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ORIGINAL ARTICLE

Posterior segmental fixation for thoraco-lumbar and lumbar fractures: a comparative outcome study between open and percutaneous techniques

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ABSTRACT

Purpose: Showing results of open and percutaneous surgical management of traumatic AO type A3, A4 and B2 thoracic and lumbar fractures.

Methods: Retrospective comparative analysis of traditional open fusion versus percutaneous navigated fixation of thoracic and lumbar spinal fractures. Minimum 24 months follow-up to collect ODI and VAS outcome scores for comparative analysis was required.

Results: Fifty-seven patients with a mean age of 39 years met the inclusion criteria. Twenty-six patients were in the open group (Group O) and 31 in the percutaneous group (Group P). The majority of fractures were either type A3 or A4; there were three type B chance fractures in Group O and one in Group P. VAS and ODI scores followed comparable trends in the two groups until the final follow-up. The main statistically significant result between the two groups was blood loss, which was lower in Group P (110 versus 270 ml in Group O on average), although this did not reflect into different clinical outcomes. Similar peri-operative measures of operating time and length of stay were found between the two groups. A significantly higher degree of loss of reduction was noted at follow-up in Group P (8° versus 5° in Group O on average).

Conclusions: Open and percutaneous posterior fixation techniques of thoracic and lumbar fractures in this cohort were associated with different perioperative blood losses as well as radiological measurements, but not with clinically meaningful differences in patient reported outcome measures at 24 months' follow-up.

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Thoracolumbar fracture; fixation; open; percutaneous; navigation

Introduction

Traumatic thoraco-lumbar spinal fractures can be treated in numerous ways from conservative to operative management. Various classification and scoring systems exist to describe traumatic thoraco-lumbar fractures, and when to intervene surgically.[1–4] However, there is no gold standard operation for every fracture that undergoes surgery. The general principle in fracture management is to stabilise the fracture, alleviate pain and allow bone healing, whilst preventing progressive spinal deformity and neurological deterioration. The variation in approach depends on the type and level of fracture and patient specific issues such as co-morbidities and patient preference. When opting for surgery, the conventional procedure has been an open midline approach for trans-pedicle screw fixation for stabilisation of the fracture and fusion. This has been done either in a short segment fashion (fixation above and below the fracture spanning and skipping the fractured level), in a long segment fashion (as above but with fixation two levels above and below the fractured level) or in a segmental fashion, i.e. with fixation above, at the level and at the level below the fracture.[5] Long term clinical results seem to favour the last two techniques, in particular with regards to rates of instrumentation failure and loss of kyphosis correction.[6,7] However, there has been an increasing trend towards minimally invasive spinal surgery (MIS) for percutaneous pedicle screw placement and rod fixation. It is felt MIS may be favourable in certain situations, especially improving peri-operative measures such as blood loss, soft tissue trauma, frequency of surgical site infections and length of stay in hospital.[8] Within the literature, there is a paucity of comparative evidence between conventional open and MIS techniques to match the progressive application of more minimally invasive surgery. This study aims at adding to the literature with a comparative analysis of these two surgical strategies for stabilising traumatic AO types A3, A4 and B [1] (burst and chance) fractures of the thoraco-lumbar region with segmental fixation of the injury, i.e. with inclusion of the fracture level into the instrumentation.

Methods

We conducted a retrospective comparative study between 2010 and 2014 at our institute, analysing the results and outcomes between segmental open fixation and fusion (Group O) versus minimally invasive percutaneous pedicle screw placement (Group P) using real-time navigation (with 3D image guidance) at a single institution under the care of an Orthopaedic (Group O) or a Neurosurgical (Group P) team. Patients were admitted under either team, according to the on-call rota for spinal emergencies of the same public health funded institution, a regional hospital and level 2 trauma centre covering a population of 500.000. The fractures studied were of the thoraco-lumbar spine, specifically AO types A3, A4 and B2 (burst and chance fractures).

