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Additional anterior plating enhances fusion in anteroposteriorly stabilized thoracolumbar fractures

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ABSTRACT

Introduction: To prospectively evaluate the potential radiological and clinical effect of the additional application of an anterior plate in anteroposteriorly stabilized thoracolumbar fractures.

Patients and methods: 75 consecutive patients with unstable thoracolumbar fractures underwent posterior (internal fixator) and anterior stabilization (corpectomy cage with local autologous bone grafting). 40 (53.3%) patients received an additional anterior plate (Group A), while 35 (46.6%) (Group B) did not. Plain X-rays and CT-scans were obtained pre- and postoperatively, after 12 months and at the last follow-up (mean 32 months, range 22–72). Loss of reduction, cage subsidence to adjacent vertebrae, fusion rates and clinical results were evaluated.

Results: 66 (87%) patients (36 Group A; 30 Group B) were available for follow-up. Patients in both groups were comparable regarding age, gender, comorbidities, localization and classification of fracture. Average loss of reduction was 2.4° in Group A, and 3.1° in Group B (not significant). Cage subsidence did not differ significantly between both groups, too. However, after 12 months the rate of continuous osseous bridging between endplates was significantly higher in Group A (63% vs. 25%) ($p < 0.05$). After 32 months this difference was even higher (81% vs. 33%) ($p < 0.001$). The bony fusion mass was located beneath or around the anterior plate in 94% of patients. There was no significant difference in clinical outcome.

Conclusions: Additional anterior plating in anteroposteriorly stabilized thoracolumbar fractures leads to significant faster fusion but does neither influence reduction loss nor cage subsidence. The anterior plate serves as a pathway for bone growth and increases biomechanical stability, resulting in a higher fusion rate.

Introduction

Modern operative treatment of thoracolumbar spinal fractures aims to ensure adequate primary stability in order to prevent reduction loss and facilitate fracture healing. Therefore, many authors have stated that highly unstable fractures should be stabilized with both posterior and anterior instrumentation [1–3]. To avoid morbidity of iliac crest bone grafting, corpectomy cages can be used for vertebral body replacement.

Biomechanical studies could demonstrate that additional anterior plating could further increase the instrumentation's primary stability [2,4]. The possible clinical advantage of additional anterior plating including mainly the acceleration of the bony fusion has not yet been elucidated. On the other hand, it is possible that the increased stress shielding effect could lead to the opposite result, namely the delay of the bony fusion [2,5,6].

The aim of this prospective, non-randomized study was to analyze the potential radiological and clinical implications of additional anterior plating in patients with anteroposterior instrumentation of a thoracolumbar fracture. The primary hypothesis was that patients treated with additional anterior plating would demonstrate significantly higher fusion rates, compared to patients, where a cage was solely applied. A second hypothesis was that additional anterior plating would significantly prevent loss of reduction and subsidence of the cage, which would result in an improved radiological and clinical outcome.

Patients and methods

75 consecutive patients having suffered an unstable thoracolumbar injury (from T6 to L5) of type A.3, B or C according to the Magerl AO-classification [7] were included in this prospective, non-randomized study. All patients had a burst type fracture of the

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vertebral body. Patients with osteoporosis were excluded from the study.

All patients were initially treated by posterior stabilization with an internal fixator (USS Fracture, Synthes, Solothurn, Switzerland).

Following posterior instrumentation, the patients were subjected in a second session to an anterior corpectomy of the fractured vertebra and implantation of an expandable cage (VBR, Ulrich, Ulm, Germany). 40 patients (53.3%) additionally received in the same operative session an anterolaterally implanted plate. The non-angular stable "St. Georg" plate (Link, Hamburg, Germany) with monocortical screws was used in 21 cases, while 19 patients received an angular stable plate with monocortical screws (LCP, Synthes, Solothurn, Switzerland).

The decision to additionally apply the plate was based on surgeon's intraoperative subjective judgement concerning fracture stability, but was not related either to fracture type or to any other objective criteria.

Patients receiving additional plating constituted Group A, while patients treated without plating were characterized as Group B.

The patients were evaluated radiologically and clinically every 12 months postoperatively up to 72 months.

