Association of clinical parameters of operatively treated thoracolumbar fractures with quality of life parameters

Ulrich Thormann · Hans-Josef Erli · Marc Brüggmann ·
Gabor Szalay · Gudrun Schlewitz · Hans-Christoph Pape ·
Reinhard Schnettler · Volker Alt

Received: 22 May 2012/Revised: 18 March 2013/Accepted: 25 April 2013/Published online: 7 May 2013
© Springer-Verlag Berlin Heidelberg 2013

Abstract

Purpose The intention of the current work was to assess the association between clinical parameters and seven different quality of life (QoL) instruments after surgical treatment of thoracolumbar spinal fractures after an average follow-up of 4.2 years.

Methods The following human-related quality of life and PRO measures of 66 patients were correlated to clinical parameters such as fingertip-to-floor distance (FFD), Schober measurement, pressure and percussion pain in the lumbopelvine area (PPP), and paravertebral muscle tension: reALOS, SF-36, VAS, VAS spine score, BDI, the GBB-24, and the IES-R.

Results Overall, there was a significant association between the clinical parameters of the thoracolumbar spine such as PPP, paravertebral muscle tension, FFD and Schober's sign on one side, and the seven tested instruments on the other side.

Conclusions PPP and FFD as well as a small Schober measurement are clinical parameters which significantly influence QoL after surgical treatment of thoracolumbar fractures.

Keywords Trauma · Spine · Quality of life · Outcome measures · Lumbar region

Introduction

Patient reported outcome (PRO) measures and assessment of health-related quality of life (HRQoL) gain importance in all clinical fields including orthopedic trauma surgery and spine surgery. Fractures of the thoracolumbar spine are major injuries that often require surgical intervention and are known to have an important impact on the long-term outcome after trauma [1]. Most of the studies on the outcome after fractures of the thoracolumbar spine focused on radiological parameters, return to work, activity, and pain [1–16] without consideration of specific HRQoL outcome measures. Assessment of HRQoL after thoracolumbar fractures with generic instruments such as Short Form-36 health survey (SF-36) has only been reported in a few works [1, 17–20], which are all limited by the low number of the used HRQoL instruments. Only Briem et al. [1] used five different measures [Visual Analogue Scale (VAS), SF-36, Hannover Functional Ability Questionnaire (HFAQ), Pain Regulation Questionnaire (PRQ), and Post-traumatic Stress Disorder (PTSD) screening instrument by Stieglitz]. Furthermore, from typical clinical parameters in the outcome assessment after thoracolumbar spinal fractures such as fingertip-to-floor distance (FFD), pressure and percussion pain (PPP) of the thoracolumbar-pelvic area, and alterations of the paravertebral muscle tension, only FFD

U. Thormann (✉) · G. Szalay · G. Schlewitz · R. Schnettler ·
V. Alt

Department of Trauma Surgery, University Hospital
Giessen-Marburg GmbH Campus Giessen,
Rudolf-Buchheim-Str. 7, 35390 Giessen, Germany
e-mail: Ulrich.Thormann@chiru.med.uni-giessen.de

H.-J. Erli
Department of Trauma and Orthopedic Surgery,
Vivantes Humboldt Hospital, Am Nordgraben 2,
13509 Berlin, Germany

M. Brüggmann
Department of Pain Therapy and Palliative Care, Medical Centre
Aachen GmbH, Mauerfeldchen 25, 52146 Würselen, Germany

H.-C. Pape
Department of Trauma and Reconstructive Surgery, University
Hospital Aachen, Pauwelsstraße 30, 52074 Aachen, Germany

was reported in two studies after surgical treatment to have a significant association with a spine specific VAS [14, 16]. A significant association between a clinical parameter and a generic QoL measure such as SF-36 or instruments measuring depression or PTSD such as BDI and IES-R has never been shown.

The intention of the current work was to assess, after surgical treatment of thoracolumbar spinal fractures after an average follow-up of 4.2 years, the association between clinical parameters and seven different QoL instruments including generic measures (SF-36, VAS), spine specific instruments [Hannover spine score (VAS spine score)], traumatic specific measures [revised Aachen Longterm Outcome Score (reALOS)], and instruments measuring depression, physical complaints, and PTSD: revised Impact of Event Scale (IES-R), Beck Depression Inventory (BDI), and Giessener Complaint Questionnaire (GBB-24).