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Inclusion criteria were above described traumatic fractures of the thoraco-lumbar spine, not requiring direct decompression of the dural sac due to progressive motor deficit, patients aged 18 years or older and a minimum follow-up time of two years to ensure adequate surveillance of fracture fixation failure or progressive deformity. Exclusion criteria were pathological fractures including fractures related to osteoporosis and cancer and patients with less than two years follow-up.

In both groups, after confirmation of informed consent by the treating team and induction of general anaesthesia, patients were positioned prone on a radiolucent breakable table over bolsters supporting chest and pelvis and relieving pressure from the abdomen as well as allowing passive and partial reduction of the fractured segment. Prepping and draping of the surgical site were identical. Spinal cord potentials were not recorded in either group.

In Group O, after fluoroscopic confirmation of the affected levels, a midline incision was performed over the segment to be instrumented, the fascia incised, the supraspinous and interspinous ligaments left intact if found to be so, the laminae and facets exposed via a subperiosteal dissection avoiding monopolar cautery and the exposure limited laterally to the origin of the transverse processes. Facets were then cut and decorticated both at the level and below the level of the fracture, saving those of the upper instrumented level. Cancellous bone retrieved from facets was prepared for subsequent posterior grafting and supplemented with 10 ml of tricalcium phosphate bone substitute. 6.5 mm diameter polyaxial titanium pedicle screws were positioned at the level above and below as well as at the fractured level after free manual probing and tapping of the pedicles with fluoroscopic assistance. Screw length was chosen at individual levels in order to reach the anterior third of the vertebral body, while at the fracture level the length was generally shorter than above to allow for potential anterior revision in case of later development of non-union. Titanium alloy rods, 5.5 mm in diameter, were later measured and cut as well as either left straight or contoured, according to the predicted kyphosis and lordosis of the levels involved. Reduction of the fracture was achieved by positioning on the table, release and cut of facet joints and finally by segmental compression of the levels above and below the fractured vertebra, using the latter as a pivot for compression and reduction. No distraction was ever applied to achieve reduction. A cross-connector could be used, depending on the perceived intraoperative stability of the construct. After fluoroscopic bi-planar views of implant positioning and fracture reduction, the laminae of the vertebrae involved were decorticated and mixed bone graft as described above was applied after thorough irrigation of the wound and haemostasis. The wound was then closed in layers with absorbable sutures and the skin approximated with metal staples.

In Group P, 3.5 mm diameter Jamshidi bone biopsy needles were positioned with stab incisions in the pedicles above, at the level and below the fracture under real time navigation after acquiring CT (3D) imaging. Following positioning of K wires, tapping and insertion of 5.5 or 6.5 titanium polyaxial fenestrated screws was done before contouring and positioning of 5.5 mm titanium rods. Reduction was achieved as per Group O with segmental compression through dedicated levers across the percutaneous fixation system, but without removal of the facet joints. No attempt at achieving fusion was made with decortication or application of bone substitutes. The stab wounds were then closed with metal staples or nylon interrupted sutures.

In Group O, direct decompression was performed via hemilaminectomy, only in case of symptoms related to frank radicular compression by bone fragments. No prophylactic laminectomy or direct manipulation of the posterior bony fragments was ever attempted, irrespective of the amount of canal compromise given the inclusion criterion of absence of motor deficit.

In Group O, a postoperative standing X-ray was routinely requested for the next day or for as soon as the patient would tolerate standing (Figure 1(A–D)). In Group P, a CT scan was achieved at the end of the procedure (Figure 2(A–D)). Patient controlled analgesia with opiates was usually withdrawn 24 hours after surgery and pain controlled with titrating doses of Paracetamol and weak opiates such as Tramadol. No restrictions to mobilisation or any use of postoperative braces were prescribed in postoperative instructions, in order to encourage and assist patients in mobilisation as early as tolerated with the aid of a team of physiotherapists.

