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ORIGINAL ARTICLE

Dorsal instrumentation with and without vertebral body replacement in patients with thoracolumbar osteoporotic fractures shows comparable outcome measures

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Abstract
Purpose In the surgical treatment of osteoporotic spine fractures, there is no clear recommendation, which treatment is best for the individual patient with vertebra plana and/or neurological deficit requiring instrumentation. The aim of this study was to evaluate clinical and radiological outcomes after dorsal or 360° instrumentation of osteoporotic fractures of the thoracolumbar spine in a cohort of patients representing clinical reality.
Methods A total of 116 consecutive patients were operated on between 2008 and 2020. Inclusion criteria were osteoporotic fracture, thoracolumbar location, and dorsal instrumentation. In 79 cases, vertebral body replacement (VBR) was performed additionally. Patient outcomes including complications, EQ-5D at follow-up, and sagittal correction were analyzed.
Results Medical and surgical complications occurred in 59.5% of patients with 360° instrumentation compared to 64.9% of patients with dorsal instrumentation only ($p=0.684$). Dorsal instrumentation plus VBR resulted in a sagittal correction of $9.3 \pm 7.4°$ (0.1–31.6°) compared to $6.0 \pm 5.6°$ (0.2–22.8°) after dorsal instrumentation only, respectively ($p=0.0065$). EQ-5D was completed by 79 patients after 4.00 ± 2.88 years (0.1–11.8 years) and was 0.56 ± 0.32 (−0.21–1.00) for VBR compared to 0.56 ± 0.34 (−0.08–1.00) without VBR after dorsal instrumentation ($p=0.994$).
Conclusion 360° instrumentation represents a legitimate surgical technique with no additional morbidity even for the elderly and multimorbid osteoporotic population. Particularly, if sufficient long-term construct stability is in doubt or ventral stenosis is present, there is no need to abstain from additional ventral reinforcement and decompression.

Keywords Osteoporosis · Osteoporotic fracture · 360° instrumentation · Dorsal instrumentation

List of Symbols

ASA-PS	American society of anaesthesiologists physical status
BMD	Bone mineral density
CT	Computed tomography
DGOU	German society for orthopaedics and trauma
EQ-5D	European quality of life-5 dimensions
OF	Osteoporotic fracture
PMMA	Polymethyl methacrylate
VAS	Visual analogue scale
VBR	Vertebral body replacement

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Introduction

Osteoporosis is a systemic disease characterized by reduced bone mass and disruption of bone architecture, resulting in an increased risk of fragility fractures which represent the main clinical consequence of the disease [1, 2]. Fragility fractures of the spine are associated with substantial pain and suffering, disability, and even death due to cardiopulmonary complications [3]. The economic burden of incident and prior fragility fractures (mainly hip and vertebral fractures but also fractures of the pelvis, rib, humerus, tibia, fibula, clavicle, scapula, sternum, and other femoral fractures) in the EU was estimated at € 37 billion, and costs are expected to increase by 25% in 2025 [4]. Osteoporotic vertebral fractures affect approximately 25% of all postmenopausal women and older men aged > 70 years [5, 6]. Most osteoporotic vertebral fractures are treated conservatively with bed rest, analgesics, bracing, early rehabilitation, and osteoporosis treatment with bisphosphonates [7, 8]. However, in some patients the fracture healing is impaired, leading to major complications such as pseudarthrosis, final vertebral collapse, spinal deformity, and spinal cord compression. Although these complications are rare, they are strongly related to poor prognosis, prolonged back pain, strong impairment of daily living activities, and reduced quality of life [9].