Patients and methods

Inclusion criteria

Patients after surgical treatment by dorsal, ventral or dorsoventral stabilization of a fracture of the lumbar (L2–L5), or thoracolumbar spine (Th12 and/or L1) at the Department of Trauma Surgery, University Hospital Aachen with an age between 18 and 65 years, adequate knowledge of German language, without a history of psychiatric disorders, residence <50 km away from Aachen, and a minimum follow-up of 1.5 years after initial surgery were included. Patients with serious post-traumatic neurological impairment (Frankel [21] scale A–D) at the time of follow-up were excluded.

Health-related quality of life parameters

At the time of follow-up, all HRQoL-sheets (Table 1) were given to the patient with a short standardized instruction after their consent. Beside, the well-known PRO measures such as SF-36, revised-IES, Beck Depression Inventory, Giessener Complaint Questionnaire, and Visual Analogue Scale, two less known instruments were used. The revised Aachen Longterm Outcome Score (reALOS) is an outcome measure for polytraumatized patients, which has been used to assess quality of life (QoL) after trauma [22, 23]. Furthermore, the Hannoverian spine score (VAS spine score) assesses the patient-related outcome after spinal injury and has often been used in this context [14, 16, 18, 24]. Correct understanding of the questionnaires by the patient was evaluated followed by independent completion of the questionnaires to minimize potential interview bias. Subsequently, clinical examination of the patient was performed.

For a better comparison of the differences in between the different instruments, we translated the results of the HRQoL questionnaires percentaged.

Clinical parameters and clinical scores

Range of motion of the thoracolumbar spine was assessed by FFD and Schober, and Ott measurements. For pain assessment, the spinous processes and the facet joints of the thoracolumbar spine, the iliosacral joints, the dorsal iliac crest, and the dorsal superior iliac spine were examined by finger pressure and hand percussion (PPP). If pain perception in one or more of these regions was remarked, the patient had PPP in the lumbopelvine area. Furthermore, painless and painful tension of the paravertebral muscles of the thoracolumbar spine was assessed by palpation with the thumb. The hardening of the paravertebral muscles of the thoracolumbar spine were compared to the region of the cervicothoracic spine. A comparable method was used by Michel et al. [25].

Data analysis

For each clinical parameter, two groups were generated. The threshold for each parameter was either the median for FFD, Schober, and Ott measurement or the differentiation between painless and painful muscle tension and PPP. Thus, one group with a clinical outcome “worse” than the median and one group with a clinical outcome “better” than the median were generated for each parameter.

For each of the clinical parameters, median results of both groups for every HRQoL measure were calculated. Those results of the two groups were then analyzed for statistical significant differences using SPSS V12.0. Level of significance was considered to be <5 % with two sided *t* test. The simultaneously performed nonparametric tests (Wilcoxon, Kolmogorov–Smirnov, Wald–Wolfowitz) were also able to confirm the results.

For better comparison of the several HRQoL questionnaires, the results are presented in a percentage ratio with 100 % representing the highest possible figure and 0 % representing the lowest possible figure of each dimension.

Furthermore, we performed stepwise multiple regression analysis.

Results

Patients

In this retrospective study, 66 patients with 34 (51.5 %) male and 32 (48.5 %) female patients were included. The average age of the patients was 45.6 (± 12.8) years with a

Table 1 Instruments, their variables and dimensions used to assess HRQoL and patient reported outcome (PRO) in this study

Instrument	Variable	Dimension	Analysis
Revised Aachen Longterm Outcome Score (reALOS) [22, 23]	Quality of life (QoL) after trauma	Physical condition	Score 25–100
		Mental condition	Higher Score = Better QoL
		Everyday efficiency	
		Social behavior	
Short form 36 (SF-36)	Health-related quality of life (HRQoL)	Physical function	Score 0–100
		Physical role function	Higher Score = Better QoL
		Physical pain	
		Global health	
		Vitality	
		Social function	
		Emotional role function	
		Physic well-being	
Visual Analogue Scale (VAS)	Global health status	1 dimension	Score 0–10 Higher Score = Better QoL
Hanoverian Spine Score (VAS Spine Score) [24]	Back-related quality of life	Total score of 19 items	Score 0–100 Higher Score = Better QoL
Giessener Complaint Questionnaire (GQB-24)	Physical complaints	Total score of 24 items	Score 0–96 Higher Score = More complaints
Beck Depression Inventory (BDI)	Depression	Total score of 21 items	Score 0–63 Higher Score = More depressive symptoms
Impact of Event Scale revised (IES-R)	Post-traumatic stress disorder (PTSD)	Intrusion	Score 0–110
		Avoidance	Higher Score = More symptoms of PTSD
		Hyperarousal	
		Total score	