Radiological evaluation

Conventional standing anteroposterior (ap) and lateral radiographs of the operated spinal region were obtained at the follow-up visits. Additionally, a CT-scan with two-dimensional reconstruction was performed at 12 months and final follow-up (LightSpeed 8/16, General Electric, Fairfield, CT, USA; slice thickness: 2.5 mm, reconstruction: 1.5 mm). A second CT-scan was performed only in patients, in which fusion rate was initially judged as "incomplete" or "no fusion" in the first CT-scan.

At each time point conventional radiographs were evaluated by use of the Osiris® Software program and following parameters were defined: the bisegmental kyphosis angle (BKA) defined as the angle between the superior endplate of the cephalad intact vertebra and the inferior endplate of the caudal intact vertebra, as measured by the Cobb method (Fig. 1), as well as the cage subsidence, defined as the ratio of the distance between the centres of the adjacent intact superior and inferior endplates to the backside length of the cage. Since measuring the absolute length of the cage can vary, this ratio using the cage length as a constant factor, was utilized to detect even subtle subsidence (Fig. 2).

Two-dimensional reconstructions as well as transverse images of CT scans were selected to evaluate the progress of the bony fusion (Fig. 3). Images were evaluated for the existence of osseous structures, signs of osteolysis and resorption zones at three prior defined locations, namely the inside of the cage, the periphery of the cage and in cases where the additional plate had been applied, directly underneath the plate. Criteria for bony fusion were defined as follow:

- ossification inside the cage
- formation of bridging bone along the stabilized segment
- lack of osteolysis areas and resorption zones.

In cases of additional anterior plating it was evaluated, whether there was an osseous bridge formed directly underneath or along the plate's surface.

According to these and similarly to the criteria described by McAfee for interbody fusion [8] three fusion grades were differentiated (Table 1): complete fusion; incomplete fusion; apparently no fusion.

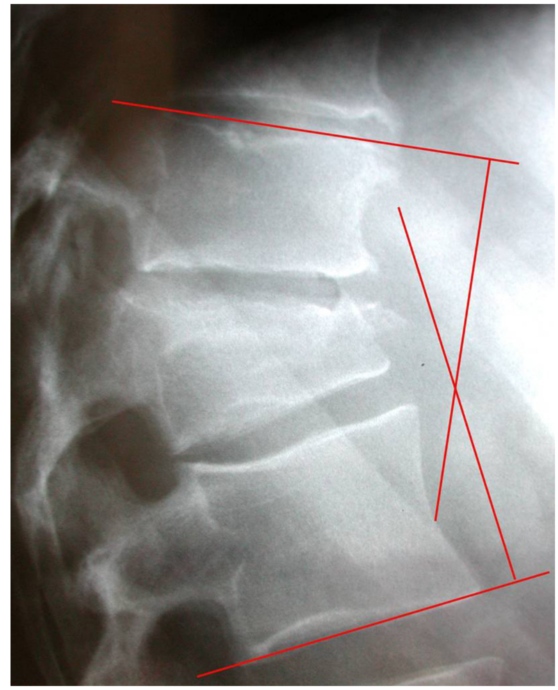

Fig. 1. Bisegmental kyphosis angle (BKA) is defined as the angle between the superior endplate of the cephalad intact vertebra and the inferior endplate of the caudal intact vertebra, as measured by the Cobb method.

Radiological evaluation was performed by two independent observers, a radiologist experienced in spinal imaging and a spinal surgeon not involved in the surgical treatment.

Clinical evaluation

The neurological status of the patients according to the Frankel/ASIA classification, as well as the patient' range of motion (ROM) of

