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ORIGINAL ARTICLE

Does kyphotic deformity correlate with functional outcomes in fractures at the thoracolumbar junction treated by 360° instrumented fusion?

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Abstract Sagittal balance and its relationship with back pain and functional outcomes has become an important factor in the management of thoracolumbar fractures. The kyphosis threshold at the thoracolumbar junction (TLJ) that produces a significant functional impairment remains unclear. Ninety-four patients who were treated surgically for TLJ fractures were evaluated after a follow-up period of 2–10 years. Functional evaluation based on the Oswestry and Hannover Scores (HS) was performed. Additionally, such patients underwent clinical and radiological evaluation. A significant inversely proportional correlation between the HS and the degrees of local kyphosis ("K-Angle") ($p = 0.0172$) was found. A significant directly proportional correlation between Oswestry Score and "K-Angle" ($p = 0.0142$) was found. Significantly poorer scores with both measurement tools (Hannover and Oswestry Scores) were found in patients with a kyphosis higher than 12°.

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Introduction

Short-segment instrumentations with pedicle screws and rods have become a standard treatment option for "unstable" thoracolumbar fractures in many centers. However, a high incidence of loss of correction with such instrumentations, especially in burst fractures, has been reported [1–5]. On the other hand, it has been widely reported that in conservatively treated fractures, the local deformity tends to recur to degrees similar or greater than the initial values, regardless of the method of reduction and the use of casts or orthoses [6–11]. There is still controversy if kyphotic deformity after surgical treatment of thoracolumbar junction (TLJ) fractures can affect patients' outcome, and given such case, what degree of deformity would be *relevant* for functional detriment? In addition, there is not a consensus about values for maximal tolerable deformity in surgically treated TLJ fractures.

The literature describes that certain degree of local kyphosis can produce back pain after fractures of the TLJ fractures. We suspect that a significant *functional* impairment, before pain becomes the central issue, results as a consequence of a low degree of kyphosis. This effect may be underestimated due to the use of inadequate diagnostic tools for disability. Some patients may not complain of pain, because after injury, they have quit performance of "painful" activities, which were not considered painful before the fracture. Therefore, although they may not complain of pain, they may be experiencing functional limitations.

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This theory may be confirmed or rejected by defining clinical outcomes based on more sensible and comprehensive measurement tools than solely pain survey. Pain scale, used as an isolated measure of clinical outcome, may be insufficient. Instead, more comprehensive outcome-measurement instruments that integrate physical, social and mental health aspects should replace the former. Outcome-measuring questionnaires such as the Oswestry Disability Index (ODI) and the Hannover Score (HS) are more comprehensive and have greater sensibility and specificity than the pain visual analogue scale. Thus, if "pain" is the basis for describing clinical outcomes, the transition from pain to no pain is usually described between 15° and 20° kyphosis [10]. However, if other outcome-measurement tools are added to the pain scales, "clinical outcomes" could be interpreted as fair or definitively poor in patients with kyphosis far below 20°. The goal of our study is to investigate whether local kyphosis correlates with the Hannover and the Oswestry Scores in patients treated surgically for fractures at the TLJ, and given such case, to determine the degree of kyphosis significant for such scores.

Materials and methods

Retrospective study

Collection and analysis of admission data of all patients treated at our institution between January 1993 and December 2001 for fractures at the TLJ was done. Patients who met the inclusion criteria were recruited. Such patients were invited (by letter) to a follow-up examination, which was performed at the outpatient clinic.

Inclusion criteria were as follows:

1. Acute traumatic fractures located between T12 and L2 (we considered less than 4 weeks as acute, to avoid including structured post-traumatic kyphosis patients).
2. Treatment with the same technique [posterior/anterior instrumented fusion with Harms cage and Moss-Miami (Johnson and Johnson) screws].
3. Evidence of successful fusion.
4. Minimum 2-year follow-up.

Exclusion criteria were as follows: age under 18, no upper age limit was set, osteoporotic fractures, fractures of locations other than T12, L1 or L2, more than 4 weeks between the injury and the surgery, prior surgery of thoracic or lumbar spine, prior spinal disease, history of drug or alcohol abuse.

All patients were either operated by the senior surgeon or one of the two trained staffs.

The variables analyzed were as follows:

1. Clinical outcome
2. Sagittal deformity
3. Pain degree
4. Neurological condition
5. Range of motion
6. Type of fracture
7. Length of the follow-up period
8. Number of segments fused
9. Other variables such as demographic data, smoking condition, type of accident.

