Combined posterior–anterior stabilisation of thoracolumbar injuries utilising a vertebral body replacing implant

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Abstract The authors report on a prospectively followed series of 35 patients with injuries of the thoracolumbar spine from T7 to L3. The radiological course after combined posterior–anterior surgery with anterior column reconstruction with a distractible vertebral body replacing implant demonstrated a stable reconstruction technique with almost no re-kyphosing. In 18/18 patients with CT follow-up intervertebral fusion was observed as bony bridging lateral to the VBR implant. The functional/clinical outcome of the patients was analysed with a set of eight validated outcome scales. After an average follow-up period of 2½ years encouraging results were noticed. The neurological improvement rate (≥ 1 Frankel/ASIA grade) was 8/12 patients (67%) with a complete recovery in 6 cases. 17/29 patients returned to former occupation; 20/29 patients returned to former leisure activities; 24/28 patients rated their general outcome as “unlimited and pain free” or “occasionally and/or mild complaints” with a VAS score of >80 (scale 0–100). The psychometric questionnaires revealed good results with strong correlation comparing the different scoring systems statistically: mean McGill Pain Questionnaire 12.5 (0–40); mean Oswestry Disability Index 20% (0–51). 13/29 patients scored <4 in the Roland and Morris Disability Questionnaire. The German back pain questionnaire (Funktionsfragebogen Hannover Rücken) showed a mean “functional capacity” of 75%, corresponding with moderate restriction. We concluded the presented method as highly effective to completely reduce

and maintain an anatomic spinal alignment. The outcome tended to be better in comparison with non-operatively treated patients as well as with norm populations with low back pain.

Keywords Spinal injuries · Surgical procedures · Spinal fusion · Patient outcome assessment · Follow-up studies

Introduction

Several treatment options for thoracolumbar injuries are still under debate. Many reports and even multicenter studies have not fully answered the question of how to treat these injuries best. Consequently, up to now, a “gold standard” does not exist [37, 46–48, 55]. Even in case of associated neurologic deficit the choice of treatment seems to be open and we lack a proof for superiority of any surgical treatment [15].

With regard to the most common injury—the A 3 lesion according to the AO/Magerl classification (incomplete to complete burst fractures; [69])—we still have good scientific justification for all treatment options. On one hand, throughout the world non-operative treatment might still be the most frequently chosen way to treat these lesions [23, 45, 82, 84, 98, 101, 104]. On the other hand, numerous authors favour surgical treatment, even in patients without neurologic deficit [1, 12, 13, 17, 25, 26, 57, 66, 76, 77, 99]. Furthermore, various surgical techniques have been described and remain a matter of discussion. The variety of techniques reach from posterior stabilisation alone over anterior alone to combined approaches [17, 25, 43, 65, 74–76, 92, 106]. Open, minimally-invasive, and endoscopic approaches have been described as well [10]. The necessity

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for additional posterior or intervertebral fusion is under discussion. Yet, we lack a scientific evidence for any superiority of all known treatment options!

Limitations for each of the methods and its indications became clearer over the last 20 years. The more the anterior destruction and impairment of load bearing capacity of the anterior column we face, the more anterior reconstruction in addition to stabilisation in front or back should be considered [46, 49, 50, 84, 98, 99]. The short-segmental posterior internal fixator is still the gold standard device for reduction and stabilisation. For reconstruction of the anterior column a tendency towards titanium implants can be observed [62, 99]. One aspect might be the significant comorbidity of autogenous iliac crest graft harvesting [96, 103, 105]. A second might be the availability of distractable implants to be placed in minimal-invasive technique [53]. Although satisfying biomechanical in vitro behaviour of these implants was proven, only few clinical results and outcome reports have been published so far [51, 52].

We report on a prospectively followed series of patients with injuries of the thoracolumbar spine with focus on both the technical results with the combined posterior–anterior technique and the outcome of the patients.

Materials and methods

From January 2000 until December 2003, 35 patients with injuries of the thoracic and lumbar spine were operatively treated with combined posterior stabilisation and anterior reconstruction with a titanium implant for vertebral body replacement (SynexTM, Synthes Medical, Oberdorf, Switzerland). 29 patients (9 female, 20 male) with an average age of 48 (24–72) years were included in a follow-up study. The drop out of six patients was due to not willing to participate ($n = 3$) or not traceable with unknown address ($n = 3$). The mean follow-up period was 31 (12–55) months. The average age at follow-up was 50 (27–74) years.