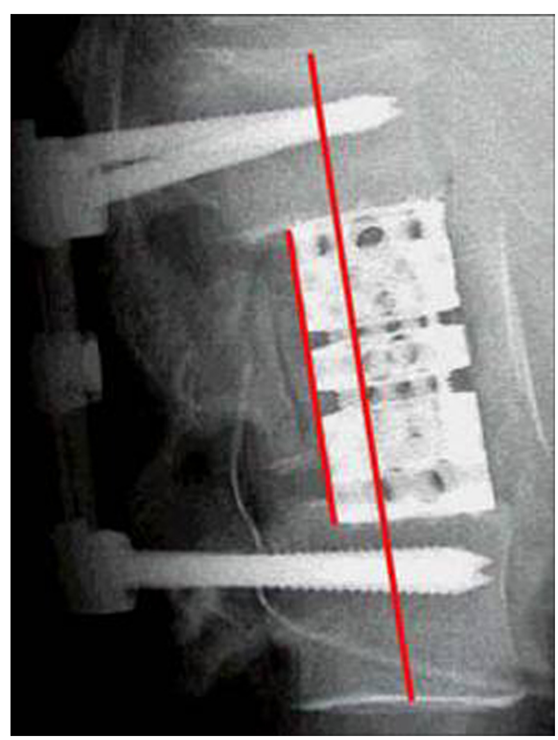

Fig. 2. Cage subsidence is defined as the ratio of the distance between the centres of the adjacent intact superior and inferior endplates to the backside length of the cage.

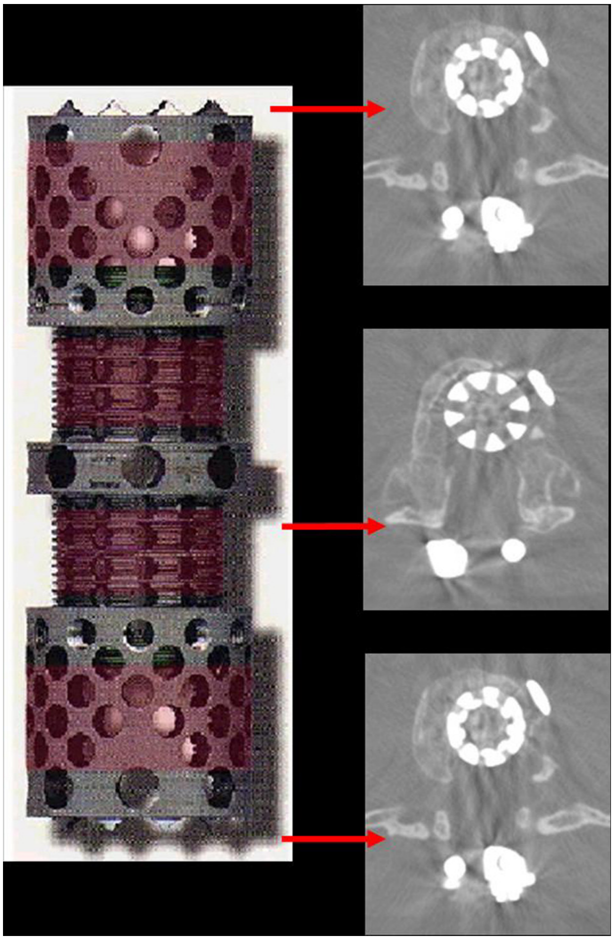

Fig. 3. To evaluate progress of the bony fusion on CT-scan, three transverse images were selected; the first demonstrating the middle of the cage, while the other two were taken from the interface between the end of the cage and the cranial and caudal intact endplate respectively.

the thoracolumbar spine (flexion, finger-to-ground-distance) were evaluated.

The Visual Analog Scale (VAS) was used for patients' self-evaluation of perceived back and leg pain. Moreover, the patients were asked to categorize their rest and/or stress pain as permanent, frequent, occasional or absent.

Finally the pain course compared to previous follow-up visit was documented as worse, unchanged, better or pain free.

Statistical analysis

The normal distribution of the variables was assessed with the non-parametric Kolmogorov–Smirnov test. Paired sample values were compared with the Wilcoxon-test, while for independent sample values the Mann–Whitney test was used. Statistical correlations were calculated by use of Spearman's rank correlation coefficient, while the χ^2-test was used for binomial distribution. For statistical correlations of interval-scaled, normally distributed sample values the Pearson's correlation coefficient was used. Statistical analysis was conducted using SPSS 14 (SPSS, Inc., Chicago, IL, USA).

Table 1
Grades used for evaluation of fusion.