There have been considerable attempts to structure the process of decision-making for conservative versus surgical treatment in these patients, such as the osteoporotic fracture (OF) classification based on the work of the Spine Section of the German Society for Orthopaedics and Trauma (DGOU) [10]. While this is helpful for many cases and practitioners, a considerable number of cases end up in an ambiguous category, leaving it up to the surgeon to decide on the treatment strategy, especially if vertebrae plana or neurological deficit urges for instrumentation. In the case of surgical treatment, the surgical procedure of dorsal instrumentation with and without kyphoplasty as well as vertebral body replacement (VBR) is still neither structured nor supported with sufficient data. Particularly, biomechanical considerations such as restoration of the ventral spinal column with higher deformity correction rates have not been taken into account sufficiently in these classifications. Arguments against ventral reinforcement, such as calcified, and therefore completely rigid disks do also not hold up against our surgical experience of quite soft disks even when operating on considerably old patients. Furthermore, data on the role of fracture-related anterior spinal stenosis, location of the fracture in the junctional parts of the spine, or fracture-related neurological deficits are still scarce.

The aim of this study was to examine the clinical and radiological outcomes of patients with osteoporotic fractures of the thoracic and lumbar spine treated with or without a combined 360° instrumentation based on the mentioned classifications as stratification.

By this, we do not intend to compare both approaches as competing options but, on the contrary, describe clinical reality in a large spine center mirroring various surgical approaches of different surgeons as it is the case all over the world.

Methods

Hypothesis

Our hypothesis is that if sufficient long-term construct stability is in doubt after dorsal instrumentation or ventral stenosis is present, additional ventral reinforcement and decompression via 360° instrumentation are feasible and safe and offer a viable option.

Ethics

The study was approved by the local ethics board (registration number: 5022/11). We performed the study in accordance with the Declaration of Helsinki.

Study protocol

This study was performed in accordance with the STROBE statement. Patients with suspected osteoporosis on radiographs between 2008 and 2020 were considered eligible for this study and retrospectively examined. Inclusion criteria were patients undergoing dorsal instrumentation of the fractured spine with and without additional VBR at our institution. Subsequently, patients undergoing vertebroplasty only or conservative treatment were not included in this study. For all patients, the fractures were classified according to the OF classification and according to the OF classification-based score by Blattert et al. [10, 11]. The OF classification-based score by Blattert et al. was introduced in 2018 and is calculating a score based on the OF classification of the fracture, bone mineral density, existence of an ongoing fracture, pain levels, neurological deficits, mobilization under analgesia, and health status [11]. Perioperative complications requiring medical attention regarding further treatment and diagnostics were analyzed during the whole inpatient stay. A structured query in accordance with the European Quality of Life-5 Dimensions (EQ-5D) for Germany was performed for every patient in a phone call follow-up or regular follow-up in our outpatient department.

Surgical procedure

Indications for the operative procedure were discussed at our neurosurgical department meeting consisting of seven experienced neurosurgeons with spinal focus. Surgical experience regarding indication and operative procedures was persistent over recruitment time. Dorsal instrumentation was routinely performed with navigated pedicle screws instrumentation: two segments above and two segments below the fractured vertebrae. No hooks or wires were implanted. In the case of additional VBR, surgery was performed via a lateral approach during the same index admission in. Therefore, the fractured vertebrae and adjacent vertebral disks were resected and anterior decompression was performed if spinal stenosis was present.

Radiographic analysis

For radiographic analysis, the anterior height and posterior height of the interspace between the lower endplate of the upper vertebrae and the upper endplate of the lower vertebrae of the fractured level were measured. Furthermore, the resulting angle between the upper endplate of the upper vertebrae and the upper endplate of the lower vertebrae of the fractured level in a sagittal view was acquired (Fig. 1). Measurements were taken on preoperative CT (computed tomography) scans and plain standing X-rays postoperatively. In cases with VBR, measurements were acquired preoperatively on CT scans, after dorsal instrumentation and after VBR on plain standing X-rays (Fig. 1).

Data analysis

Statistical analyses were performed using Prism (version 8.4.1; GraphPad Software, La Jolla, CA, USA). Descriptive statistics including mean, median, minimum, maximum, and standard deviation were calculated for patient- and fracture-related characteristics including radiographic measurements. Furthermore, cohorts treated with and without VBR were compared. Therefore, Mann–Whitney U tests for unpaired samples as well as Fisher's exact tests with a level of significance set at $p < 0.05$ were performed.