Operative treatment

The surgical method included a posterior reduction and stabilisation with internal fixator (USSTM pedicle screw system, Synthes Medical, Oberdorf, Switzerland) and posterior interlaminar fusion with autogenous bone. An additional cross-link was used in all cases. The anterior reconstruction was performed as a one- or two-stage procedure (Table 1). For anterior reconstruction, the vertebral body replacing implant SynexTM was chosen. The implant was surrounded by autogenous bone for interbody fusion. If necessary, synthetic β -tricalciumphosphate (ChronosTM, Synthes Medical, Oberdorf, Switzerland) was added to

Table 1 Frequencies of patients with acute injury, non-acute injury and posttraumatic deformity, share of patients with one-stage and two-stage procedure ($n = 29$)

	Acute (≤ 3 weeks)		Non-acute (> 3 weeks)		Posttraumatic deformity		Total
	<i>N</i>	%	<i>n</i>	%	<i>n</i>	%	
One-stage	13	54	2	100	3	100	18
Two-stage	11	46	0	0	0	0	11
Total	24	100	2	100	3	100	29

increase the amount of fusion material. A detailed description of the surgical technique has been published [53].

Documentation

For data recording the documentation set for spinal injuries, its treatment and patient follow-up forms of the second multi-centre study of the German Trauma Association's work group "spine" was used [55]. In addition, we utilised a set of validated outcome scales for measuring the patients' outcome with regard to subjective function and complaints:

- Details of accident, spinal injuries and associated injuries according to AO classification of spinal injuries, Abbreviated Injury Scale (AIS) and Injury Severity Scale (ISS) [6, 7, 69]
- Neurologic impairment according to Frankel/ASIA [3, 34]
- Details of surgical treatment and complications
- X-ray and CT data: segmental angulation was measured as endplate angle (EA) between both endplates adjacent to the fused segments in the lateral projection (Fig. 1). Negative values indicate kyphosis while positive values indicate lordosis, respectively. The mean difference between preoperative and postoperative angulation was calculated as correction angle (CA), the mean difference between postoperative value and follow-up angulation as loss angle (LA), and the mean difference between preoperative angulation and follow-up result as gain angle (GA).

A follow-up CT scan was not included in the study protocol. Nevertheless, the available data was analysed.

- Follow-up, including data on periods of physiotherapy, activities, and employment
- Outcome according to the following validated psychometric questionnaires (Table 2): Visual Analog Scale (VAS), The McGill Pain Questionnaire (MPQ), The Roland and Morris Disability Questionnaire (RDQ), Oswestry Disability Index (ODI), a German back pain

Fig. 1 Endplate-angle EA: measurement of segmental angulation in patients with monosegmental (*left*) and bisegmental reconstruction (*right*); positive values (+) indicating lordosis, negative values (–) indicating kyphosis

questionnaire (Funktionsfragebogen Hannover, Rücken; FFbH-R), Short Form health survey 36 (SF-36); Every Day Life Questionnaire (EDLQ); a German questionnaire for pain regulation (Funktionsfragebogen zur Schmerzregulation; FSR)

SPSS for Windows Version 12.0 and standardised tests were used for data analysis and statistical evaluation.

Results

Falls from a height ($n = 12$) were the predominant cause of injury, followed by ski-injuries ($n = 5$) and banal falls. The group consisted of 24 patients with acute (≤ 3 weeks), two patients with non-acute (> 3 weeks) fractures and three patients with posttraumatic deformity of the thoracic and lumbar spine.

The first lumbar vertebral body (L1) was most frequently affected ($n = 17$), followed by T12, and L2 (Fig. 2). In six cases only one segment was affected by the injury, whereas in 21 patients two segments were involved. We treated two patients with multi-level lesions (unaffected segments between fractured vertebrae).

Classification

The injuries were classified according to the AO classification by Magerl et al. [69]. Predominantly, we observed Type A (compression/burst; $n = 20$), followed by Type B (distraction injuries; $n = 5$), and Type C (rotational injuries; $n = 4$) lesions.

A one-stage procedure was performed in 13 out of 24 patients with acute injuries (Table 1). A staged procedure

was used for the remaining 11 patients. The average interval between anterior and posterior surgery was 9 (1–29; SD 9.5) days. In patients with non-acute injuries ($n = 2$) or posttraumatic lesions ($n = 3$) a one-stage procedure was performed.

One-stage procedure ($n = 18$)

As anterior approach thoracoscopy was chosen in 12 patients, respectively a thoracotomy in 4 and a lumbotomy in 2 cases. A monosegmental anterior reconstruction with SynexTM was performed in 5 and a bisegmental one in 13 patients.

One perforation of the aorta occurred by dislocation of a guidance k-wire during thoracoscopy. After conversion to thoracotomy, the aorta was successfully sutured without any consequences. A blood loss of 3,600 ml in this case was compensated by 6 erythrocyte concentrates. No other complications were observed in this group.

The mean operative time in this group was 217 min (SD, 170–300 min). The mean fluoroscopy time was 80 s (SD 36, 23–136). The mean intraoperative blood loss was 1,211 ml (SD 1,043; 400–3,600 ml). The mean time of hospital stay until the patients were discharged was 15 (9–28) days.

Two-stage procedure ($n = 11$)

Four patients with type A, three with type B, and four with type C injury were treated with staged operations. The mean interval between posterior and anterior surgery was 9 days (SD 9.5; 1–29 days).

