follow-up in a patient who refused removal of fixator (Fig. 6a–c).

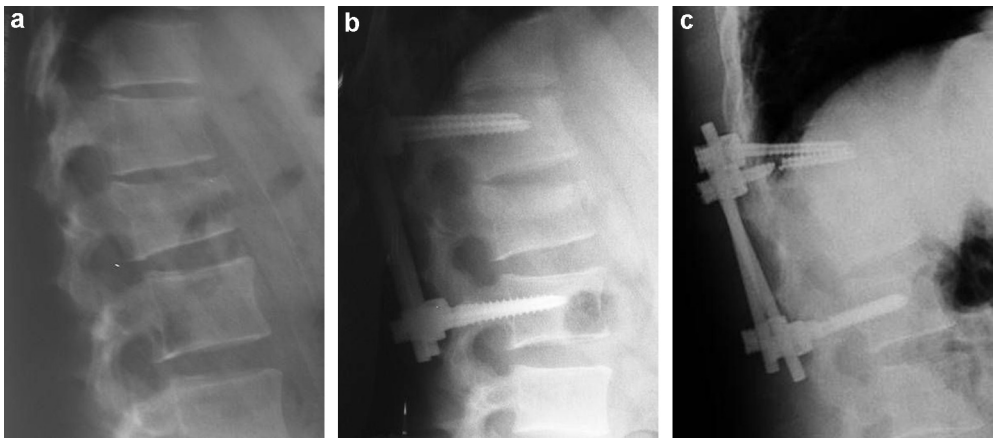

Fig. 6. a: preoperative; b: 1 year and c: five years postoperative X-ray showing the failure of percutaneous instrumentation due to the absence of the fusion that leads to cranial and caudal screws breakage.

5. Discussion

Standard midline posterior spinal approaches can lead to a significant muscle morbidity resulting from iatrogenic muscle denervation, increased intramuscular pressure, ischemia, due, for example, to the use of retractors and revascularization injury [15]. All of these effects can lead to important postoperatively symptoms [16]. The posterior conventional approach can be, also associated with significant morbidity due to increased infection rates and high blood loss [17]. Chronic denervation and atrophy of muscles increase incidence and intensity of postoperative pain [19]. Consequently, the rationale for applying percutaneous techniques in the management of thoraco-lumbar trauma is to reduce the approach-related morbidity associated with conventional techniques (Fig. 6). These aspects are well-known in polytrauma patients underwent percutaneous screw fixation who showed a better outcome compared to open surgery group [18]. The use of minimal invasive surgery for treatment of thoracic and lumbar fractures is nowadays a largely debated issue. However, few have described percutaneous technique for treatment of thoraco-lumbar and lumbar vertebral fractures [19,20]. Minimally invasive surgery (MIS) allows to reduce intra-operative blood loss, in our experience average blood loss was 82 mL, no patients required intra-operative and postoperative blood transfusion, all patients were able to walk one day after surgery with consequent lower incidence, pulmonary emboli, use of analgesic drugs and hospitalization cost [21,22]. A limitation to percutaneous screw fixation is the absence of arthrodesis, however fixation without fusion for the treatment of vertebral fractures showed good results if the score according to load-sharing classification is 6 or less [19]. In medical literature, pedicle screw displacement rates strictly depend on the surgeon's experience and different methods of screw evaluation, ranging from 8% to 40% in open surgery [23,24]. McGowan et al. [25] reported 6% pedicle violation for 118 percutaneous screw inserted from T10 to S1. In our study, percutaneous pedicle screw was implanted from T10 to S1 reporting a pedicle violation of 4.28% for 140 screws. In the authors' experience, the learning curve plays a primary role in the correct screw positioning. Brace and bed rest represent a possible treatment for thoraco-lumbar or lumbar type A fractures and is considered a valid alternative to surgical approach. The main disadvantage is represented from residual kyphotic deformity after treatment. Percutaneous treatment allows SI correction comparable with those reported for open surgery [21]. Tropiano et al. reported an increase of kyphotic deformity, yet after four months increased at last follow-up after closed reduction in patients affected from thoraco-lumbar and lumbar burst fractures treated with brace [4]. Surgical treatment allows significant reduction of regional deformity, moreover instrumentation is useful to maintain a good alignment until healing of the fractured vertebra, in our series a decrease of SI correction is visible only to 6 months and is not statistically significant in either the thoraco-lumbar or lumbar spine. Siebenga et al in 2006 studied radiological and clinical outcomes in two groups of patients treated with surgical and conservative approach and described a significant difference of reduction and clinical outcome in favour of surgical treated patients [26]. In our study, all patients treated showed a good improvement of the sagittal deformity after surgery, the correction was maintained until the last follow-up. In our experience, an important parameter to evaluate clinical outcome is represented by the pre-operative SI, in fact there is a statistically significant correlation between a lower value of SI before surgery and a better clinical outcome after surgery. A smaller pre-operative deformity is correlated to preservation of the vertebral body structure allowing a better maintenance of the deformity correction during follow-up. According to literature, improvement of SI value was more significant in thoraco-lumbar fracture, this difference is due to the biomechanics propriety of this segment that represent a transition zone from the inflexible thoracic spine to the mobile lumbar spine [4]. Blondel et al., in their experience, described good results associating balloon kyphoplasty and percutaneous osteosynthesis with polyaxial screw to preserve the minimally invasive aspect of the procedure, obtaining an improvement in the mean local kyphosis, with 2° angle loss at 24 months of follow-up.