range of 19–64 years. Male patients had an average height of 178 cm (± 7.4 cm) and an average weight of 82.4 kg (± 14.8 kg). In female patients, an average height of 165 cm (± 6.0 cm) and an average weight of 66.0 kg (± 14.4 kg) were noted.

Vertebral fractures and surgical treatment

All above-mentioned patients suffered from fractures of the lumbar (L2–L5) ($n = 24$, 36.3 %) or thoracolumbar spine (Th12 and/or L1) ($n = 42$, 63.7 %). AO-Magerl type A3 burst fracture with an incidence of 50 cases (75.8 %) was by far the most frequent fracture type. Type B and Type C fractures occurred only in five (7.6 %) and two (3.0 %) cases, respectively. The other nine cases (13.6 %) were classified as type A2 fracture. In 15 cases (23 %), more than two motion segments were affected.

All patients were surgically treated either by combined dorsoventral stabilization with internal fixateur and ventral fusion with autogenous anterior iliac crest bone graft/cage ($n = 30$, 45.5 %), stand-alone dorsal stabilization with

internal fixateur and filling of the vertebra with autologous cancellous bone graft (direct or transpedicular) ($n = 34$, 51.5 %), or stand-alone ventral fusion and instrumentation ($n = 2$, 3.0 %). At time of follow-up in 60 out of 66 patients (91 %), the implant was already removed.

Clinical parameters

28 (42.4 %) of the patients showed no PPP in the lumbopelvine area, whereas 38 (57.6 %) of the patients reported of pressure and percussion pain in this region. Painful and painless paravertebral muscle tension was found in 17 (25.8 %) and 38 (57.6 %) of the patients. In 11 (16.7 %) of the patients, no muscle tension of the paravertebral muscles was found.

The FFD ranged from 0 to 60 cm with a median of 20.0 cm. Schober's sign ranged from 9 to 19 cm with a median of 14 cm, and Ott's sign ranged from 29 to 36 cm with an median of 31.7 cm.

As mentioned in the “[Materials and Methods](#)” section, the median of FFD was calculated to be 20.0 cm. 32 (48.5 %) patients exhibited an FFD of <20.0 cm and 34

patients (51.5 %) of more than 20.0 cm. The median for Schober's sign was 14 cm and 40 patients (60.6 %) yielded better and 26 patients (39.4 %) a worse range of motion in relation to the median of 14 cm. For Ott's sign, 33 patients (50 %) had a better and 33 patients (50 %) a worse outcome compared to the median of 31.7 cm. FFD and Schober measurement had a strong correlation ($r = 0.565$; $p < 0.001$; $N = 66$).

Clinical parameters and HRQoL

Overall, there was a significant association between the clinical parameters of the thoracolumbar spine such as pressure and percussion pain (PPP), paravertebral muscle tension, FFD and Schober's sign on one side, and the seven tested QoL instruments on the other side. Between Ott's sign, which mainly assesses range of motion of the upper thoracic spine and the tested HRQoL, no significance was found.

Pressure and percussion pain and HRQoL

PPP showed a significant association to reALOS, SF-36, VAS spine score, Visual Analogue Scale, GBB-24, BDI, and IES-R (Fig. 1). PPP exhibited significant differences to 18 of 19 tested dimensions of these HRQoL instruments. Patients without PPP had a significant better HRQoL outcome than those with PPP in one or more locations of the lumbopelvine area in 18 dimensions except of emotional role functioning of the SF-36.