An anterior approach thoracoscopy was chosen in nine patients, respectively: a thoracotomy in one and a

Table 2 Psychometric questionnaires used for assessment of patients' outcome

Name, reference	Scoring	Description
Visual Analog Scale (VAS) [54]	19 items 0–100 (100 = best score, no complaints/pain)	19 questions, each to be answered on a 100-mm scale, total score is calculated as mean of all answered items.
McGill Pain Questionnaire (MPQ) [73]	20 items 0–78 (0 = best score, no complaints/pain)	Based on multidimensional pain concept of Melzack and gate control theory, consists of 78 pain describing words, combined into 3 major groups of word descriptors: sensory, affective, evaluative dimensions. Words are used by patients to denote subjective pain experience. By addition of all points a total value is calculated.
Roland and Morris Disability Questionnaire (RDQ) [85]	24 items 0–24 (0 = best score, no complaints/pain)	Score was originally designed for use in primary care as well as for research. 24 questions, related to impairment due to back pain. Total score is calculated by addition of all marked items.
Oswestry Disability Index (ODI) [30, 71, 72]	10 items 0–100 (0 = best score, no complaints/pain)	10 items relating to every day activities (personal care, lifting, walking, sitting, standing, sleeping, sex life, social life, travelling). Score was designed to evaluate back pain as well as physical disability in daily life. Each item is scored from 0 to 5. Total ODI score is calculated by summing up all scored points and dividing the sum by the highest reached score. German version, validated by Mannion et al.
Funktionsfragebogen Hannover – Rücken (FFbH-R) [81]	12 items 0–100 (100 = best score, no complaints/pain)	German back pain questionnaire. Questionnaire assesses the subjective attitude of back pain as well as the effect on functionality and mobility of the spine with everyday activities. 12 items referring to everyday life aspects: Mobility, personal hygiene, dress, objects lifting and moving. Total score giving percentage value: normal functional capacity (100–80%), moderate functional capacity (79–60%), significant restriction of functional capacity (<60%).
Short Form health survey 36 (SF-36) [21]	36 items 0–100 (100 = best score, no complaints/pain)	Score was developed and frequently tested to describe the health status and quality of life. 36 questions, which can be evaluated on a profile of eight scales. Four scales, physical functioning, physical role, bodily pain, general health represent the topic physical health. The scales vitality, social functioning, emotional role and mental health evaluate the patients' mental health. German version, validated by Bullinger et al.
Every Day Life Questionnaire (EDLQ) [20]	42 items 9–45 (45 = best score, no complaints/pain)	The Every Day Life Questionnaire correlates to the German Test "Alltagsleben". The 42 items, marked on a five point Likert scale. 6 subscales: bodily condition, psychical constitution, functional role in daily life, social life, soulfulness, medical supply. High score values indicate good life quality
Funktionsfragebogen zur Schmerzregulation (FSR) [90]	56 items 8–56	German questionnaire for pain regulation. 56 items, 7 subscales, 2 main scales. Questionnaire evaluates pain perception as well as individual behaviour due to pain.

Fig. 2 Frequencies of injured levels of the spine

lumbotomy in one case. In one case SynexTM was applied monosegmentally. In all remaining cases ($n = 10$) two segments were bridged.

In eight patients a decompression was necessary. In two patients only a posterior decompression of the spinal canal was performed, while in three patients the decompression was completed during anterior surgery. In three patients the canal was only decompressed from the front.

In four patients a dura tear was observed and closed with suture via the posterior approach.

We observed three postoperative complications: one patient suffered from a pneumonia, in one patient drainage of a pleural effusion became necessary. One patient sustained a severe soft tissue damage above the thoracolumbar

C type lesion with severe neurologic deficit (Frankel/ASIA B) due to direct trauma. In this case surgical revision was necessary for debridement and later free-flap wound closure. During first revision a misplaced screw was revised.

The mean time for the posterior surgery was 160 min (SD 51; 85–225 min.). The mean anterior operative time was 170 min (SD 39; 120–240 min.). Fluoroscopy time averaged 77 s for the posterior surgery (SD 51; 25–129 s) and 76 s for the anterior operation (SD 39; 45–115 s).

The mean intraoperative blood loss was 867 ml (SD 815; 300–1,800 ml) for the posterior, and 1,143 ml (SD 938; 300–2,500 ml) for the anterior surgery, respectively.

The mean time of hospital stay until the patients were discharged was significantly ($P < 0.05$) longer in this group with 25 (16–47) days.

Neurological course

On admission 12 out of 29 patients suffered from an associated neurologic deficit: 4 had an incomplete paraplegia (Frankel/ASIA D), 6 an incomplete paraplegia (Frankel/ASIA C) and 2 an incomplete paraplegia (Frankel/ASIA B). A complete paraplegia (Frankel/ASIA A) was not observed.

At follow-up an improvement of at least 1 Frankel/ASIA grade was observed in 8 out of 12 patients (67%). A complete recovery was observed in 6 patients: 4 patients improved from Frankel/ASIA D to Frankel/ASIA E and 2 patients from Frankel/ASIA C to E. 23 patients had no neurological deficit at follow-up.