Results

Patient characteristics

A consecutive series of 116 patients (83 women, 33 men) with 129 fractures of the thoracic and lumbar spine were analyzed. All patients underwent dorsal instrumentation. In 79 cases, VBR was performed additionally via a lateral retroperitoneal or transthoracic approach. No access surgeon was used. Gender and age distribution (74.0 ± 8.6 (47.9–91.8) years with VBR vs. 75.4 ± 11.2 (48.8–92.4) years without VBR) were equal between both groups (Table 1). Risk factors were distributed similarly between both groups with a median ASA-PS (American Society of Anaesthesiologists physical status) class of 2 (1–4) for 360° instrumentation and 3 (1–4) for dorsal instrumentation ($p = 0.172$; Table 1). The OF and OF classification-based score were 4 (2–5) and 8 (2–15) for patients with VBR and 4 (2–5) and 9 (4–12) for patients without VBR, respectively ($p = 0.797$; $p = 0.855$; Table 1). Main indications for surgical treatment were fracture-related spinal stenosis from anterior, which was present in 59 cases of patients with VBR and 19 cases without VBR, junctional location of the fracture (36 patients with VBR and 12 patients without VBR), vertebra plana (30 patients with VBR and 16 patients without VBR), and fracture-related neurological deficits (18 patients with VBR and 8 patients without VBR) (Table 1).

Surgical data

In 55.2% of cases, the most severe fracture according to the OF classification-based score was located in the lumbar

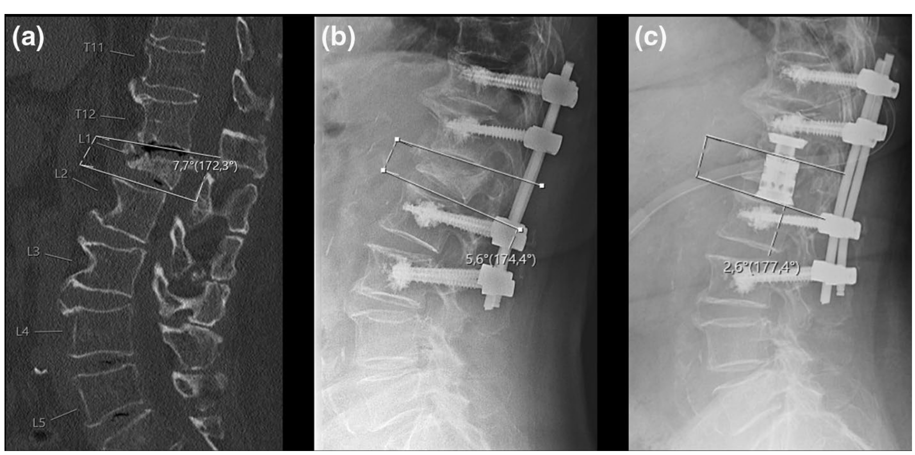

Fig. 1 Analysis of the fractured vertebral body. It illustrates the angle of the fractured vertebral body measured between the upper plate of the vertebral body above and the upper plate of the vertebral body below the fractured vertebra. The angle of the fractured vertebra was measured before **A** and after dorsal instrumentation **B** as well as after 360° instrumentation **C**

Table 1 Patient data and risk factors

n (%)	360° instrumentation	Dorsal instrumentation	*p* value
Number of patients	79 (68.1)	37 (31.9)	–
Female gender	58 (73.4)	25 (67.6)	0.5166
Age at surgery (*y*; mean ± SD; range)	74.0 ± 8.6 (47.9–91.8)	75.4 ± 11.2 (48.8–92.4)	0.270
Risk factors			
Diabetes mellitus	11 (13.9)	2 (5.4)	0.220
Corticosteroids	14 (17.7)	8 (21.6)	0.800
Smoking	13 (16.5)	8 (21.6)	0.606
ASA-PS class			
Median (range)	2 (1–4)	3 (1–4)	0.172
Class 1	3 (3.8)	2 (5.4)	
Class 2	44 (55.7)	14 (37.8)	
Class 3	30 (38.0)	20 (54.1)	
Class 4	2 (2.5)	1 (2.7)	
Indication for surgery			
Junctional location of the fracture	36 (45.6)	12 (32.4)	0.226
Vertebra plana	30 (38.0)	16 (43.2)	0.685
Fracture-related neurological deficit	18 (22.8)	8 (21.6)	> 0.999
Fracture-related spinal stenosis from anterior	59 (74.7)	19 (51.4)	0.019
OF score	4 (2–5)	4 (2–5)	0.797
OF classification-based score (Blattert et al. 2018 [9])	8 (4–12)	9 (2–15)	0.855
Postoperative inpatient (d; mean ± SD; range)	19.8 ± 11.9 (6–77) Median 16	14.9 ± 12.4 (2–53) Median 11	0.001