Patients of both groups were followed-up for a minimum of two years at regular intervals with X-rays on arrival to the outpatient department at 3, 12 and 24 months. Clinical outcomes were compared using Oswestry Disability Index (ODI) and Visual Analogue Score (VAS) scoring systems at every clinical appointment and additionally at 6 and 18 months follow-up by telephone interview (Figures 3 and 4). Radiological parameters included in the analysis were post-traumatic kyphosis values and their post-treatment variations according to the Regional Kyphosis Angle (RKA),[9] i.e. the Cobb angle measured from the upper to the lower endplates of the vertebrae, above and below the fractured one (Figure 5, Table 2). Correction of RKA was calculated as percentage difference between the preoperative and postoperative RKA values (on X-rays in Group O and CT in Group P). Loss of RKA was similarly calculated between the postoperative and the follow-up RKA values (on standing X-rays in both groups, Table 2).

Peri-operative measures were recorded and compared (blood loss, operating time and length of stay in hospital). Complications were recorded as customary in this type of studies and included surgical site infections, CSF leaks, symptomatic mal-positioning of implants, development of deep vein thrombosis (DVT), pulmonary embolism (PE), pseudoarthrosis, loss of correction and death.

Student's t and Wilcoxon signed-rank tests were applied to assess normally and abnormally distributed clinical and demographic data respectively. The Kruskal–Wallis nonparametric H-test was used to test whether the three different fracture types originated from the same distribution. The Alpha error level was set at $p < .05$ and tests applied to measure differences in comparable groups.

Results

A total of 57 patients met the inclusion criteria. 26 patients were in the open surgery group (Group O) and 31 in the percutaneous fixation group (Group P). Middle aged men were significantly more numerous than same age women, and perhaps not surprisingly fracture prevailed in the thoraco-lumbar area, and were mostly burst type injuries with involvement of the upper endplate or AO type A3.[1] Fracture types were evenly distributed among Groups with the exception of B type fractures, only one of which was treated percutaneously. Nevertheless, given the sample size, no significant difference in fracture distribution was observed among groups. The main area where we found a statistical difference was in blood loss between the two groups, with

Figure 1. Pre- (A–B), post-operative (C–D) and follow-up (E–F) imaging of a patient treated for an A3 type fracture with open segmental fixation.