The same senior staff or one of the two trained staff surgeons did all surgeries. A single-staged circumferential surgery with a classic anterior left approach, a partial or complete vertebrectomy and canal release when needed was performed. Harms' cage filled with autogenous bone graft was then placed for anterior support (Johnson and Johnson, Acromed). Pedicular screws were then placed posteriorly (Moss-Miami, J&J, Acromed), under compression against the cage, and posterolateral autogenous bone was also used. In cases a laminectomy was needed, it was performed. In cases of severe instability (e.g., type "C" fractures), usually the posterior decompression and stabilization was performed first.

Clinical outcomes were measured with the Hannover VAS-Spine Score [12] and the ODI version 2.0 [13]. The Hannover VAS-Spine Score is a specific rating scale for outcome assessment in patients with thoracolumbar fractures and fracture dislocations. It consists of 18 items that evaluate back pain and functional limitations, using 100-mm visual analogue scales. The overall score is the mean of all items answered and can reach values between 0 and 100. The reference score in a healthy population averages 91.95. It has a high reliability and internal consistency (Cronbach's $\alpha = 0.9117$).

Sagittal deformity was measured in X-rays taken using a standardized protocol of orthogonal posteroanterior and lateral views (preoperatively, postoperatively and upon follow-up). Additional standing lateral dynamic X-rays were taken at the follow-up. The sagittal deformity was evaluated using the superior–inferior endplate angle ("K-Angle") with the Cobb method (Fig. 1). This method has demonstrated to be accurate, reproducible and with an acceptable intra- and interobserver variability [14]. Negative values of the "K-Angle" represent lordosis, while positive values represent kyphosis. Fusion was considered successful when bone bridges were evident, in the absence of implant fracture or loosening, and with absence of rotation or translation at the dynamic X-rays.

Pain was measured using a 100-mm visual analogue scale.

Neurological status was evaluated using the American Spine Injury Association Score (ASIA).

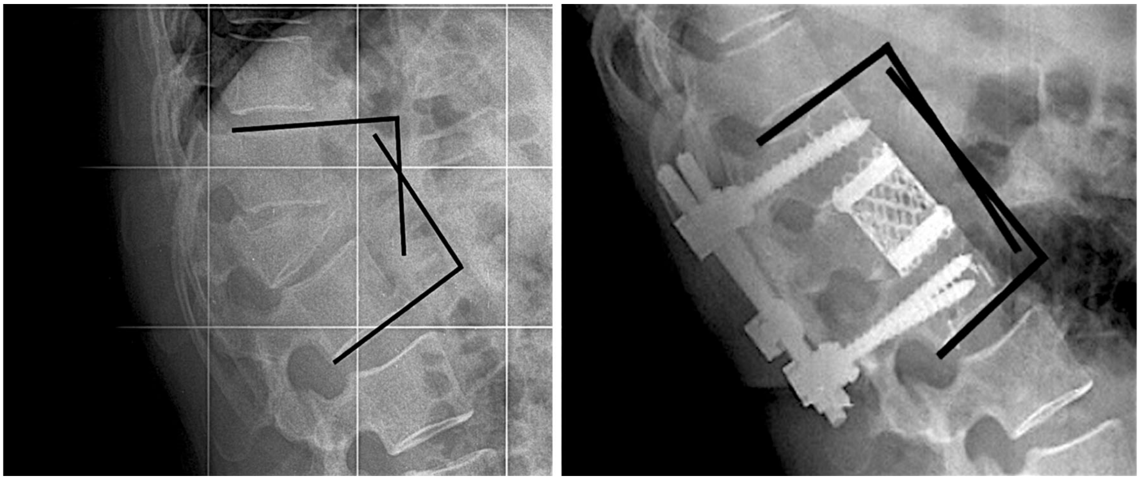

Fig. 1 Measurement of the "K-Angle"

Range of motion (ROM) was measured by means of the finger-to-ground distance, the Schober test (lengthening of a 10-cm distance cranial to L4 in maximum spinal flexion) and the Ott test (lengthening of a 30-cm distance caudal to C7 in maximum spinal flexion).

Fractures were classified according to the classification of Magerl et al. [15].

Statistical analysis

Averages, ranges and standard deviations were calculated.