Paravertebral muscle tension and HRQoL

Paravertebral muscle tension showed as well a significant association to all of the seven instruments (reALOS, SF-36, VAS spine score, VAS, GBB-24, the BDI, and the IES-R) (Fig. 2). 15 of 19 dimensions yielded a significant difference between patients with and without painful paravertebral muscle tension in the outcome of HRQoL. Patients without painful paravertebral muscle tension had a significantly better QoL after trauma of the thoracolumbar spine.

Fingertip-to-floor distance and HRQoL

Patients with a smaller fingertip-to-floor distance than 20 cm had a significant better HRQoL in six of seven instruments compared to those with a distance more than 20 cm (Fig. 3). There was a significant difference between the two groups in the reALOS, SF-36, VAS spine score, VAS, GBB-24, and BDI. Only the IES-R did not exhibit significant differences. For all other six instruments, 14 of the 16 dimensions significant differences between the two groups existed.

Schober's sign and HRQoL

Patients with a Schober's measurement larger than 14 cm were found to have a better outcome in five of seven HRQoL instruments than those with a smaller measurement (Fig. 4). In 8 of 19 dimensions of the reALOS, SF-36, VAS spine score, VAS, and BDI patients with a larger distance achieved a significant better QoL. Only GBB-24 and IES-R could not show a difference between these two groups.

Ott's sign and HRQoL

For Ott's sign, no significant difference between patients with a range of motion of the upper thoracic spine of more or <31.7 cm was found for all HRQoL dimensions (Fig. 5).

Correlation analysis

The above-mentioned results of the t test and nonparametric analysis were confirmed by correlation analysis (Table 2, 3, 4). For heuristic reasons, we calculated stepwise multiple regression analysis (constant included; p of F in 0.05; p of F out 0.10). Best predictors for all reALOS scales, SF-36, and for BDI were PPP and FFD.

Discussion

To the authors' best knowledge, there is currently no study addressing the association between clinical parameters and several global HRQoL measures in patients with surgically treated fractures of the thoracolumbar spine. Therefore, this work reports for the first time on the association of clinical parameters such as PPP, painful paravertebral muscle tension, FFD, Schober measurement, and seven different QoL instruments including generic measures (SF-36, VAS, VAS spine score, reALOS, IES-R, BDI, GBB-24). The main outcome is the significant association of typical clinical parameters with HRQoL instruments. PPP, painful paravertebral muscle tension, FFD, and Schober measurement were significantly correlated with almost all dimensions of the above-mentioned HRQoL instruments. The strongest association was found between PPP and the seven instruments which was statistically significant in 18 of 19 dimensions (94.7 %). Both painful paravertebral muscle tension and FFD had statistical significant association with the HRQoL in 15 of 19 dimensions (78.9 %). Those three clinical parameters exhibited significant associations to 48 of a total of 57 HRQoL parameter not only of the specific spine (VAS spine score) or trauma specific (reALOS) scores, but also on global HRQoL outcome measurement (SF-36, VAS) and instruments measuring depression,

Fig. 1 Percentaged HRQoL results of patients with or without pressure/percussion pain (* $p < 0.05$)

Fig. 2 Percentaged HRQoL results of patients with painful or painless paravertebral muscle tension (* $p < 0.05$)

physical complaints, and PTSD (BDI, GBB-24, IES-R). For those instruments, significant association was shown in 31 of 42 dimensions (73.8 %).

Measurements of forward bending demonstrated good reliability and validity to assess trunk mobility in the past [25–29].

FFD is a global measurement for trunk motion and has several confounding factors such as flexibility of hamstring muscles or mobility of the pelvis. But, as a general instrument for assessing trunk mobility, it has a good reliability and is a common used measure in clinical practice [29]. Saur et al. [29] showed a good inter-observer reliability and a FFD of 0 cm in healthy patients without

low back pain. Certainly, the variability among healthy patients in many clinical measures is high, especially regarding age, gender, and physical fitness; but in our study, we wanted to identify patients with lower HRQoL among injured patients. Compared to patients with Bechterew's disease ($\mu = 19.71 \pm 15.73$), our results are almost the same. FFD was reported to be an important outcome parameter in spinal fracture patients [14, 16]. However, none of those studies could show statistically significant association between FFD and global HRQoL. Knop et al. and Reinhold et al. reported on statistically significant association between FFD and VAS spine score, but not to general HRQoL instruments.