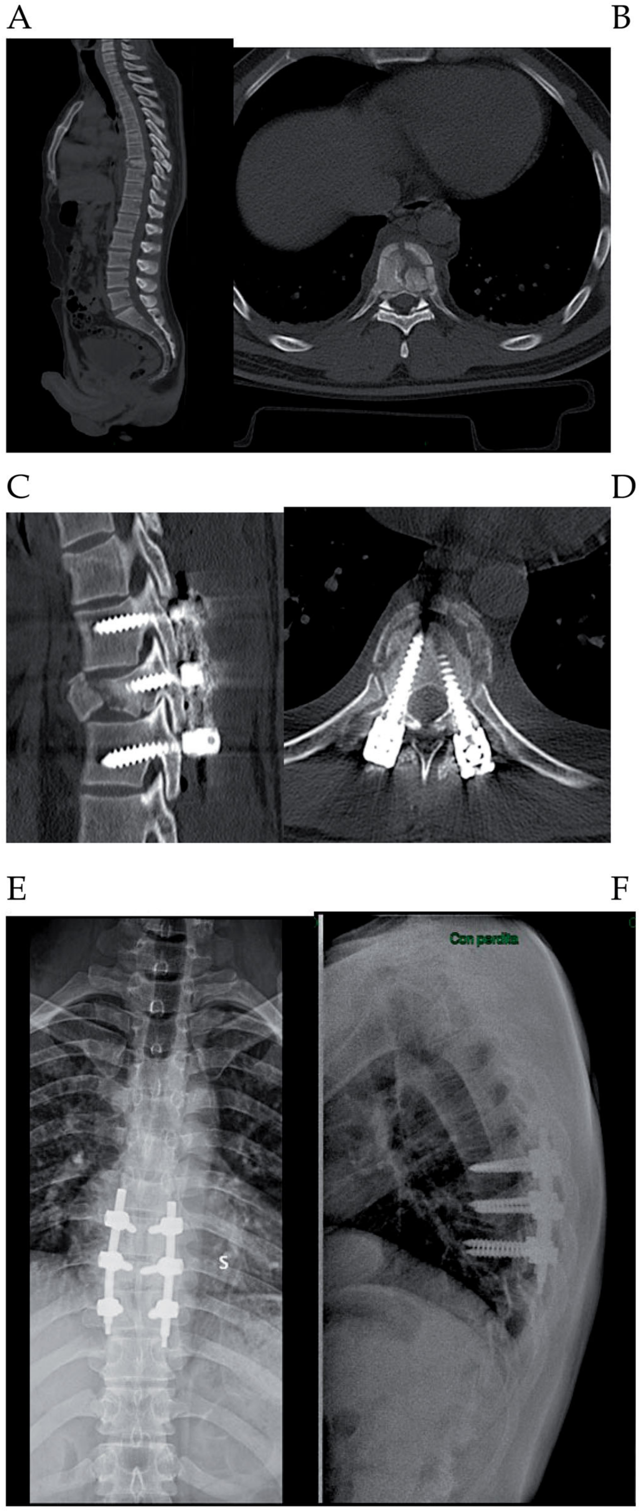

Figure 2. Pre- (A–B), post-operative (C–D) and follow-up (E–F) imaging of a patient treated for a B2 type fracture with closed segmental fixation.

Group O at 270 ml ± 35 ml and Group P at 110 ml ± 25 ml. No statistically significant difference was found in operative time. Length of hospital stay was similar at 6 days on average in both Groups (Table 1).

Considering the overall number of patients treated for traumatic AO type A3-4 and B2 fractures between 2010 and 2014 at our Institution, the rate of follow-up at 2 years was 26 out of 35 (74%) in Group O and 31 out of 40 (77%). One Patient in Group O succumbed 12 months after index surgery to sudden cardiac death, while the remainder did not have sufficient data for inclusion in the study.

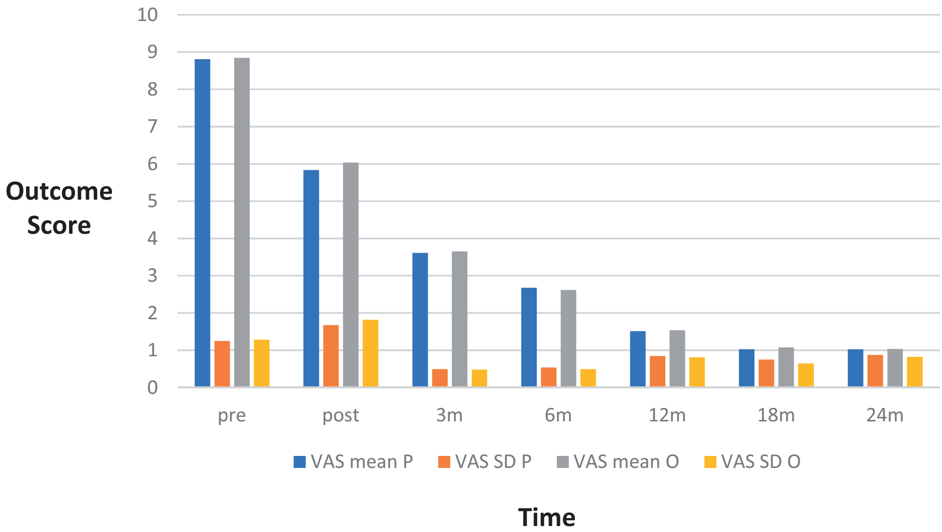

Figure 3. Comparative VAS means and standard deviations (SD) in the percutaneous (P) and open (O) fixation groups.