It shows the patient data for patients undergoing 360° instrumentation as well as only dorsal instrumentation including fracture-related data. Both cohorts show a similar distribution of risk factors including the ASA-PS (American Society of Anaesthesiologists physical status) class and classification of osteoporotic fractures (OF)

spine for cases with 360° instrumentation, compared to 50% for cases with dorsal instrumentation, with 43.0% and 35.1% of surgeries performed percutaneously ($p = 0.419$; Table 2). Cement augmentation of screws was performed in 98.7% of cases with VBR compared to 94.6% of cases with dorsal instrumentation only ($p = 0.238$; Table 2). Surgery was performed 3.7 ± 3.7 (0–15) days from admission for patients with 360° instrumentation and 5.6 ± 6.1 (0–24) days from admission for patients with dorsal instrumentation.

Clinical outcome

Regarding patients with 360° instrumentation, 59.5% of patients developed complications postoperatively, compared to 64.9% of patients who underwent only dorsal instrumentation ($p = 0.684$; Table 3). Wound healing disorders including wound infections were reported in 12.7% of patients who underwent 360° instrumentation and in 24.3% of patients with dorsal instrumentation ($p = 0.176$; Table 3). Regarding permanent surgery-related neurological deficits persisting at the time of discharge, two patients in the group of dorsal instrumentation showed postoperative deterioration of motor function of the lower extremities due to secondary hemorrhage. For 360° instrumentation, a permanent loss of bladder and bowel control occurred in one case after dorsal instrumentation due to persistent stenosis at the fractured level, which was still present at the follow-up examination. Further complications are listed in Table 3.

At the end of the study, a follow-up including quality of life (EQ-5D Germany) was obtained, which was completed by 79 patients (52 with VBR) after 4.00 ± 2.88 years (0.1–11.8 years). Follow-up was performed 3.70 ± 2.45 years (0.30–9.04) postoperatively for 360° compared to 4.58 ± 3.55 years (0.13–11.84) for dorsal instrumentation ($p = 0.427$; Table 4). Quality of life was 0.56 ± 0.32 (− 0.21–1.00) for patients with VBR compared to 0.56 ± 0.34 (− 0.08–1.00) of patients without VBR after dorsal instrumentation ($p = 0.994$; Table 4). Reoperation rates due to construct failure or adjacent segment degeneration in a long-term follow-up were low at 13.5% and 11.1% for cases with VBR and without VBR ($p > 0.999$; Table 4).

At the time of follow-up, opioids were taken by 29.6% of patients with dorsal instrumentation compared to 26.9% among patients after VBR ($p = 0.797$). Systemic osteoporosis medication was taken in 73.1% of patients after VBR compared to 51.9% in patients after dorsal instrumentation ($p = 0.081$).

Table 2 Surgical data

n (%)	360° instrumentation	Dorsal instrumentation	*p* value
Number of fractures	85	44	–
Operated levels (mean ± SD; range)	4.6 ± 2.2 (2–18)	4.6 ± 1.8 (2–10)	0.449
Cement augmentation of screws	78 (98.7)	35 (94.6)	0.238
Cement augmentation of fractured vertebra	–	4 (10.8)	–
Percutaneous instrumentation	34 (43.0)	13 (35.1)	0.419
Fractured segment			
Thoracic fracture	38 (44.8)	22 (50.0)	n.s
T 4	0 (0.0)	2 (4.5)	
T 5	0 (0.0)	1 (2.3)	
T 6	4 (4.7)	1 (2.3)	
T 7	2 (2.4)	2 (4.5)	
T 8	3 (3.5)	3 (6.8)	
T 9	4 (4.7)	2 (4.5)	
T 10	1 (1.2)	2 (4.5)	
T 11	5 (5.9)	2 (4.5)	
T 12	19 (22.4)	7 (15.9)	
Lumbar fracture	47 (55.2)	22 (50.0)	
L 1	17 (20.0)	5 (11.4)	
L 2	12 (14.1)	2 (4.5)	
L 3	11 (12.9)	6 (13.6)	
L 4	4 (4.7)	4 (9.1)	
L 5	3 (3.5)	5 (11.4)	