T test, Wilcoxon test and Mann–Whitney *U* test were used. Multiple linear regression analyses were used to search for predictors of the Hannover VAS-Spine Score and ODI. The selection of risk factors was done using the stepwise technique, including in the regression models those with $p \leq 0.2$. Possible associations between the clinical outcome measurements (Hannover VAS-Spine Score and ODI) and the "K-Angle," pain degree, ROM, the ASIA Motor Index Score (MIS), the length of the follow-up period, the number of segments fused and the type of the fracture were investigated. Potentially confounding variables such as smoking habit, type of accident, age and gender were also analyzed. Correlation coefficients were calculated.

Significance level was established at $p < 0.05$.

Results

Of 125 patients who met the inclusion criteria, 94 were available for evaluation.

The mean age at follow-up was 49.06 years (20–77 years). Mean follow-up: 71.6 months (26.8–127.6 months).

Table 1 Fracture classification

Fracture classification	Frequency	Percent
C3	0	0
C2	6	6.4
C1	14	14.9
B3	0	0
B2	3	3.2
B1	11	11.7
A3	50	53.2
A2	8	8.5
A1	2	2.1
Total	94	100.0

There were 52 male and 42 female patients.

Patient's distribution by fracture classification after the classification of Magerl et al. [15] is shown in Table 1. The extension of the fusion was performed monosegmentally in 6 patients, bisegmentally in 81 and multisegmentally in 7.

At follow-up visit, 51.1 % of the patients reported some discomfort or pain at the surgical site, which averaged 34 mm in the visual analogue scale.

Nineteen patients had motor deficit upon admission. The MIS of these patients averaged 94 points. At follow-up control, the MIS of this group of patients ascended to 96 points ($p < 0.0001$, Wilcoxon test). One of the five patients classified as Frankel-ASIA "A" upon admission changed to "D." Of the six patients classified as Frankel-ASIA "B," 2 evolved to "C," and two to "D" at follow-up. All the three "C" cases upon admission, evolved to "D" at follow-up. Five patients were classified as "D" upon admission, two of them evolved to "E" (Table 2). No patient sustained neurological deterioration.

ROM values are listed in Table 3.

Preoperatively, the “K-Angle” averaged 15.8° (range −3 to 49). Postoperatively, the “K-Angle” averaged −0.7° (range −20 to 28). At follow-up, the “K-Angle” averaged 4.5°, range −25° to 35°.

HS averaged 65.5 (range 0.38–100). The ODI averaged 26.4 (range 0–98).

Among the analyzed variables, the following was found to be significant predictors of the HS: pain, “K-Angle,” smoker's condition, fusion length and finger-to ground distance (Table 4). The regression equation for the HS is:

$$\begin{aligned}\text{Hannover} = 102.8 - \text{‘K-Angle’} \times 0.4 - \text{pain degree} \\ \times 7.1 - \text{number of fused segments} \times X \\ - \text{‘finger-to-ground-distance’} \times 0.2\end{aligned}$$

where “X” is 9.3 in bisegmental fusions and 16,1 for tri- or multisegmental fusions.

Significant predictors of the ODI were as follows: pain, age, “K-Angle,” finger-to ground distance and the Schober test (Table 5). The regression equation for the Oswestry Score is:

$$\begin{aligned}\text{Oswestry} = -24.1 + \text{‘VAS - pain’} \times 5.5 + \text{‘K - Angle’} \\ \times 0.4 + \text{age} \times 0.3 + \text{‘Finger-to-ground-distance’} \\ \times 0.1 + \text{Schober (cm)} \times 1.1.\end{aligned}$$

The Pearson's correlation coefficient analysis (Tables 6, 7) showed a significant inversely proportional correlation between the HS and the “K-Angle” ($p = 0.0172$, $r = -0.26$), the pain degree ($p < 0.00001$, $r = -0.83$) and the finger-to-ground distance ($p = 0.0012$, $r = -0.39$).

There was a significant proportional correlation between the ODI and the “K-Angle” ($p = 0.0142$, $r = 0.26$), the pain degree ($p < 0.00001$, $r = 0.74$) and the finger-to-ground distance ($p = 0.0003$, $r = 0.41$). The detriment of the ODI and the HS increases with progression of the degree of kyphosis (Figs. 2, 3).

Patients with “K-Angle” >12° showed significantly worse scores on the Hannover VAS-Spine Score and the ODI ($p = 0.025$, and $p = 0.039$, respectively, Mann–Whitney test), compared to those with 12 or less degrees of kyphosis.

No association between the variable K-Angle and pain was found. In addition, no association between the ASIA Motor Score and the ODI or the HS was found.

Discussion

In our study, local kyphosis at the TLJ showed a correlation with the Hannover and the Oswestry Scores. The group of patients with kyphosis of the TLJ that exceeded 12° showed significantly poorer averages of Hannover and Oswestry Scores. Both scores showed a linear correlation with the local kyphosis at the TLJ.