Associated injuries

A total of 15 out of 29 patients (52%) suffered from an isolated spinal injury, while 11 patients had at least one significant associated injury and 3 patients were polytraumatized. The 15 patients with isolated spinal injury scored 3 points in the Abbreviated Injury Scale for “Thorax” or “Abdomen”, depending on the level of injury. This was corresponding to an Injury Severity Score (ISS) of 9 points. All patients with associated injuries scored ≥ 16 points in the ISS. The overall mean ISS was 16 (SD 9.8; 9–48).

Radiographic evaluation

In six patients with injuries of the thoracolumbar junction SynexTM was used for monosegmental reconstruction (Fig. 3). The mean segmental EA on admission was -17° . The kyphotic deformity was reduced to a mean postoperative EA of $+2^\circ$. At follow-up the mean EA was $+0.5^\circ$. The mean operative reduction was 18.7° . We observed a

mean difference between trauma series and follow-up angulation (GA) of 17.2° (Table 3).

In 23 patients SynexTM was bisegmentally implanted (Fig. 4). Due to different anatomic angulation we differed between the three spinal sections: thoracic spine (T7–T8; $n = 3$), thoracolumbar junction (T12–L2; $n = 17$), and the lumbar spine (L3; $n = 3$). The mean “radiologic benefit” until follow-up, the so called GA was $+14^\circ$ in the thoracic spine, $+12.3^\circ$ at the thoracolumbar junction, and $+3.3^\circ$ in the lumbar cases (Table 4). The relatively minor radiological benefit in those three patients with lumbar fractures resulted from one case where we observed a sinking of the cage into the osteoporotic adjacent endplates. This led to a loss of correction of 15° . Nevertheless, bony fusion occurred and an acceptable alignment remained (Fig. 5).

CT scan and fusion rate

Anterior interbody fusion was assessed by a follow-up CT scan in 18 patients. In all patients fusion was observed as bony bridging lateral to the SynexTM. In 15 out of those 18 patients bilateral fusion mass was visible, in 3 patients only unilateral.

In the remaining 11 patients the anterior fusion was assessed by conventional radiography: 3 cases were rated as fused, in 8 cases a definite fusion was uncertain.

Follow-up

The mean length of the primary hospital stay was 18 (9–47) days, 19 out of 29 patients proceeded in a rehabilitation clinic for 7.5 (2–50) weeks. 15 patients out of 29 obtained physiotherapy for 2.1 (1–12) months.

A total of 7 patients out of 29 were already unemployed or retired before the injury. 8 had a sedentary job, 3 were in light work, and 11 in hard work.

At time of follow-up 17 out of 29 returned into their former occupation, 4 of them with mild restriction. 2 patients changed their occupation, another 3 had to quit work due to the injury due to incomplete paraplegia (Frankel/ASIA C at follow-up).

A total of 20 out of 29 patients returned into their former leisure activities, 8 of them with mild restriction. 5 patients complained of clear limitations in leisure time activities due to the injury, 3 patients could only accomplish their daily activities and 1 patient became a nursing case.

A total of 12 out of 28 patients rated their subjective “back function” as “unlimited and pain free”. Another 12 patients described “occasionally and/or mild complaints”. 1 patient complained of “frequently mild complaints”, and another 3 patients were clearly limited by “frequently intense complaints”.

Fig. 3 Forty-eight-year-old female, collision with car as a bike-rider, flexion-distraction injury T12 (B 1.2; burst-split fracture with posterior disruption, indicated by transverse lesion of spinous process T11), sensory deficit Frankel/ASIA D (a); posterior stabilisation and

monosegmental anterior reconstruction (b); solid interbody fusion after implant removal (c); unchanged alignment at follow-up 5½ years after surgery (d)

Table 3 Radiographic evaluation of monosegmentally implanted Synex™ ($n = 6$), mean $\pm$ SD and range of monosegmental angles

	Preop SA (°)	Postop SA (°)	Follow-up SA (°)	Reduction CA (°)	Re-kyphosing LA (°)	Benefit GA (°)
Thoracolumbar (T12–L1)	-17 ± 4.6 (–23 to –9)	$+2 \pm 2.5$ (–2 to +4)	$+0.5 \pm 3.3$ (–3 to +5)	18.7	1.5	17.2

Approach-related “mild complaints” were reported by four patients regarding the anterior approach, while three rated them as “severe and frequent”.

At the iliac crest donor site 19 out of 28 patients were pain free, 8 patients reported “occasional/mild complaints” and 1 patient rated them as “frequent/intense complaints”.

Psychometric questionnaires

Visual analog scale (VAS)

As an individual “norm value” before the injury the patients retrospectively scored 89.3 ± 16.3 (46–100). 24 out of 29 patients stated a widely unimpaired back function

(VAS > 80). At the time of follow-up the mean score was significantly ($P = 0.008$) decreased with 69.6 ± 23.7 (17–99). As difference between pre-injury and follow-up, we calculated a mean individual “score loss” of 19.7 ± 21.3 (0–81). 6 patients had a score loss of 0, 1 patient scored a “score loss” of 81 points. These values showed a good correlation to all other questionnaires.