This table compares the surgical procedures regarding dorsal instrumentation for patients with and without additional vertebral body replacement. No significant differences were found between both cohorts

Table 3 Postoperative complications

n (%)	360° instrumentation	Dorsal instrumentation	*p* value
Overall	47 (59.5)	24 (64.9)	0.684
Systemic infections	23 (29.1)	9 (24.3)	0.661
Wound healing disorder/secondary hemorrhage	10 (12.7)	9 (24.3)	0.176
Wound infections	3 (3.8)	3 (8.1)	0.382
Intensive care unit	10 (12.7)	6 (16.2)	0.579
Permanent surgery-related neurological deficit	1 (1.3)	2 (5.4)	0.238

This table lines up the rate of postoperative complications for both cohorts. All infections requiring systemic antibiotic treatment, excluding wound infections, were considered as systemic infections. Wound infects were listed separately in the group of wound healing disorders

Radiological outcome

For patients undergoing dorsal instrumentation followed by VBR, the correction of the angle of the fractured spine levels was 6.4 ± 5.0° (0.5–22.7°) after dorsal instrumentation and increased to 9.3 ± 7.4° (0.1–31.6°) after VBR (Fig. 2). For patients undergoing dorsal instrumentation only, a correction of 6.0 ± 5.6° (0.2–22.8°) was achieved (Fig. 2). Correction after VBR was significantly higher ($p = 0.0065$) than correction in cases with dorsal instrumentation without VBR. The curvature correction at the fractured vertebral body for the thoracic spine was 6.4 ± 6.3° and 10.3 ± 7.2° (dorsal only vs. 360°; $p = 0.017$) and 5.6 ± 4.9° and 8.5 ± 7.5° (dorsal only vs. 360°; $p = 0.148$) for the lumbar spine. Cage subsidence on postoperative imaging occurred in 72 fractures (84.7%) measuring 5.7 ± 3.6 (0–14) mm.

Discussion

Since 2018, the OF classification based on the work of the Spine Section of the DGOU has been introduced as a novel diagnostic tool [10]. The proposed OF classification served as an attempt to group the most common osteoporotic fracture types. According to this study, OF types 4 and 5 were declared as clear indications for surgical treatment [10]. OF type 3 fractures remained a debatable type, which might be treated surgically or conservatively [10]. OF type

Table 4 Patient outcome

n (%)	360° instrumentation	Dorsal instrumentation	*p* value
Number of patients	52 (65.8)	27 (73.0)	–
Time of follow-up (years; mean ± SD; range)	3.70 ± 2.45 (0.30–9.04)	4.58 ± 3.55 (0.13–11.84)	0.427
EQ-5D Germany (mean ± SD; range)	0.56 ± 0.32 (− 0.21–1.00)	0.56 ± 0.34 (−0.08–1.00)	0.994
Reoperation rates	7 (13.5)	3 (11.1)	> 0.999
Opioids	14 (26.9)	8 (29.6)	0.797
Systemic osteoporosis medication	38 (73.1)	14 (51.9)	0.081

It shows the long-term patient outcome including quality of life (EQ-5D Germany). Reoperation rates include failure of construct as well as adjacent segment degeneration