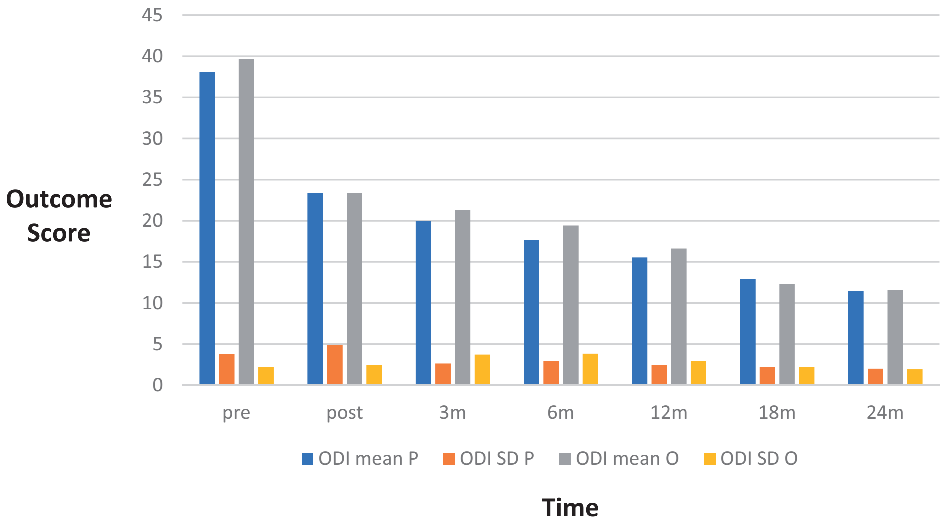

Figure 4. Comparative ODI means and standard deviations (SD) in the percutaneous (P) and open (O) fixation groups.

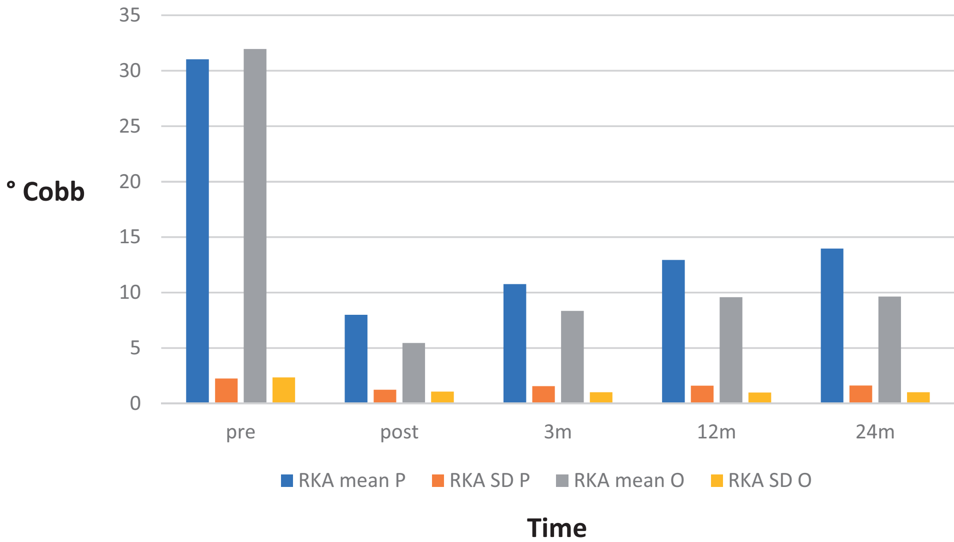

Figure 5. Comparative RKA means and standard deviations (SD) in the percutaneous (P) and open (O) fixation groups.

Table 1. A Summary of demographics and results in the 2 comparative groups.

	Group O	Group P	*p* Value
Mean Age (years)	38	41	.12
Follow-up (months)	24	24	1
Sex (M:F)	23:3	28:3	.02*
Mean Operating Time (min)	75	84	.14
Mean Blood Loss (mls)	270	110	.03*
A3 Type fracture	20	18	.60
A4 Type fracture	8	6	.92
B2 Type fracture	4	1	.12
Level of fracture	T1-10: 3	T1-10: 4	.50
	T11-L1: 20	T11-L1: 22	.10
	L2-4: 3	L2-4: 5	.61
Mean Length of Stay in Hospital	6 days	6 days	1
Number of patients	26	31	.08

*Significant.