Our aim was to search predictors for the Oswestry and HS, in patients treated with circumferential-instrumented fusion. We centered our interest in some variables that are not deeply studied in the literature. Initially, most results were published in terms of radiological or general clinical outcomes. In the last years, an increasing trend has been

Table 2 Cross-tabulation of Frankel-ASIA upon admission and at follow-up

	Follow-up					
	A	B	C	D	E	Total
Frankel-ASIA upon admission versus Frankel-ASIA at follow-up cross-tabulation						
Admission						
A	4	0	0	1	0	5
B	0	2	2	2	0	6
C	0	0	0	3	0	3
D	0	0	0	3	2	5
E	0	0	0	0	75	75
Total	4	2	2	9	77	94

Table 3 Range of motion at follow-up assessment

	Mean	Minimum	Maximum
Finger-to-ground distance (cm)	18.6	0.0	100.0
Schober test (cm)	12.6	0.0	15.0
Ott test (cm)	31.1	0.0	35.0

Table 4 Regression model for the Hannover VAS-Spine Score

Hannover VAS-spine score	Coefficient	Standard error	95 % CI	t	p
Intercept	102.8	5.6	91.5 to 114	18.5	0.000
VAS (pain)	−7.1	0.6	−8.3 to −5.9	−11.87	0.000
K-Angle	−0.4	0.2	−0.7 to −0.1	−2.65	0.011
Smoker's condition	6.5	3.2	−0.1 to 12.9	2.0	0.05
Length 1[a]	−16.1	8.3	−32.9 to 0.2	−1.9	0.059
Length 2[b]	−9.3	5.2	−19.7 to 1.1	−1.8	0.079
F-G-D[c]	−0.2	0.1	−0.4 to 0.0	−1.8	0.086

$R^2 = 0.87$

[a] Tri- or multisegmental fusions

[b] Bisegmental fusions

[c] Finger-to-ground distance

Table 5 Regression model for the ODI

ODI	Coefficient	Standard error	95 % Confidence interval	*t*	*p*
Intercept	−24.1	12.4	−49 to 0.8	−2	0.0057
VAS (pain)	5.5	0.5	4.4 to 6.6	10.1	0.000
Age	0.3	0.1	0.06 to 0.5	2.6	0.013
K-Angle	0.4	0.2	0.06 to 0.7	2.4	0.02
F–G–D[a]	0.1	0.07	−0.03 to 0.3	1.6	0.123
Schober	1.1	0.8	−0.5 to 2.6	1.4	0.166

$R^2 = 0.77$

[a] Finger-to-ground distance

Table 6 Correlation between the Hannover VAS-Spine Score and the K-Angle, pain degree, ROM, MIS, length of follow-up and age

Variable	Pearson's *r*	*p*
K-Angle	−0.26	**0.017**
Back pain (100 mm VAS)	−0.83	**0.00001**
F–G–D[a]	−0.39	**0.0012**
Schober	0.15	0.2516
Ott	0.14	0.3158
MIS	0.01	0.9141
Length of follow-up (months)	−0.02	0.5652
Age	−0.02	0.8364

Bold values are statistically significant ($p < 0.05$)

[a] Finger-to-ground distance

Table 7 Correlation between the ODI and the K-Angle, pain degree, ROM, MIS, length of follow-up and age

Variable	Pearson's *r*	*p*
K-Angle	0.26	**0.0142**
Back pain (100 mm VAS)	0.74	**0.00001**
F–G–D[a]	0.41	**0.0003**
Schober	−0.12	0.3114
Ott	−0.10	0.4311
MIS	−0.09	0.3828
Length of follow-up (months)	0.08	0.4722
Age	0.13	0.2048

Bold values are statistically significant ($p < 0.05$)

[a] Finger-to-ground distance

showed toward the clinical–functional outcomes. Under this scenario, we believe that it is important to understand as better as possible, which are predictors for these outcomes. We are aware that the treatment method, by itself, could be of capital importance. However, we did not intend to compare which therapeutic option is better, but we needed to explore which variables could influence the outcomes *in patients treated with the technique described in our study*. Among a list of possible independent (explanatory) variables, we analyzed those we intuitively thought could be correlated with both scores (ODI and Hannover), again, in patients treated with the aforementioned procedure. The selection of the predictors (risk factors) was done using the stepwise technique, including in the regression models all variables with statistical significance. We decided not to include patients under 18, due to legal reasons. On the contrary, we decided not to set an upper age limit, in order to avoid a potential bias. The minimal age in this studied group of patients was 20 and the maximum 77 years. When we made the statistical analysis, we found that age did not correlate with the HS; thus, when predicting Hannover (again, in patients treated as described), age should not be taken into consideration. ODI is different: age appeared as a significant predictor. This result confirms that it was appropriate not to set an upper age limit, as it should be considered a predictor for the ODI.