McGill Pain Questionnaire (MPQ)

The mean MPQ at follow-up was 12.5 (0–40) whereby the male patients (40 points) scored ten points higher compared to the women (30 points). Most often (13/29) current pain was described as “annoying”.

Fig. 4 Fifty-nine-year-old female after fall from ladder, complete axial burst fracture (A 3.3) without neurologic deficit (**a**); postoperative result after one-stage combined stabilisation and reconstruction

(**b**); solid interbody fusion and unchanged alignment before implant removal (**c**); late follow-up 31 months after surgery (**d**)

Table 4 Radiographic evaluation of bisegmentally implanted SynexTM ($n = 23$), mean $\pm$ SD and range of bisegmental angles

	Preop SA (°)	Postop SA (°)	Follow-up SA (°)	Reduction CA (°)	Re-kyphosing LA (°)	Benefit GA (°)
Thoracic (T7–T8)	-26.7 ± 5 (–33 to –22)	-11.3 ± 4 (–15 to –7)	-12.7 ± 2.3 (–14 to –10)	15.3	1.3	14
Thoracolumbar T12–L1	-7.9 ± 11 (–30 to +18)	$+7.3 \pm 7.7$ (–8 to +18)	$+4.5 \pm 4$ (–7 to +15)	15.2	2.8	12.3
Lumbar L3	3.7 ± 3 (0 to +6)	$+14 \pm 8$ (+5 to +20)	$+7 \pm 15$ (–10 to +18)	10.3	7.0	3.3

Roland and Morris Disability Questionnaire (RDQ)

A significant correlation ($P = 0.06$) was observed with VAS, FFbHR, and ODI.

Thirteen out of 29 patients scored a RDQ <4 . 6 patients scored between 4 and 8 (“light impairment”). More severe

impairment was noted in another 6 patients (mean score 9–12), and 4 patients with a mean score of >12 .

Most often sentence 2 and sentence 11 was stated: “I change position frequently to try to get my back comfortable” ($n = 14$) and “Because of my back, I try not to bend or kneel down” ($n = 14$).

Fig. 5 Seventy-two-year-old patient, burst fracture A 3.3, osteoporosis, increasing and incapacitating pain 5 days after car injury (**a**); satisfactory result after bisegmental stabilisation and reconstruction

(**b**); sinking of SynexTM into both adjacent endplates with significant re-kyphosing 2 months postoperative (**c**); 3 years follow-up showed unchanged situation (**d**) with solid 360° fusion in CT scan (**e**)

Oswestry Disability Score (ODI)

The mean ODI at follow-up was 20% (0–51). A distinct impairment was stated for the following activities: “lifting heavy weights” ($n = 5$), “walking” ($n = 5$) and “standing” ($n = 5$).

German back pain questionnaire (Funktionsfragebogen Hannover Rücken; FFbHR)

This questionnaire assesses the patients’ personal attitude towards their injury and the impairment in daily activities. The mean “functional capacity” was 75%, corresponding with moderate restriction.

A total of 12 out of 29 patients scored a “normal functional capacity” (80–100%). 8 patients scored “mild/moderate” (60–79%) and 9 “relevant restriction of the functional capacity” (<60%).

The most frequently found problems were “fast running > 100 m” ($n = 13$), “lifting a suitcase” ($n = 7$) and “30-min standing” ($n = 7$).

Short Form health survey 36 (SF-36)

This questionnaire assesses physical health as well as patients’ psychological status.

The section “physical health” combines four different scales: physical function 60.6 (5–100), physical role 55.2

(0–100), bodily pain 63.0 (10–100) and general health 67.9 (25–100).

“Mental health” is defined by another four scales: vitality 59.1 (10–90), social function 79.1 (25–100), emotional role 70.1 (0–100), mental health 70.8 (12–96).

Question 2 refers to the state of health 1 year ago. 3 out of 29 patients felt a little worse, 12 rated their state of health similar to the status 1 year ago, 7 patients reported “mild improvement” and another 7 even a “significant improvement”.

Everyday Life Questionnaire (EDLQ)

This questionnaire measures aspects of everyday life. At follow-up the patients scored in six subscales: bodily condition 34.3 (22–45), psychical constitution 35.5 (15–45), functional role in daily life 36.0 (13–45), social life 36.1 (21–45), soulfulness 11.8 (3–15), medical supply 11.5 (3–15).

German questionnaire for pain regulation (Fragebogen zur Schmerzregulation; FSR)

The average score in seven subscales was as follows: competence 39.1 (15–56), intensity of pain 23.5 (4–48), anxiety 30.0 (8–54), depression 23.4 (3–45), avoidance 24.0 (2–45), resignation 25.9 (8–43) and distraction 29.6 (3–45).