Table 2. A Summary of the complications and clinical outcomes between the 2 groups.

	Group O	Group P	*p* Value
RKA % corr.	85 (26°)	75 (23°)	.05*
RKA % lost corr.	20 (4°)	35 (7°)	.05*
Superficial infection	nil	Nil	–
Deep infection	nil	1/31	.02*
Pseudoarthrosis	nil	Nil	–
Metalwork failure	nil	Nil	–
New neuro def.	nil	Nil	–
Reoperation rate	nil	1/31	.02*

RKA: regional kyphotic angle; Corr.: Correction; Def.: deficit.
*Significant.

There was no significant difference in patient assessment outcome measures (ODI and VAS) between groups during and at follow-up, with similar trends of progression: Figures 3 and 4 depict trends of ODI and VAS outcome curves in Group O and Group P at 3, 6, 12 and 24 months intervals compared to pre and postoperative values.

With regards to complications (Table 2) there was one deep infection, which surprisingly was encountered in Group P and treated successfully with surgical debridement and targeted I.V. antibiotic for six weeks. No metalwork failure was found in either group or any patient had to undergo revision surgery for implant malpositioning in either group. No patients developed new neurological deficits either per or post-operatively. Neither group required removal of metalwork nor even more of note, anterior reconstruction at follow-up, despite the presence of AO type A4 highly comminuted fractures involving both endplates.[1,5] Nevertheless, in both Groups a loss of correction was observed averaging 20% in Group O and 35% in Group P at follow-up. In fact, in Group P we observed both a significantly lower initial correction and a higher tendency to lose correction between the postoperative and 3rd month follow-up and between the 3rd month and the 12th month of follow-up, which stabilised by 24 months (Table 2 and Figure 5).

Discussion

The thoraco-lumbar area is the most frequent spinal region to suffer from injury, yet despite the high frequency there is not a definitive universal treatment algorithm. This may not be surprising as the severity of the injury may reflect the clinical treatment strategies, as well as other patient factors such as poly-traumatic injuries, age, intensive care status, co-morbidities, patient preference, availability of resources and so forth.

Goals of surgery are to stabilise the fracture and alleviate mechanical related pain, preventing progressive deformity and neurological deterioration. The best way to achieve this surgically has been an area of debate.[10] Conventional open fracture stabilization has been well documented to be an effective option, allowing decompression of neural structures if required whilst stabilising the fracture with instrumentation and fusion.[11] Minimally invasive percutaneous trans-pedicle instrumentation has however become an increasingly popular approach in treating thoraco-lumbar spinal fractures.[8,11] The pace of its application has not necessarily matched the comparative literature between these two surgical strategies, and for this reason the paucity of the literature has prompted this study to analyse our results comparing open versus percutaneous fixation of AO type A3, A4 and B thoraco-lumbar fractures.[1–3] Both open and MIS strategies have clear advantages in ensuring spinal stabilization, easing mechanical pain and preventing further neurological injury.

It has been demonstrated that short fixation utilizing open or MIS techniques has comparable long-term outcomes for patients.[12,13] A criticism of MIS fixation for spinal fractures has been the inability to obtain a fusion compared to an open technique with bone graft. However, Wang et al have demonstrated that fusion is not necessary to achieve satisfactory surgical and patient outcomes after MIS fixation and additionally patients had less pain and more spinal motion segments preserved.[14] Unlike open surgery, MIS does not afford the option of directly decompressing the spinal cord and therefore patient selection must appropriate and in those without neurological injury or compression of neural structures.