Our results should be a guide to predict ODI and HS *only for patients with fractures at the thoracolumbar junction treated with the technique described in our study*. We cannot extrapolate to other methods of treatment. An extrapolation cannot be proven or refused with this study model. We chose not to analyze other techniques, because we needed more information about the outcomes with this specific technique, due to a lack of data in the literature. Our results may or may not be reproducible for patients treated with, for example, posterior instrumentation. For this purpose, a further study should be designed. Nonetheless, our results are of importance for those instances when a circumferential-instrumented fusion is required or selected.

In order to avoid being misinterpreted: We do not aim to prove whether circumferential fusion is better or worse than other techniques. But we felt the need to identify variables that could influence our clinical–functional outcomes for this specific technique. We certainly are expectant (even anxious) to know whether the K-Angle is also significant when we treat patients with posterior instrumentations, since an important proportion of our

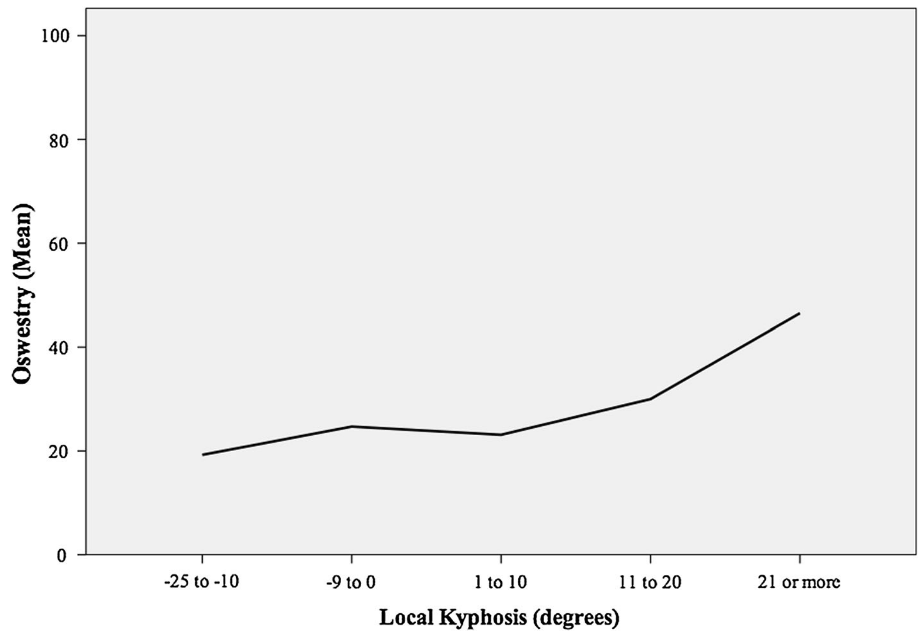

Fig. 2 The ODI deteriorates as the K-Angle increases

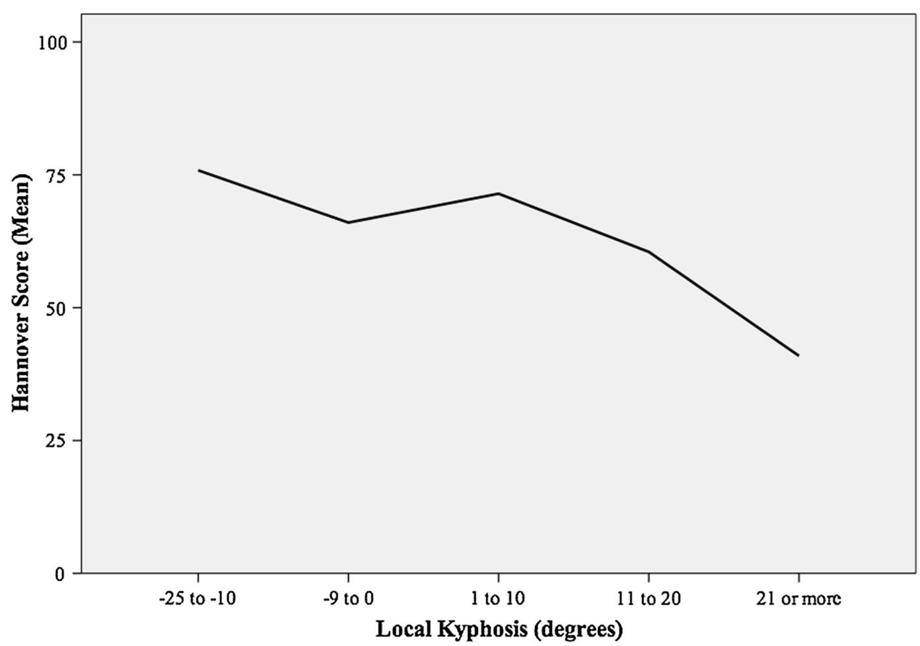

Fig. 3 The Hannover VAS-Spine Score deteriorates as the K-Angle increases

patients are treated in this manner. This was not the purpose of this study but we hope, will be for a future one.

The number of patients included in our study help us to infer that other confounding variables, especially pelvic parameters, which are constitutional, and therefore not susceptible to changes, had a Gaussian distribution in our studied cohort. Thus, such a "systematic" bias should not have interfered in our results. We did not intend to measure the pelvic parameters, because this was not our purpose. A further prospective study could be carried out to correlate the functional outcomes with kyphotic deformity in patients with different patterns of pelvic parameters/morphology and to establish adaptability ranges for each of these patterns at each fracture location (thoracic, thoracolumbar and lumbar). However, this could be difficult to be performed, since many of the sagittal balance measurements are performed in standing X-rays, which could be difficult to achieve in an acute traumatic