Worst case scenario in clinical outcome

The number of patients followed was 29 out of 35 (83%). To enhance reliability of the study we assumed the six cases (17%) dropped out all to having scored an “unsatisfactory result” only. As a “worst case scenario” we would then have observed the following results.

The rate of patients returning into their former occupation would have been 17/35 (49%), those patients returning to former leisure activities would have been 20/35 (57%) respectively. With regard to “back function” the rate of patients with a good outcome (“unlimited and pain free” or “occasionally and/or mild complaints”) would have been 24/35 (69%).

Discussion

The epidemiologic data of our study group with an average age of 48 years and a sex distribution with 2/3 male patients correlates well with published data [47, 50, 58, 62, 83]. In contrast to other studies we also included non-acute injuries (10%) and posttraumatic instabilities (7%). We observed a typical distribution of the injured levels of the

spine, involving most frequently the L1 vertebrae followed by T12. The different subtypes of burst fractures (A3 according to AO/Magerl [69]) were observed in 69% of the cases. The share of distraction (B type; 17%) and rotational injuries (C type; 14%) was comparable to published data [47, 64, 70]. 48% of the presented patient group sustained associated injuries, correlating to observations of a multi-center studies (42% [47]). Saboe et al. [87] reported comparable rates of associated injuries in patients with lumbar (72%) and thoracic (82%) spine trauma.

Thirty-five percent of our patients with type A lesion presented with neurological deficit on admission (Frankel/ASIA B-D). The frequency was in accordance with Reinhold et al. (38.5% [83]), but clearly higher compared with Magerl (14% [70]) and previously published data (22% [47]). Reports on neurological recovery in the literature are inconsistent and vary between 0 and 100% (Table 5)! Possibly due to consequent and immediate treatment of patients with neurological deficit we found a comparably good recovery rate of 67%.

Several authors have reported disappointing results after posterior reduction and stabilisation alone. Additional transpedicular bone-grafting did not prevent from re-kyphosing and the reported loss of correction after posterior fixation was significant [2, 46, 49, 50, 100]. However, with regard to clinical outcome several authors reported good results with posterior stabilisation alone [65, 75, 84, 100]. Therefore, the relevance of achieving an optimal “technical/radiological result” with anatomic alignment and definite stability by interbody fusion is still under debate. Still, there is remaining uncertainty on how much surgery is necessary for which quantity of anterior column impairment.

In case of significant impairment of the anterior column, i.e. burst type fractures, with decreased load-bearing capacity one surgical approach is to combine the posterior reduction by internal fixator with a direct anterior and solid reconstruction [13, 16–18, 25, 57, 58, 92, 99]. To decrease approach-related morbidity and late complaints, thoracotomy has been replaced by minimal-invasive technique. By splitting the diaphragm the whole thoracolumbar junction can be addressed with a thoracoscopic approach [10, 11]. Clinical advantages compared with open technique have been proven in the past [33, 35, 38, 61, 79].

Another aspect in anterior surgery is the reconstruction technique: autogenous strut grafting might be associated with donor-side morbidity [96, 103, 105]. After biomechanical testing of new titanium implants for vertebral body replacement [51, 52] preliminary clinical reports on this combined posterior–anterior technique have been published [11, 44, 58, 62, 63, 92, 99]. A description of the technique has previously been published [53]. However, studies analysing the outcome with regard to different

Table 5 Literature review: frequencies (percentage) of patients with neurologic recovery by ≥ 1 grade in Frankel/ASIA scale

Author(s)	Material and methods	Compl. para	Incompl. para
An et al. 1991 [4]	L3–L5; op. posterior and conservative	2/2 (100%)	9/9 (100%)
Andreychik et al. 1996 [5]	L2–L5; op. different techniques and conservative	3/3 (100%)	13/16 (81%)
Blauth et al. 1987 [14]	T6–L5; op. posterior ($n = 44$) and anterior ($n = 28$)	1/17 (6%)	21/33 (64%)
Davies et al. 1980 [24]	T11–L2; conservative (reduction, immobilisation)	3/14 (21%)	19/20 (95%)
Dickson et al. 1978 [27]	T4–L4; op. posterior (Harrington)	7/42 (17%)	38/47 (81%)
Esses et al. 1991 [28]	T7–L5; op. posterior (internal fixator)	2/9 (22%)	4/19 (17%)
Eysel et al. 1991 [29]	T1–L5; op. posterior (different implants)	4/23 (17%)	25/57 (44%)
Gertzbein 1992 [37]	T1–L5; op. posterior (different implants)	15/67 (22%)	84/106 (79%)
Gertzbein 1992 [37]	T1–L5; op. anterior/combined (different implants)	8/10 (80%)	61/80 (76%)
Gertzbein 1992 [37]	T1–L5; conservative	3/12 (25%)	15/16 (94%)
Haas et al. 1991 [40]	T4–L5; op. anterior (winkelinstab. Platten)	1/17 (6%)	11/22 (50%)
Jones et al. 1987 [41]	T1–L5; conservative (reduction, immobilisation)	0/10 (0%)	17/17 (100%)
Kaneda et al. 1997 [43]	T6–L5; op. anterior (Kaneda)	0/0 (0%)	140/148 (95%)
Knop et al. 2001 [46]	T10–L2; op. posterior/anterior/combined	3/7 (43%)	44/64 (69%)
Korovessis et al. 1994 [56]	T1–L5; op. posterior (Harrington)	0/8 (0%)	8/10 (80%)
Liljenqvist et al. 1995 [67]	T9–L3; op. posterior (internal fixator)	0/0	5/8 (63%)
Lindsey et al. 1991 [68]	T4–L4; op. posterior (internal fixator)	0/0	14/28 (50%)
Sasso et al. 1993 [88]	T1–L5; op. posterior (different implants)	2/24 (8%)	17/25 (68%)
Shiba et al. 1994 [94]	T11–L5; op. posterior (internal fixator)	1/17 (9%)	20/28 (71%)
Tasdemiroglu et al. 1995 [97]	T11–L1; op. posterior (different implants)	3/14 (21%)	16/25 (64%)
Wiberg et al. 1988 [102]	T4–L1; op. posterior (Harrington)	2/6(33%)	20/24 (83%)