Grade	Type of fusion	Fusion characteristics
Grade 1	Complete fusion	- Complete ossification inside cage - Continuous osseous bridge - No resorption zones (Fig. 5a and b)
Grade 2	Incomplete fusion	- Complete ossification inside cage - No continuous osseous bridge - No resorption zones (Fig. 5a and b)
Grade 3	Apparently no fusion	- Incomplete ossification inside cage - No continuous osseous bridge - Resorption zones

Table 2
Cause of injury ($n = 66$).

Cause of injury	Number (%) of fractures
Fall from a height	36 (54.5%)
Traffic accident	12 (18.2%)
Fall from a stair	6 (9.1%)
Other causes	12 (18.2%)

Results

Demographical data

66 (88%) patients (44 men, 22 women) with a mean age of 41 years (range 17–76) at the time of surgery were available for follow-up (36 Group A, 30 Group B). 6 patients lived too far away to attend examination, 2 refused examination for personal reasons, and one was deceased unrelated to surgery. The mean follow-up time was 32 months (range 22–72).

One patient had suffered two unstable lumbar fractures that were both treated with corpectomy and cage application.

Further fracture characteristics are displayed in Tables 2 and 3.

There was no statistically significant difference among the demographic characteristics between patients initially included in the study and those available for follow-up, as well as among Group A and Group B patients in terms of patients' sex, age and type of fracture.

Surgical data

All patients were initially treated with posterior stabilization of a mean of 2.3 segments (range 1–5) at a mean of 2.8 days (range 0–27) after the accident. Ventral corpectomy was performed at a mean of 14 days (range 5–32) after accident.

In all cases the cage was filled with autologous cancellous autograft harvested from the removed vertebral body that was also applied over the implanted cage.

Table 3
Radiological data.

	Overall ($n = 67$)	Group A ($n = 37$)	Group B ($n = 30$)
BKA (°)			
Pre-op	13.4	14.2*	12.4*
Operative correction	11.2	11.4*	10.8*
Post-op	2.2	2.8*	1.6*
12 m post-op	4.2	4.1*	4.4*
32 m post-op	4.8	5.1*	4.6*
Correction loss 32 m post-op	2.6	2.3*	3*
Remaining correction	8.6	9.1*	7.8*
Cage subsidence			
12 m post-op	6.4	6.2*	6.6*
32 m post-op	8.8	8.6*	9*

Statistical significance refers to "Group A compared to Group B" for BKA and cage subsidence at each time point.
* Not statistically significant.

Radiological data

X-ray evaluation

The data of each group are depicted in Table 3. For the overall patient group the results were as followed: Preoperatively, the mean bisegmental kyphosis angle (BKA) was 13.4° (range 1–41°). Through surgical treatment a significant correction of the BKA was obtained (mean 11.2°, range 1–28°) ($p < 0.001$). After 32 months postoperatively a minor, but significant loss of correction was present (mean 2.6°, range 0–12°) ($p < 0.001$), resulting in a mean remaining BKA correction of 8.6° (range 0–26°) compared to the preoperative BKA values. The major correction loss (mean 2°, range 0–9°) as well as the major cage subsidence (after 12 months: mean 6.4, range 1.4–14.8; after 32 months: mean 8.8, range 1.4–16.2) occurred within the first 12 months postoperatively. There was a significant correlation between cage subsidence and loss of correction ($p < 0.05$).

Statistical analysis failed to reveal any statistically significant differences between the two groups (A and B) in terms of preoperative BKA, mean operative correction, mean loss of correction after 32 months, remaining correction and cage subsidence after 32 months (Table 3).

When the patients' subgroups according to fracture type and fracture site (thoracic or lumbar spine) were compared to each other no statistically significant differences between Group A and Group B patients were found.

Similarly, no difference was revealed, when the subgroups according to the used type of plate were compared to each other.

CT-scan evaluation

Overall the fusion progress was evaluated after 12 months postoperatively as complete (Grade 1) (Fig. 4a and b), in 45% of patients, as incomplete (Grade 2) (Fig. 5a and b), in 53% of the cases and as not fused (Grade 3) in 2% of the cases. At the 32 months follow-up, there were 60% of the cases classified as Grade 1 and 40% as Grade 2. Patients from Group A with incomplete fused segments at the 12 months follow-up displayed a significantly higher fusion improvement by the next evaluation, compared to Group B patients ($p < 0.05$).