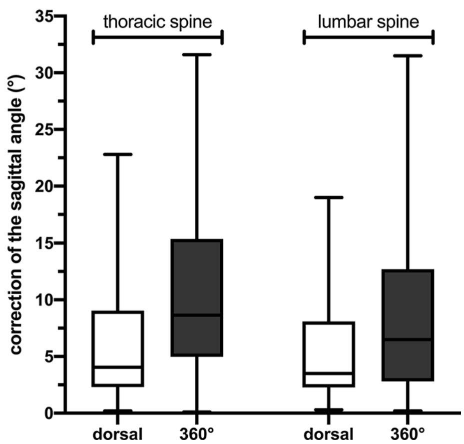

Fig. 2 Radiological outcome: Correction of the fracture-related sagittal angle. It shows the curvature correction at the fractured vertebral body for the thoracic (dorsal only vs. 360°; $p = 0.017$) and lumbar spine (dorsal only vs. 360°; $p = 0.148$) comparing patients undergoing dorsal instrumentation (dorsal) to patients with 360° instrumentation (360°)

1 and OF type 2 fractures were reported as indications for conservative treatment [10]. Together with this classification, the working group developed a score for therapeutic decision-making and proposed guidelines for treatment [12]. Alternative augmentative procedures for OF type 1 and 2 fractures like vertebroplasty or kyphoplasty have been further introduced [11]. In OF type 3, 4, and 5 fractures, dorsal instrumentation with or without vertebral body replacement or polymethyl methacrylate (PMMA) cement augmentation of the inserted pedicle screws was recommended [12]. Minimal invasive techniques like percutaneous instrumentation and hybrid monosegmental instrumentation combined with kypho- or vertebroplasty were favored especially in OF type 3 fractures [12]. The OF classification-based score by Blattert et al. further classified three groups based on fracture morphology (OF type), bone mineral density (BMD) and *T*-score, dynamics of the fracture process, pain score (visual analogue scale (VAS) score), associated neurological deficits, patient mobility, and general health status (ASA-PS class) [11]. However, this score does not include factors like fracture-related spinal stenosis from anterior or junctional location of the fracture, which are essential factors in surgical decision-making.

Our study was performed to analyze the clinical and radiological outcomes of patients with osteoporotic thoracolumbar fractures in a real-life setting in which other factors were revealed to influence surgical strategy considerably apart from the available literature. The indications for a staged approach in our study population originated from clinical presentation with new neurological deficits, major spinal stenosis from anterior, vertebra plana, or location of vertebral fracture in a junctional spinal segment (Table 1). Depending on the subjective opinion of the treating surgeon, additional VBR was performed or waived after dorsal instrumentation according to the above-mentioned arguments including neurological status of the patient postoperatively as well as intraoperative findings and correction of the sagittal angle on postoperative X-ray scans. By that, this series represents clinical reality very closely. Indications for the operative procedure were discussed at our neurosurgical department meeting. While surgical experience was persistent over recruitment time, there was a steady change in paradigm regarding more aggressive treatment strategies. Therefore, similar patients were treated differently over time resulting from clinical experience. This also accounts for the number of patients treated with percutaneous instrumentation, where there was a clear trend toward percutaneous instrumentation even in cases with additional decompression and cases of the upper thoracic spine.

In previous studies, experts advised a hybrid approach with kyphoplasty as anterior stabilization technique or less invasive techniques in the elderly population [13, 14]. Furthermore, authors reported beneficial results with a posterior approach only through short-segment fixation and postulated a safer way of treatment for patients at high surgical risk [15]. Our results do not justify this statement anymore. Particularly, kyphoplasty of the fractured vertebra cannot be regarded as any additional reinforcement in instrumented fractures. The intervertebral disks are still soft in many patients and allow for enough elasticity to cause screw loosening; at least kyphoplasty does not prevent this. Open ventral VBR, in contrast, provided reliable reinforcement, better curvature correction (Fig. 2), no risk of additional cement embolism, and the option of ventral decompression. Moreover, blood loss in VBR of osteoporotic fracture is minimal and not comparable to acute traumatic fractures of younger patients whose vertebra have a strong blood supply due to their bone marrow still being a major part of hematopoiesis. This is not the case in the elderly [16]. Complication rates in spinal surgery vary greatly between studies ranging from 17 to 52%, identifying age over 65 years as a risk factor for increased complication rates [17–19]. Due to multimorbidity and high age, complications rates overall were expectedly high among patients in our study which is still in the usual international range if urinary tract infection and other minor events are included. However, patients undergoing 360° instrumentation experienced complication rates comparable to those in patients treated solely with posterior instrumentation including rates of wound healing disorder, need for intensive care unit treatment, and rates of new postoperative neurological deficits (Table 3). In addition to that, high failure rates up to 24% due to bending or breaking of instrumentation have been reported with the use of short-segment fixation for thoracolumbar burst fractures, compared to an overall reoperation rate including adjacent segment degeneration and failure of construct of 13% in our study representing a more aggressive approach [20].