incompl. para incomplete paraplegia (Frankel/ASIA B-D), *compl. para* complete paraplegia (Frankel/ASIA A)

aspects of pain, impairment and quality of life utilising validated scales remained rare. Briem et al. [17] presented follow-up data utilising the SF-36 questionnaire.

Operation

In the majority of cases (62%) a single-stage combined posterior–anterior surgery was chosen. In the literature a variable rate of single-stage procedures was reported in comparison with two-stage operations: 38% by Knop et al. [48], 15% by Lange et al. [62], and Vieweg et al. [99] only included two-stage combined procedures. In our series, all patients undergoing emergency stabilisation due to neurologic deficit and with indication for immediate decompression a staged procedure was chosen. In 8 out of 11 patients with staged surgeries the spinal canal has revised. In addition, mainly polytraumatised patients and more C type injuries were observed in this group. Therefore, significant differences were observed according to previously published results [48] in two-stage procedures: The mean operative time was significantly longer with 5 (4–6.4) h in comparison with 3.6 (2.8–5) h. Intraoperative X-ray time was 122 (50–183) s, compared with an average 80 (23–135) s in single-stage operations and the estimated intraoperative blood loss was increased

with 1,900 (900–3,200) ml compared with 1,211 (400–3,600) in one-stage procedures.

The role and timing of surgical decompression of the spinal canal is still under debate [15]. In accordance with other authors, we favour an immediate decompression of neural structures in case of neurological deficit combined with significant narrowing of the spinal canal [31, 32, 36, 78, 80, 86]. In 48% of the presented cases a decompression was performed: anterior ($n = 9$), posterior ($n = 2$) and combined ($n = 3$) posterior/anterior. This measure in almost one half of the patients is clearly effecting the above mentioned data. The rate of neurologically impaired patients and the rate of necessary decompression demonstrates a selection of more severe cases in comparison with average trauma collectives.

X-ray

Radiographic evaluation proved an effective reduction with only minor loss of correction. The mean re-kyphosing ranged between 1.3° (monosegmental reconstruction) and 2.8° (bisegmental reconstruction). The unsatisfactory average result in those three patients with lumbar fractures resulted from one patient with the complication of sinking of the cage into the osteoporotic adjacent endplates (Fig. 5).

Table 6 Reported results in the SF-36 score: different study groups, standard population, and “back pain” population in comparison own data

Study group/item	Own data	Briem et al. 2003 [17]	Kraemer et al. 1996 [59]	Reinhold et al. 2003 [83]	Back pain population [19]	German norm population [19]
<i>n</i>	29	19	24	43	243	2,914
Spinal lesion	Injury/posttr.	Injury	Burst fx	Injury	Various	Ø
Level	T7–L3	T10–L2	T11–L4	T5–L5		
Average age	48	42	34	38		
Treatment	Operative	Operative	Conserv. and op.	Conserv.		
Mean follow-up (years)	2½	2	4	16		
Physical functioning index	60.6	80.7	66	66.3	54.5	83.7
Role-physical index	55.2	65.8	45	58.3	30.5	80.6
Bodily pain index	63.0	62.2	62	56.6	25.7	72.7
General health perceptions index	67.9	74.0	64	58.8	42.8	61.0
Vitality index	59.1	57.9	56	57.9	37.6	61.2
Social-functioning index	79.1	80.9	79	77.9	56.0	86.8
Role-emotional index	70.1	78.9	69	83.3	57.2	88.9
Mental health index	70.8	78.1	78	42.7	55.2	72.4
Unweighted mean	65.7	72.3	65	63	45	68

The overall findings are in accordance with findings by Lange et al. [62, 64] and Vieweg et al. [99]. In contrast, several reports are indicating significant loss of reduction after posterior stabilisation only [42, 49, 66, 84, 100]. Notable, an interbody fusion was proven in all 18 patients undergoing a follow-up CT scan. The fusion rate in our patient group was at least 21/29 patients at follow-up. Lange et al. and Vieweg et al. reported follow-up fusion rates of 83 and 90% [62, 99]. Other authors found comparable fusion rates in thoracolumbar trauma patients after anterior reconstruction with autogeneous strut grafts between 73 and 100% [9, 18, 25, 46, 93]. In accordance with a previously published study we regularly found a bony bridging lateral to the vertebral body replacement and rarely anterior.