Fig. 3 Percentaged HRQoL results of patients with more or less FFD than the median (* $p < 0.05$)

Fig. 4 Percentaged HRQoL results of patients with a bigger or smaller Schober measurement (* $p < 0.05$)

Specific range of motion measurement of the thoracolumbar spine (Schober) was mainly significantly related to spine and trauma specific instruments. Schober measurement showed statistical significant association to spine specific outcome measurements such as reALOS (3 of 4 dimensions) and VAS spine score (1 of 1), whereas in more general instruments such as SF-36 (2 of 8 dimensions), VAS (0 of 1), GBB-24 (0 of 1), and IES-R (0 of 3) only low association can be stated.

We have seen no significant difference in HRQoL and clinical measures, such as FFD or Schober's sign between the thoracolumbar (Th12/L1) and lumbar (L2–L5) group. This could be explicable due to complete removal of

implants at the time of follow-up. Furthermore, no significant difference was noted if more than two motion segments were affected. But a limiting factor is the small sample size of 15 patients who suffered a fracture within more than two segments. There was no statistically significant association between cervicothoracic specific Ott measurement and general QoL or spine specific HRQoL measurement, which can be explained by the fact that the thoracolumbar but not the cervicothoracic spine was affected in the study group confirming the specificity of this study.

Further, strengths of the study are the considerable long follow-up with an average of 4.2 years of 66 patients with a

Fig. 5 Percentaged HRQoL results of patients with a bigger or smaller Ott measurement (* $p < 0.05$)

Table 2 Spearman coefficient of clinical parameters with reALOS at time of follow-up

	reALOS physic condition	reALOS mental condition	reALOS everyday functioning	reALOS social behavior
Painful muscle tension	−0.512**	−0.483**	−0.400**	−0.501**
PPP	−0.406**	−0.416**	−0.428**	−0.476**
FFD	−0.646**	−0.539**	−0.414**	−0.499**
Schober measurement	0.486**	0.373**	0.218	0.384**
Ott measurement	0.085	0.005	0.102	−0.128

* $p < 0.05$, ** $p < 0.01$

Table 3 Spearman coefficient of clinical parameters with SF-36 at time of follow-up

	SF-36 physical functioning	SF-36 physical role functioning	SF-36 physical pain	SF-36 health	SF-36 vitality	SF-36 social functioning	SF-36 emotional role functioning	SF-36 mental well-being
Painful muscle tension	−0.423**	−0.386**	−0.339**	−0.158	−0.327**	−0.346**	−0.222	−0.172
PPP	−0.513**	−0.311*	−0.456**	−0.336**	−0.266*	−0.344**	−0.310*	−0.310*
FFD	−0.651**	−0.579**	−0.471**	−0.500**	−0.463**	−0.292*	−0.386**	−0.232
Schober measurement	0.448**	0.395**	0.193	0.259*	0.181	0.070	0.221	0.055
Ott measurement	0.132	0.063	0.167	0.047	0.060	0.050	−0.086	−0.088

* $p < 0.05$, ** $p < 0.01$

minimum follow-up of 1.5 years. AO-Magerl type A3 burst fracture with an incidence of 50 cases (75.7 %) was by far the most frequent fracture type contributing to a homogenous study group.

A limitation of this study is its retrospective character. Furthermore, the availability of the reALOS and the VAS spine score only in German language limits the transferability of these scores and their related detail results into the international community. The influence of the different

operative techniques on HRQoL after thoracolumbar spine fracture was not object of this survey, because this would exceed the sample size. Although major multicenter studies [1, 14, 16] were performed, no correlation between different treatment options and HRQoL could be objectified so far.

For heuristic reasons, we performed stepwise multiple regression analysis, which also showed PPP and FFD as good predictors for HRQoL in reALOS, SF-36, and BDI.