When the two groups were compared at the 12 months follow-up there was a significantly higher fusion rate in Group A patients compared to these of Group B ($p < 0.05$). After 32 months, the results were similar in favour of Group A compared to Group B ($p < 0.001$) (Table 4).

Table 4
Fusion rates.

Fusion grade	Overall ($n = 67$) %	Group A ($n = 37$) %	Group B ($n = 30$) %
Grade 1			
12 m post-op	45	63*	25*
32 m post-op	60	81**	33**
Grade 2			
12 m post-op	53	37*	71*
32 m post-op	39	19**	64**
Grade 3			
12 m post-op	2	0*	4*
32 m post-op	1	0**	3**

Statistical significance refers to "Group A compared to Group B" for each fusion grade at each time point.
* $p < 0.05$.
** $p < 0.001$.

The bridging bone between the vertebrae was located beneath or around the anterior plate in 94% of Group A patients (Fig. 4a and b).

This significant difference between the two groups was also evident when the subgroups according to fracture type (AO type A, B, C) ($p < 0.05$), fracture site (thoracic or lumbar spine) ($p < 0.05$) as well as plate type ($p < 0.05$) were examined.

Clinical results

Neurological status

Data were available for 58 (87.9%) patients (31 Group A; 27 Group B). Upon admission 15.5% of the patients were classified as having a complete paralysis (Frankel A), 12% an incomplete paralysis (Frankel B, C, D), while 72.5% of the patients were neurologically intact (Table 5).

The neurological status of Group A patients improved by a mean of 1.6 points in the Frankel scale, and by a mean of 2.2 in Group B. This difference was not statistically significant.

Spinal mobility

ROM improved between the 12 months and the 32 months follow-up visits, but this improvement was not statistically

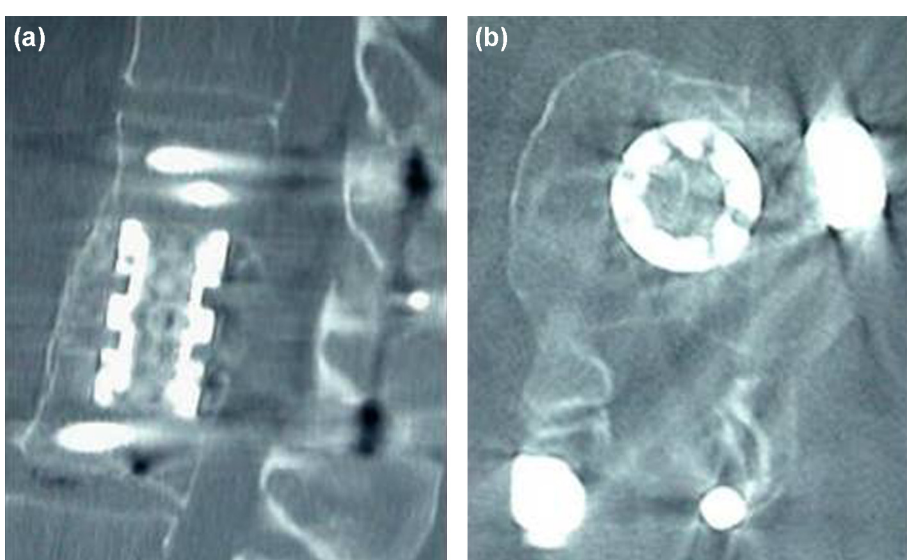

Fig. 4. (a, b) Complete osseous fusion (Grade 1) with additional anterior plating: osseous bridging (*) and new bone formation underneath the plate (←).