Follow-up

Length of hospital stay and rehabilitation period corresponded with previously published data [46, 83]. We observed a mean working inability of 4 (0–16) months, and 66% of the patients returned to their former jobs. Reinhold et al. observed a rate of 62% in a non-operatively treated collective [46, 83].

The majority of the patients (72%) returned to former spare time activities. After conservative treatment only one half of the patients carried out the same leisure activities compared with their pre-injury status [46, 83].

Forty-two percent of our patients reported “normal and painfree back function”. Another 42% reported occasional or light complaints. These results are comparable with published data [46, 62, 83].

Psychometric questionnaires

To assess the patients’ outcome we utilised a set of validated questionnaires (Table 2). The VAS score describes functional restrictions and complaints with regard to the spine. It has been validated in German [54]. The retrospective score for the pre-injury status showed a normal age-related distribution. Due to the spinal injury and its treatment an average score loss of 19.7 points was noted. This was comparable with data reported by Lange et al. [62]. Reinhold et al. [83] even found a score loss of 32.2 points in a late follow-up after non-operative treatment.

The McGill Pain Questionnaire gives an overview about quality and character of pains. By the majority the pain intensity was reported as “annoying”. In relation on the emotional aspect (scale four) pain was reported as “tantalizing”.

At the time of follow-up 2 years after the operation, Goulet et al. [39] reported complaints at the donor site in 21.1% of the patients. Other authors also found significant disadvantages of the autogeneous bone harvesting [8, 60, 89, 91, 96, 103, 105].

The Roland and Morris Disability Score quantifies the patients subjective impairment due to back pain in everyday life. There was a significant correlation to the VAS score as well as to our patients’ age. Especially in younger patients a good “spinal function” could be restored. Elder patients avoided certain activities to prevent pain.

The Oswestry Disability Index is a frequently used scale for evaluation of spine-related physical impairment in daily life. There was a significant correlation with the leisure activities and the neurological state. Possibly one-fifth of

the patients had complaints while lifting and carrying various objects as well as in continuous standing.

The Hannover back questionnaire yielded similar results in comparison with the Roland and Morris Score and the Oswestry Disability Index. We found an average functional capacity of 75%, corresponding to a moderate restriction of spine functionality. Reinhold et al. [83] reported similar findings after non-operative treatment of spinal injuries.

The SF-36 assesses the health-related quality of life. The comparison with published data (Table 6) confirmed a result within the range of a normal population. Even though our results might be slightly inferior to a norm population, we consider them encouraging as it was a study group with a neurologic impairment in 12 out of 29 patients on admission. Additionally, all data from operatively treated patients showed a tendency towards superior outcome in SF-36 in comparison with late results after non-operative treatment [83]. Interestingly, our results were much closer to those of the published norm population and tend to be better in comparison with the average score of a population with chronic back pain [19].

The Every Day Life Questionnaire showed a high correlation to SF-36 results. The questionnaire to pain regulation (FSR) determines the ability of pain coping. As expected, patients with a high competence-estimation and good coping mechanisms experienced pain in a significantly decreased intensity. However, low pain competence resulted in pathologic behaviour patterns like avoidance and resignation and lead to incriminating emotions [90].

For the FSR also an average score of a population with chronic back pain as well as late results after non-operatively treated thoracolumbar fractures was available [83, 90]. In comparison, we found a tendency towards a better outcome. After combined posterior–anterior surgery with Synex™, the patients scored 23.5 in “intensity of pain”. The corresponding scores were 29.5 (chronic back pain) and 31.7 (conservatively treated thoracolumbar injuries).

Comparing all outcome data of the questionnaires with our radiological data statistically, no correlation was observed. This corresponds to previously published findings, showing no correlation between clinical outcome and radiological course [5, 22, 24, 65, 75, 95, 101]. This fact clearly emphasises the importance of thorough outcome evaluation on a patient-based, subjective, and validated base.

Conclusion

With regard to the *technical result*, we consider the presented method of vertebral replacement with a distractible titanium device after posterior reduction and stabilisation

as highly effective in (a) complete reduction to anatomic alignment and (b) retaining the achieved result until secure fusion with almost no loss of correction occurred.

With regard to the *clinical outcome*, our results obtained from validated outcome scales confirmed an encouraging overall outcome. The outcome tended to be better in comparison with non-operatively treated patients as well as with norm populations with low back pain. However, a complete recovery without remaining impairment still cannot be achieved after severe thoracolumbar trauma.

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