Radiation exposure is elevated with minimally invasive surgery using fluoroscopic guidance in placing screws. Although the accuracy is better, the irradiation to staff and patient is greater.[14,15] The advantage of using real-time navigation, as in our study P Group, significantly reduces the amount of radiation exposure to the operating team and patient. Often only one set of images captured at the beginning of the case is sufficient enough to place screws. The accuracy rate is also improved for pedicle screws minimising cortical breaches. A meta-analysis study published by Nai Feng Tian et al reports rates of screw malposition up to 28% for open conventional surgery using fluoroscopy, and that the results considerably improve with the use of navigation, the best being with fluoro-3D navigation.[16] Other documented advantages of MIS surgery include minimising soft tissue injury, thereby decreasing the amount of operative blood loss, and having a shorter operative time when compared to open fixation.[16–19] There is evidence of favourable pain control and VAS scores compared to open procedures and lower lengths of stay in hospital.[8,16–19] The MIS group has also lower rates of infection reported in a comparative meta-analysis review by Phan et al.[20] There is some anecdotal evidence that experienced surgeons may well be equally as quick in operative times with an open fixation compared to MIS surgeons. This has been the case in our series and may reflect a surgeon's experience and familiarity with a technique. Additionally, the elevated awareness for tissue preservation and surgical time may help to reduce infection rates both in the traditional open [5] and in the percutaneous technique.[19] An inadequate sizing of the skin portals was in our opinion an essential contributor to the single case of surgical site infection observed in a precipitation trauma patient in Group P of this series.

Our study has the inherent limitations of a retrospective analysis, however the evidence level in the literature is similar with a dearth of prospective randomized comparative studies. Our patient numbers are equal if not higher than other retrospective comparative studies. No formal cost analysis has been possible in our series as all patients were treated in a public hospital funded by the National Health System with fixed reimbursement rates for surgery and hospital stay (at 7,500 Euros by the time of this writing) and with the in-house availability of both real time navigation and O-arm intraoperative imaging. Nevertheless, it is arguable that by considering the cost of advanced intraoperative imaging and of fenestrated screws, the balance of expenditure would clearly swing in favour of the open group.

We have compared the results of two experienced teams in our Institute with over ten years exposure to spinal trauma cases and therefore hopefully been able to eliminate some dilution effect which may be encountered sometimes if multiple institutes with surgeons with variable experience are collated. This could also account for similar lengths of hospital stay and operative time in our cohorts. Nevertheless, the potential confounding factors of having two different operating teams as well the presence of real time navigation only in Group P has to be acknowledged.

The clinical outcome was comparable between the two groups at 24 months follow-up in our study. Short segment fixation with inclusion of the fractured vertebra also helped to save motion segments both in the open [5]and in the closed group.[21,22] There was clearly a higher loss of regional kyphosis correction in the percutaneous cohort as well as less capability to restore the RKA postoperatively, but there was no need for anterior reconstruction in either group during the follow-up period in both A3 and A4 type injuries, possibly reflecting the greater stability provided by the instrumentation of the fractured vertebra. Neither of our two groups required removal of metalwork in the 24 months analysed.

In previous meta-analyses a lower ability of percutaneous techniques to correct kyphotic angles has been reported but generally not followed over time.[8,20] In the authors' experience percutaneous instruments may afford lower reduction ability related to soft tissue (particularly fascial) and facet joint restraints. Furthermore, in both Groups a significant loss of correction was noted principally between the first and the 3 months follow-up, with a second non-significant deflection at 12 months of follow-up possibly reflecting the use of polyaxial screws rather than monoaxial, more rigid screws. This could be a matter of further investigation.

In conclusion, segmental open and navigated percutaneous fixation have both certainly an actual role in managing burst and Chance type fractures of the thoraco-lumbar spine. Which approach to take is one that reflects a surgeon's equipment in terms of technical resources but also the clinical scenario and other patient factors? In cases such as patients in intensive care with poly-trauma, concerns of prolonged surgical time, blood loss and risk of infection, the availability of minimally invasive techniques can be paramount in offering a management plan. Minimally invasive navigated percutaneous segmental fixation can add to the surgeon's armamentarium and management paradigm, despite predicted lower corrective power and potential for loss of correction. However, the role of open segmental fixation remains well established and one must tailor the management approach that best suites the patient's needs and clinical situation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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