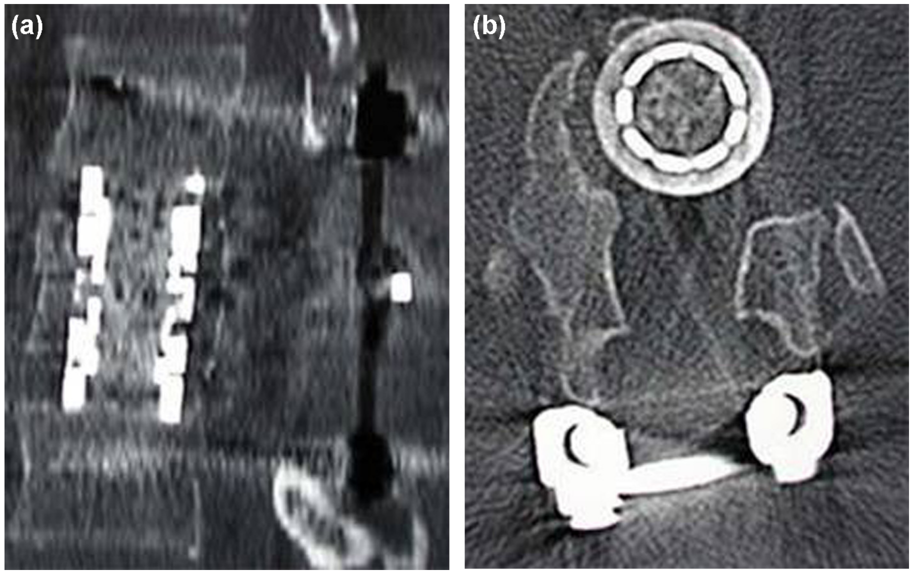

Fig. 5. (a, b) Incomplete osseous fusion (Grade 2) without additional anterior plating: new bone formation is detectable only inside the cage (*).

significant. There was no significant difference between Group A and Group B patients.

Pain intensity and progress

Pain evaluation with use of the VAS-score demonstrated an overall significant improvement between the 12 months and the 32 months follow-up visit for back and leg pain ($p < 0.001$).

At the final follow-up visit, 90% of the patients reported no or only occasional rest pain, while 68.3% reported no or only occasional stress pain.

When pain intensity and changes were analyzed for Group A and B patients, no statistically significant difference among the two groups was revealed.

Discussion

Several authors have claimed the necessity of the operative treatment of unstable thoracolumbar fractures [9,10]. But there still exists controversy as far as the most adequate surgical treatment is concerned [9–13]. The combined approach is favoured by several authors [1–3,12,14] based on improved biomechanical and radiological results that demonstrate an increased primary stability of the construct [2,13,15–17]. Furthermore, recently introduced corpectomy cages have replaced traditionally used tricortical iliac autograft [2,18,19]. The aim of this prospective study was to analyze the potential radiological and clinical implications of the additional application of an anterior plate in patients treated with anteroposterior stabilization of a thoracolumbar fracture.

Our primary hypothesis that additional anterior plate application would significantly improve fusion rates was confirmed. Our results demonstrate that there was a significantly faster and higher fusion rate in the plating group (Group A) compared to the non-plating group (Group B) both at the first and at the second follow-up, indicating that additional plate application plays a significant role in augmenting the fusion process. Moreover, bridging bone was located beneath or around the anterior plate in 94% of Group A patients (Fig. 4a and b). There exists experimental evidence [2,4] that plate application additional to a cage significantly increases the primary stability of the construct, possibly by protecting the cage from compressive loads [2,5,15] and preventing resorption of corticocancellous autograft [14]. Although stress shielding has been implicated by some authors in causing "device related osteopenia" when highly rigid implants are used [6,20], other authors could show higher axial compression forces with combined stabilization [21]. The significant higher fusion rate in our study, together with the higher fusion rates reported in literature [20,22] demonstrate that the advantages of adequate primary stability overwhelm any potential drawbacks.

Our reported grade I fusion rates (45% at 12 months follow-up and 60% at 32 months follow-up) when compared to those reported in the literature being as high as 66–100% [1,2,9,10,30] appear to be relatively low. This might be due to our strict fusion criteria. We judged fusion as complete only if bridging osseous bone between endplates was evident.

Another possible explanation is that in the majority of the aforementioned studies [1,3,12,23] fusion was judged based solely on lateral radiographs. There exists evidence [1,3,24] that fusion judgement based solely on plain radiographs is inadequate, since

Table 5
Neurological status ($n = 58$).