population, where decisions are taken almost always in the acute phase. It makes more sense to establish the maximal acceptable residual deformity for a fusion in traumatic fractures at the TLJ, rather than determining the pattern of the pelvic parameters and the global balance at the acute phase in this population of patients, because in the acute traumatic condition, this may be very difficult to do, and since many of these parameters are constitutional, no attempt to modify them can be done. What we showed in our study is that kyphosis is a predictor for the Oswestry and HS. This variable can be modified for the sake of a better life quality of our patients.

To our knowledge, a numeric cutoff for local kyphosis after surgically treated fractures at TLJ, in terms of Oswestry or HS, *and not only pain assessment*, has not yet been elucidated. In our studied patients, this cutoff value was 12°. Possibly, the tolerance to kyphosis would be lower in the lumbar spine [26], in patients with previous abnormal sagittal balance and in those with reduced adaptation potential due to unfavorable pelvic parameters/morphology.

There is a known interdependence between pelvic incidence and lumbar lordosis. Koller [19] stated that patients have an individual adaptation potential at two levels of positional compensation: Thoracic/thoracolumbar hypokyphosis cephalad to the fractured level and increase in lumbar lordosis caudad to the fractured level. Koller also found that the lumbosacral segments caudad to a fracture could adapt in the ranges that are set by the pelvic incidence, in an inverse correlation with the degree of kyphotic deformity. That is, with the increase in the kyphotic deformity at the TLJ, the lumbar lordosis increases in ranges dictated by the pelvic incidence and sacral slope. However, this adaptative changes may have consequences: Oda [25], in an in vivo sheep model, found that a kyphotic posterolateral fusion significantly influenced cranial adjacent motion segment biomechanics by inducing more stiffness in the posterior ligamentous complex and increasing lamina strain under flexion–extension loading, indicating higher load transmission through the posterior column. The results of his histologic analysis showed significant degenerative changes in the adjacent facet joints in the kyphosis group. So, we come back to the *absolute value* of local kyphosis, which seems to be important by itself.