Table 4 Spearman coefficient of clinical parameters with IES-R, BDI, GBB-24, VAS spine score, and VAS at time of follow-up

	Impact of Event-Intrusion	Impact of Event-Avoidance	Impact of Event-Hyperarousal	BDI total score	GBB-24 total	VAS-spine score	VAS
Painful muscle tension	0.236	0.283*	0.293*	0.410**	0.369**	−0.424**	−0.174
PPP	0.205	0.310*	0.194	0.491**	0.445**	−0.556**	−0.350**
FFD	0.325**	0.258*	0.317*	0.465**	0.459**	−0.613**	−0.453**
Schober measurement	−0.006	−0.010	−0.098	−0.223	−0.236	0.422**	0.231
Ott measurement	−0.042	−0.010	−0.050	−0.114	−0.130	0.054	−0.030

* $p < 0.05$, ** $p < 0.01$

Taking more factors into consideration, the statistical value would be limited due to the sample size. So, we have opted for often-used clinical parameters in assessing spine pathologies and performed bivariate analysis by t test and correlation analysis regarding HRQoL. Nevertheless, HRQoL is a complex matter which is influenced by many different factors, and a bivariate analysis is not able to detect all influencing parameters.

The study was intended to individually assess each clinical parameter in association to HRQoL instruments for every patient. Therefore, the different clinical parameters had to be analyzed for each patient depending on the fact whether the patient had achieved a better or worse outcome compared to the median for this parameter. The threshold for each parameter was either the median for FFD, Schober, and Ott measurement or the differentiation between painless and painful muscle tension and PPP. This method was chosen due to the fact that there are currently no other clear parameters for reliable assessment of clinical outcome after thoracolumbar spinal fractures. The above-mentioned strong association justifies this approach.

For further research, a prospective clinical trial including global and spine specific instruments combining the strengths and overcoming the limitations of this study would be helpful to elucidate. Particularly, the comparison between percutaneous and open techniques in fracture treatment relating to HRQoL would be interesting and should be included in further related clinical studies.

Overall, it can be concluded that the current study is the first one to report on significant association of clinical parameters such as PPP, painful paravertebral muscle tension, FFD, Schober measurement, and seven different HRQoL instruments including generic measures (SF-36, VAS, VAS spine score, reALOS, IES-R, BDI, GBB-24) after surgical treatment of thoracolumbar fractures.

Conclusion

Besides the morphologic reconstruction of the anatomical structures, the subjective self-recognition of HRQoL is becoming more important in trauma surgery. A causal

connection between operative method or medical treatment and outcome after traumatic spine surgery could not be found yet. Aim of this study was to widely assess HRQoL of patients after surgical treatment of a fractured lumbar or thoracolumbar spine. In summary, the spine trauma still has a deep impact on HRQoL four years after surgical treatment, in physical as well as in mental dimensions. PPP in the lumbopelvine area, painful paravertebral muscle tension, and a big FFD as well as a small Schober measurement are clinical parameters which strongly influence QoL. Patients had more adverse effects of HRQoL if they have PPP or a big FFD or small Schober measurement.

Conflict of interest None.

References

- Briem D, Behehtnejad A, Ouchmaev A et al (2007) Pain regulation and health-related quality of life after thoracolumbar fractures of the spine. *Eur Spine J* 16:1925–1933
- Alanay A, Acaroglu E, Yazici M, Oznur A, Surat A (2001) Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? *Spine (Phila Pa 1976)* 26:213–217
- Been HD, Poolman RW, Ubags LH (2004) Clinical outcome and radiographic results after surgical treatment of post-traumatic thoracolumbar kyphosis following simple type A fractures. *Eur Spine J* 13:101–107
- Bertram R, Bessem H, Diedrich O, Wagner U, Schmitt O (2003) Comparison of dorso-lateral and dorso-ventral stabilization procedures in the treatment of vertebral fractures. *Z Orthop Ihre Grenzgeb* 141:573–577
- Briem D, Meenen NM, Linhart W, Burchard A, Lehmann W, Rueger JM (2000) Dorsale Stabilisierung von Frakturen des thorakolumbalen Überganges. Follow-up-Analyse und Vergleich mit konkurrierenden Methoden. *Osteosynthese International, Suppl* 1, S215–S216
- Eysel P, Hopf C, Furderer S (2001) Kyphotic deformation in fractures of the thoracic and lumbar spine. *Orthopade* 30:955–964
- Katscher S, Verheyden P, Gonschorek O, Glasmacher S, Josten C (2003) Thoracolumbar spine fractures after conservative and surgical treatment. Dependence of correction loss on fracture level. *Unfallchirurg* 106:20–27
- Liljenqvist U, Mommsen U (1995) Surgical treatment of thoracolumbar spinal fractures with internal fixator and transpedicular spongiosa-plasty. *Unfallchirurgie* 21:30–39