Long-segment fixations reduce the range of motion and improve the stiffness of constructs, which is essential in osteoporotic patients, especially in junctional segments like the thoracolumbar junction [21]. As for kyphotic deformity, previous studies found an involvement of thoracolumbar junction to be a risk factor for progressive kyphosis. This is due to the great static and dynamic load mainly applied on the anterior part of the vertebral body [8]. For patients with dorsal instrumentation, only a high rate of postoperative loss of correction with subsequent re-kyphosis was observed [22, 23].

For osteoporotic fractures of the vertebral body, it might also be relevant to reconstruct the sagittal profile; at least this is still unclear [24]. Patients with VBR showed a significantly better curvature correction in our series (Fig. 2). Whether this has any clinical benefit or implications cannot be proven in detail. However, there is a bias in the measurement of the sagittal profile as preoperative CT scans performed in all patients were compared to postoperative plain standing X-rays as preoperative plain standing X-rays were not possible due to pain, neurological deficits, or instability of the fracture in multiple cases. QoL, however, was comparable, nonetheless. Long-term patient outcome at follow-up via EQ-5D was identical in both groups 0.56 ± 0.32 vs 0.56 ± 0.34 ($p = 0.994$).

Furthermore, data on the role of neurological deficits and fracture-related anterior spinal stenosis, where the possibility of additional anterior decompression might be of benefit, are still scarce. Kaneda et al. showed a favorable outcome in a study of 27 patients with traumatic burst fractures and neurological deficits treated by anterior decompression and instrumentation with complete neurologic recovery in 66.7% and no reported new postoperative deficit [25].

In biomechanical studies, combined instrumentations provided superior rigidity and reduced ROM in all directions compared to other types of instrumentations [26]. Knop et al. compared treatment strategies of traumatic injuries of the thoracolumbar spine, showing significantly higher correction rates of the fracture-related kyphotic deformity and a significantly lower relative loss of correction in the radiological follow-up examinations for cases with 360° instrumentation [22]. Our study approves these findings, which are yet clinically irrelevant.

In this series, 360° instrumentation was done via a staged surgical approach. According to this, we observed a prolonged hospital stay in patients with 360° approach with an average of 19.8 ± 11.9 days (6–77) compared to 14.9 ± 12.4 days (2–53) in the dorsal instrumentation group (Table 1), which is the time between the two surgeries and correlates with the current literature [27]. Besides implant costs, this longer stay further increases treatment costs compared to dorsal instrumentation only. If reoperation and thus cost reduction on long-term follow-up is achieved, 360° instrumentation cannot be answered by this study.

Conclusion

To be clear, this is not a randomized trial and the overall question was not the comparison between posterior only and 360° instrumentation as competing options. We rather intended to analyze clinical reality in a large spine center mirroring various surgical approaches of different surgeons as it is the case all over the world.

Our data confirm that 360° instrumentation represents a legitimate surgical strategy if sufficient long-term construct stability is doubted by the treating surgeons or considerable ventral stenosis is present. If the treating team considers additional ventral reinforcement or decompression, such additional surgery provides no additional risk but balanced morbidity even for the elderly and multimorbid osteoporotic population. In our experience, especially percutaneous augmented dorsal instrumentation plus anterior spinal canal decompression and VBR provide a minimally invasive option if anterior spinal canal stenosis is present.

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Declarations

Conflict of interest All authors declare that they have no conflict of interest regarding the materials used or the results presented in this study. All authors declare no other relationships or activities that could appear to have influenced the submitted work.

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