If our regression models were perfect, the coefficient would have reach 1. Nonetheless, a 0.87 coefficient for the HS and 0.77 for the ODI are high enough to be taken into account. That means, that an 87 % of the observed value of the HS or 77 % in the case of the ODI can be predicted by using our models. We were positively impressed at such coefficients, since our expectations were lower. "K-Angle" is a modifiable variable (e.g., through reduction), which should be considered a predictor for functional outcomes in patients with fractures at the TLJ, and it correlates with functional detriment in a linear fashion. The clinical importance of the sagittal balance of the spine is well documented [16–23]. A positive sagittal balance has been advocated as a cause of pain [9, 16] as well as a possible risk factor for adjacent segment decompensation after instrumented spinal fusions [24, 25]. Such imbalance may have a measurable clinical effect, as stated in a multicenter retrospective review of 352 patients with adult spinal deformity and positive sagittal balance, where a linear correlation between health status measurements and anterior deviation of the C7 plumb line was found [26]. Clinical effects of low degrees of post-traumatic kyphosis may be underestimated due to the use of inadequate tools for the diagnosis of disability. Depending on the instruments used to measure functional impairment, results of the latter might be interpreted in different ways. As a consequence of this, the threshold for clinical significance of a deformity may vary. The analogue pain scale, used as an isolated measurement of clinical outcome, may be insufficient. Outcome-measuring questionnaires such as the ODI and the HS are more comprehensive and have greater sensibility and specificity than the pain visual analogue scale. Some patients may not complain of pain, if they do not further perform "painful" activities, which were not considered as such before the fracture. Therefore, a number of patients "without" pain, but with functional limitations, may exist. The moment of pain onset may be also variable, and probably insidious, as the cumulative damage of the adjacent segments due to altered biomechanics becomes symptomatic. Furthermore, muscle fatigue may play an important role in symptom onset; however, time elapsed until the muscular envelope becomes ineffective is unknown. This may be an important factor for understanding the contradictory reports of a theoretical correlation between kyphosis and clinical outcome [4, 8–11, 27–34].

Like other reports in the literature [8, 11, 29–34], we could not find a relationship between the degree of pain and the kyphosis angle. A possible explanation may be that the mean kyphosis angle was 4.5° in our patients, and in only six cases, the local kyphosis ascended to 20° or more. Pain in all these six patients was higher than the average, and the Oswestry and HS were poorer. Thus, it is possible that a correlation may exist, yet possibly at higher degrees of kyphosis, but we could not confirm this in our study, perhaps due to the small number of patients with a significant deformity in our series.

On the contrary, there are many reports that have found a correlation between deformity and pain [4, 9, 10, 27, 28]. One cause of these controversial results may be small sample sizes in several publications, or analysis errors, or error in the selection of the tools used to assess disability. We think that the main cause is that at low degrees, kyphosis simply *may not correlate* with pain intensity. However, Oswestry and HS correlate with the kyphosis at the TLJ, and this correlation progresses in a linear fashion as deformity increases, becoming significant when it exceeds the 12°. Other authors have reported the same trend in conservatively treated patients, using the Hannover, the Roland Morris Disability Spine Questionnaire, the Greenough low back outcome scale and the SF-36 [19].

We have chosen a cohort of patients treated with combined anterior–posterior fusion, because the latter was the preferred technique at this period of time in our institution, and it was not our purpose to evaluate the technique itself or to compare it with other treatment options, but to search for predictors for disability. No attempt was made in order to determine which treatment option is better, because it was not our purpose. Also, no attempt was made to establish that a circumferential fusion is better or worse than any other technique. We also treat our patients case by case, either conservatively or only by posterior fusion, and under certain circumstances, we prefer a circumferential fusion. We have excluded patients treated with other techniques or with fractures at other segments, to reduce confounding variables. Further studies are needed to determine whether the same correlation could be observed in patients treated with other treatment options. We think that if the goal of stabilization, decompression and proper deformity correction with minimal extension of fused segments is achieved, surgical technique differences may be secondary (posterior, anterior or combined anterior–posterior). A 12° K-Angle must be considered the maximal acceptable kyphosis during surgery in order to insure positive functional outcomes.

The intuitive belief that long fusions might determine poorer outcomes was confirmed herein for the HS. This reaffirms the importance of the selection of the shortest possible fusion.

Conflict of interest The corresponding author developed this study in the frame of a research fellowship supported by an academic institution without relationship with the biomedical or pharmacological industry (Deutscher Akademischer Austauschdienst). No other financial support, direct or indirect, was received by any of the authors.