9. McLain RF (2004) Functional outcomes after surgery for spinal fractures: return to work and activity. *Spine (Phila Pa 1976)*, 29:470–477
10. Seybold EA, Sweeney CA, Fredrickson BE, Warhold LG, Bernini PM (1999) Functional outcome of low lumbar burst fractures. A multicenter review of operative and nonoperative treatment of L3–L5. *Spine (Phila Pa 1976)* 24:2154–2161
11. Shen WJ, Liu TJ, Shen YS (2001) Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. *Spine (Phila Pa 1976)* 26:1038–1045
12. Walchli B, Heini P, Berlemann U (2001) Loss of correction after dorsal stabilization of burst fractures of the thoracolumbar junction. The role of transpedicular spongiosa plasty. *Unfallchirurg* 104:742–747
13. Andress HJ, Braun H, Helmberger T, Schurmann M, Hertlein H, Hartl WH (2002) Long-term results after posterior fixation of thoraco-lumbar burst fractures. *Injury* 33:357–365
14. Knop C, Blauth M, Bühren V et al (2001) Surgical treatment of injuries of the thoracolumbar transition–3: follow-up examination. Results of a prospective multi-center study by the “Spinal” Study Group of the German Society of Trauma Surgery. *Unfallchirurg* 104:583–600
15. Knop C, Fabian HF, Bastian L et al (2002) Fate of the transpedicular intervertebral bone graft after posterior stabilisation of thoracolumbar fractures. *Eur Spine J* 11:251–257
16. Reinhold M, Knop C, Beisse R et al (2009) Operative treatment of traumatic fractures of the thoracic and lumbar spinal column: Part III: follow up data. *Unfallchirurg* 112:294–316
17. Kraemer WJ, Schemitsch EH, Lever J, McBroom RJ, McKee MD, Waddell JP (1996) Functional outcome of thoracolumbar burst fractures without neurological deficit. *J Orthop Trauma* 10:541–544
18. Leferink VJ, Keizer HJ, Oosterhuis JK, van der Sluis CK, ten Duis HJ (2003) Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting. *Eur Spine J* 12:261–267
19. Knop C, Kranabetter T, Reinhold M, Blauth M (2009) Combined posterior-anterior stabilisation of thoracolumbar injuries utilising a vertebral body replacing implant. *Eur Spine J* 18:949–963
20. Wood K, Buttermann G, Mehbod A et al (2003) Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. *J Bone Joint Surg Am* 85-A:773–781
21. Frankel HL, Hancock DO, Hyslop G et al (1969) The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia I. *Paraplegia* 7:179–192
22. Paar O, Kasperk R (1992) Long-term follow-up of polytrauma. *Unfallchirurg* 95:78–82
23. Fernandez V, Erli HJ, Kugler J, Paar O (2001) Cognitive deficits after polytrauma. Studies of quality of life. *Unfallchirurg* 104:938–947
24. Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M (2001) Development and validation of the Visual Analogue Scale (VAS) spine score. *Unfallchirurg* 104:488–497
25. Michel A, Kohlmann T, Raspe H (1997) The association between clinical findings on physical examination and self-reported severity in back pain. Results of a population-based study. *Spine (Phila Pa 1976)* 22:296–303
26. Frost M, Stuckey S, Smalley LA, Dorman G (1982) Reliability of measuring trunk motions in centimeters. *Phys Ther* 62:1431–1437
27. Marras WS, Ferguson SA, Gupta P et al (1999) The quantification of low back disorder using motion measures. Methodology and validation. *Spine (Phila Pa 1976)* 24:2091–2100
28. Haywood KL, Garratt AM, Jordan K, Dziedzic K, Dawes PT (2004) Spinal mobility in ankylosing spondylitis: reliability, validity and responsiveness. *Rheumatology (Oxford)* 43:750–757
29. Saur PM, Pflugsten M, Ensink FB et al (1996) Interrater studies of evaluating the reliability of somatic findings. *Rehabilitation (Stuttg)* 35:150–160