ASIA/Frankel type	At last follow-up (Group A/Group B)				
	A	B	C	D	E
Pre op (Group A/Group B)					
A	0/1	0/0	1/1	2/2	1/1
B	0/0	0/0	0/0	0/0	0/0
C	0/0	0/0	0/1	0/0	1/1
D	0/0	0/0	0/0	0/1	2/1
E	0/0	0/0	0/0	0/1	24/17

the unavoidable overlapping of presented structures as well as the inability to depict the fusion area in the inside of the case lead to questionable results, which often overestimate fusion rates. CT scan is more sensitive in revealing even finest interruptions of the osseous structures [25] typical for a non-union. In a recent study [26] CT scan was used for evaluating fusion rates in posterior lumbar interbody fusions. Since there exist no universally accepted criteria for evaluating spinal instrumented fusions we utilized a standardized and sensitive measuring technique via CT-scans based on McAfee's criteria [8], aiming to acquire reliable and reproducible results.

Our results also demonstrate an interesting aspect concerning the fusion progress. While at the first follow-up visit all cages had already been incorporated, there was evidence of lateral and anterior complete osseous bridging just in 45% of the cases. That increased significantly to 60% at the second follow-up. This is in accordance with prior findings [2] and implies that cage incorporation between the adjacent vertebral plates is not equivalent to complete fusion as often assumed in X-rays fusion evaluation. It appears that the fusion process is initiated by the incorporation of the autograft-filled cage and continues with the gradual formation of bridging osseous structures surrounding the cage. Thus, a longer time for achieving a complete fusion should be anticipated. This finding might have further implication on future cages design. Since cage incorporation close to the endplates is the first step in the fusion process, cages should provide on the one hand adequate inside space for autograft filling and on the other hand a porous periphery that would facilitate formation of surrounding osseous bridges.

Concerning our secondary hypothesis, our results failed to demonstrate any significant prevention of reduction loss and cage subsidence. We found that the minor correction loss as well as the cage subsidence, which occurred in both groups within the first 12 months postoperatively, were significantly correlated to each other. This cage subsidence that is often reported in the literature [1,2,27] appears to be an unavoidable effect, especially within the first postoperative year. It seems that early cage subsidence causes a loss of pretension within the stabilized construct which results in a decrease of the primary stability and an overload of the remaining load bearing structures, especially the posterior fixator. Hence there appears to exist a correlation between cage subsidence and postoperative loss of correction [28,29]. Furthermore, no clinical significant differences could be found. Since even larger studies [9,10,12] have until now failed to demonstrate superiority of any treatment modality in terms of clinical results, the issue whether thoracolumbar fractures should be treated posteriorly, anteriorly, or combined still remains a matter of controversy.

Our study also has some weaknesses. First of all, it is not a randomized study, since the additional plate application was based on surgeon's intraoperative decision. Although the non-randomized plate application could possibly lead to a relevant bias, we rather believe that since no strict criteria were used, plate application was merely a random procedure. Concerning the number of patients, statistically significant results could be obtained, although one could argue that the number of patients especially that of the subgroups is relatively small.

One of the strengths of this study is that all studied patients were treated both posteriorly and anteriorly. Moreover, it is particularly important that in contrast to prior studies [18,30] the same internal fixator and the same corpectomy cage were used in all cases, rendering the type of the anterior plate the only variable. However, although LCP is an angular stable implant and might theoretically provide higher primary stability, plate type did not significantly influence the final outcome. The use of CT-scan for fusion evaluation in all patients is a further advantage of this study. Furthermore, it is a prospective study and only a relative small part of the initial cohort was lost to follow-up. Finally, there is a mean follow up time of 32 months, which is adequate for the study of fracture treatment and its consequences.

Conclusions

Our study demonstrates that application of an anterior plate additional to the corpectomy cage in anteroposteriorly treated thoracolumbar fractures significantly improves the fusion rates, but neither reduces cage subsidence nor improves clinical outcomes. The described technique with use of CT-scan and strict fusion criteria is advocated for evaluating fusion rates when corpectomy cages are used.

Conflict of interest

Frank Kandziora and Klaus John Schnake have consultant contracts with Synthes, Switzerland.

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