References

1. Alanay A, Acaroglu E, Yazici M et al (2001) Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine 26:213–217
2. Knop C, Fabian H, Bastian L et al (2001) Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 26:88–99
3. McCormack T, Karaikovic E, Gaines RW (1994) The load-sharing classification of spine fractures. Spine 19:1741–1744
4. McLain RF, Sparling E, Benson DR (1993) Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J Bone Jt Surg (Am) 75-A:162–167
5. McLain R (2004) Functional outcome after surgery for spinal fractures: return to work and activity. Spine 29:470–477
6. Alanay A, Yazici M, Acaroglu E et al (2004) Course of non-surgical management of burst fractures with intact posterior ligamentous complex: an MRI study. Spine 29:2425–2431
7. Cantor JB, Lebwohl NH, Garvey T et al (1993) Nonoperative management of stable thoracolumbar burst fractures with early ambulation and bracing. Spine 18:971–976
8. Chow GH, Nelson BJ, Gebhard JS et al (1996) Functional outcome of thoracolumbar burst fractures managed with hyperextension casting or bracing and early mobilization. Spine 21:2170–2174
9. Gertzbein S (1992) Scoliosis research society: multicenter spine fracture study. Spine 17:528–540
10. Tropiano P, Huang R, Louis C et al (2003) Functional and radiographic outcome of thoracolumbar and lumbar burst fractures managed by closed orthopaedic reduction and casting. Spine 28:2459–2465
11. Wood K, Butterman G, Mehbod A et al (2003) Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. J Bone Jt Surg (Am) 85-A:773–781
12. Knop C, Oeser M, Bastian L et al (2001) Entwicklung und Validierung des VAS-Wirbelsäulenscores. Unfallchirurg 104:488–497
13. Fairbank JCT, Pynsent PB (2000) The Oswestry Disability Index. Spine 25:2940–2953
14. Kuklo T, Polly D, Owens B et al (2001) Measurements of thoracic and lumbar fracture kyphosis: evaluation of intraobserver, interobserver, and technique variability. Spine 26:61–66
15. Magerl F, Aebi M, Gertzbein S et al (1994) A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 3:184–201
16. Lazennec JY, Ramare S, Arafati N et al (2000) Sagittal alignment in lumbosacral fusion: relations between radiological parameters and pain. Eur Spine J 9:47–55
17. Roussouly P, Gollogly S, Berthonnaud E et al (2005) Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. Spine 30:346–353
18. Vialle R, Levassor N, Rillardon L et al (2005) Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Jt Surg (Am) 87-A:260–267
19. Koller H, Acosta F, Hempfing A et al (2008) Long-term investigation of nonsurgical treatment for thoracolumbar and lumbar burst fractures: an outcome analysis in sight of spinopelvic balance. Eur Spine J 17:1073–1095
20. Stolze D, Harms J (1999) Correction of traumatic deformities. Principles and techniques. Der Orthopäde 28:731–745
21. Jackson RP, Hales C (2000) Congruent spinopelvic alignment on standing lateral radiographs of adult volunteers. Spine 25:2808–2815
22. Jackson RP, Kanemura T, Kawakami N et al (2000) Lumbopelvic lordosis and pelvic balance on repeated standing lateral radiographs of adult volunteers and untreated patients with constant low back pain. Spine 25:575–586
23. Barrey C, Jund J, Noseda O et al (2007) Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J 16:1459–1467
24. Kumar MN, Baklanov A, Chopin D (2001) Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. Eur Spine J 10:314–319
25. Oda I, Cunningham B, Buckley R et al (1999) Does spinal kyphotic deformity influence the biomechanichal characteristics of the adjacent motion segments? An in vivo animal model. Spine 24:2139–2146

26. Glassman SD, Bridwell K, Dimar JR et al (2005) The impact of positive sagittal balance in adult spinal deformity. Spine 30:2024–2029
27. Folman Y, Gepstein R (2003) Late outcome of nonoperative management of thoracolumbar vertebral wedge fractures. J Orthop Trauma 17:190–192
28. Oner FC, van Gils APG, Faber JAJ et al (2002) Some complications of common treatment schemes of thoracolumbar spine fractures can be predicted with magnetic resonance imaging. Spine 27:629–636
29. Mumford J, Weinstein JN, Spratt KF et al (1993) Thoracolumbar burst fractures: the clinical efficacy and outcome of nonoperative management. Spine 18:955–970
30. Sanderson PL, Fraser RD, Hall DJ et al (1999) Short segment fixation of thoracolumbar burst fractures without fusion. Eur Spine J 8:495–500
31. Siebenga J, Leferink VJ, Segers MJ et al (2006) Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment. Spine 31:2881–2890
32. Wood KB, Bohn D, Mehbod A (2005) Anterior versus posterior treatment of stable thoracolumbar burst fractures without neurologic deficit: a prospective, randomized study. J Spinal Disord Tech 18(Suppl):S15–S23
33. Korovessis P, Baikousis A, Zacharatos S et al (2006) Combined anterior plus posterior stabilization versus posterior short-segment instrumentation and fusion for mid-lumbar (L2–L4) burst fractures. Spine 31:859–868
34. Briem D, Lehmann W, Ruecker AH et al (2004) Factors influencing the quality of life after burst fractures of the thoracolumbar transition. Arch Orthop Trauma Surg 124:461–468