6. Conclusions

Results of our study demonstrated that percutaneous pedicle screw fixation for thoraco-lumbar and lumbar type A3 fractures is a reliable and a safe procedure. Percutaneous spinal fixation do not replace the other open technique but add to treatment options [27,28].

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

[1] Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3:184–201.
[2] Lehman W, Ushmaev A, Ruecker A, et al. Comparison of open versus percutaneous screw insertion in a sheep model. Eur Spine J 2008;17:857–63.
[3] Wood K, Butterman G, Mehbod A, et al. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg 2003;85–A:773–81.
[4] Tropiano P, Russel C, Huang CA, Louis AC, Poitout DG, Louis RP. Functional and radiographic outcome of thoracolumbar and lumbar burst fractures managed by closed orthopaedic reduction and casting. Spine 2003;28:2459–65.
[5] Oda I, Cunningham BW, Buckley RA, et al. Does spinal kyphotic deformity influence the biomechanic characteristics of the adjacent motion segment? An in vivo model study. Spine 1999;24:2139–46.
[6] Vaccaro AP, Silber JS. Posttraumatic spinal deformity. Spine 2001;26(Suppl. 24): S111–8.
[7] Heini P, Walchli B, Berlemann U. Percutaneous transpedcular vertebroplasty with PMMA: operative technique and early results. Eur Spine J 2000;9:445–50.
[8] Furderer S, Anders M, Schwindling B, et al. Vertebral body stenting. A method for repositioning and augmenting vertebral compression fractures. Ortopade 2002;31(4):356–61.
[9] Panjabi MM, Oxland TR, Kifune M, et al. Thoracolumbar burst fracture a biomechanical investigation of its multidirectional flexibility. Spine 1994;19:478–585.
[10] Wiesner L, Kothe L, Shulitz KP, Ruther W. Clinical evaluation and computer tomography scan analysis of screw traces after percutaneous insertion of pedicle screws in the lumbar spine. Spine 2000;25:615–21.
[11] Ringel F, Stoffel M, Stuer C, Meyer B. Minimally invasive transmuscular pedicle screw fixation of the thoracic and lumbar spine. Neurosurgery 2006;59:361–7.
[12] Logroscino CA, Proietti L, Pola E, Scaramuzzo L, Tamburrelli FC. A minimally invasive posterior lumbar interbody fusion for degenerative lumbar spine instabilities. Eur Spine J 2011;20:S41–5.
[13] Youkilis AS, Quint DJ, McGillicuddy JE, Papadopoulos SM. Stereotactic navigation for placement of pedicle screws in the thoracic spine. Neurosurgery 2001;48:771–9.
[14] Farcy JP, Weidenbaum M, Glassmann SD. Sagittal index in management thoraco-lumbar burst fractures. Spine (Phila Pa 1976) 1990;15:958–65.
[15] Styf J, Willen J. The effects of external compression by three different retractors on pressure in the erector spine muscles during and after posterior lumbar spine surgery in humans. Spine 1998;23:354–8.
[16] Kim KT, Lee SH, Suk KS, Bae SC. The quantitative analysis of tissue injury markers after mini-open lumbar fusion. Spine 2006;31:712–6.
[17] Verlaan JJ, Diekerhof CH, Buskens E, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine 2004;29:803–14.
[18] Scaramuzzo L, Tamburrelli FC, Piervincenzi E, Raggi V, Cicconi S, Proietti L. Percutaneous pedicle screw fixation in polytrauma patients. Eur Spine J 2013;22(Suppl. 6):S933–8.
[19] Wen-Fei N, Yi-Xing H, Yong Long C, et al. Percutaneus pedicle screw fixation for neurologic intact thoracolumbar burst fractures. J Spinal Disord Tech 2010;23:530–7.
[20] Logroscino CA, Proietti L, Tamburrelli FC. Minimally invasive spine stabilisation with long implants. Eur Spine J 2009;18:75–81.
[21] Wang MY, Anderson DG, Polestra KA, Ludwig SC. Minimally invasive posterior fixation. Neurosurgery 2008;63:A197–203.

[22] Mroz TE, Abdullah KG, Steinmetz MP, et al. Radiation exposure to the surgeon during percutaneous pedicle screw placement. J Spinal Disord Tech 2011;24:264–7.
[23] Haaker RG, Eickoff U, Steffen R, et al. Verification of the position of pedicle screw in lumbar spinal fusion. Eur Spine J 1997;6:125–8.
[24] Castro WHW, Halm H, Jerosch J, et al. Accurancy of pedicle screw placement in lumbar vertebrae. Spine 1996;21:1320–4.
[25] McGowan DP, Ruflin G, Stanisic M, et al.Percutaneus placement of pins for external spine fixation: a laboratory assessment. 1991.
[26] Siebenga J, Leferink VJ, Segers MJ, et al. Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment. Spine (Phila Pa 1976) 2006;25:2881–90.
[27] Blondel B, Fuentes S, Pech-Gourg G, Adetchessi T, Tropiano P, Dufur H. Percutaneous management of thoracolumbar burst fractures: evolution of techniques and strategy. Orthop Traumatol Surg Res 2011;97:527–32.
[28] Court C, Vincent C. Percutaneous fixation of thoracolumbar fractures: current concepts. Orthop Traumatol Surg Res 2012;98:900–9.