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# Impact of implant removal on quality of life and loss of correction in the treatment of traumatic fractures of the thoracolumbar spine

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ABSTRACT

*Background:* Benefit of implant removal in spine surgery remains unclear. While there is mostly consensus about necessity of implant removal in posterior-only stabilized patients, the effect of this measure in cases with combined anterior-posterior stabilization is undetermined. With this work we present a retrospective analysis of 87 patients with traumatic thoracolumbar vertebral fractures concerning quality of life (QOL), loss of correction (LOC) and range of motion (ROM). The effect of implant removal on the outcome 18–74 months after surgery was analyzed to determine how implant removal affects radiologic, functional and quality-of life-related parameters.

*Patients and methods:* 87 patients suffering from a traumatic vertebral body fracture (T11 – L2) were included. Quality of life was determined using four different scoring systems (SF 36, VAS, Oswestry, LBOS). Clinical examination included range of motion. Radiologic findings were correlated with QOL.

*Results:* Patients with removal of the internal fixator had a trend towards better range of motion than patients with posterior instrumentation left in place. Radiologic findings showed no correlation to QOL. Implant removal led to better values in Oswestry and SF-36. 69% of patients after removal reported a reduction of their symptoms. All patients with persistence of severe pain after implant removal belonged to subgroup II.2 (anterior monosegmental fusion with bone graft)

*Conclusion:* Removal of the internal fixator can lead to a reduction of symptoms. Patient selection is crucial for successful indication. Radiologic findings do not correlate with QOL.

## 1. Introduction

Therapy of traumatic vertebral fractures remains versatile. Severe lesions with a high degree of instability (AO type B and C) need surgical stabilization. Surgical strategies include isolated posterior stabilization with or without additional anterior fusion, using expandable cages as vertebral body replacement or an autologous bone graft, in some cases combined with an anterior locking plate system (Knop et al., 2000; Reinhold et al., 2009a; Potulski et al., 1999).

Fractures of Magerl-Type A 1.3, A 3.1/AO Type A1, A3 respectively can be treated with or without surgical intervention. Still there is no certainty which treatment leads to the best clinical results (Scholz et al., 2018). Despite the risk of surgery in general, the long immobilization and poor results in terms of anatomical reconstruction are the major drawbacks of conservative therapy (Bombardier, 2000).

Posterior approach and instrumentation using an internal fixator is the gold standard in primary surgical therapy. Implant removal is recommended 6–18 months after initial surgical stabilization in patients with isolated posterior instrumentation or additional anterior fusion of only one segment.

The relevance of implant removal on life quality, however, was not yet addressed specifically. In most publications, only the effect on spinal anatomy, measured in radiological angles like the Cobb-angle or the wedge-angle were described (Saman et al., 2013). We examined the impact of implant removal concerning quality of life and loss of correction up to 74 months after surgery.

## 2. Patients and methods

The study was approved by the local ethical committee of our

*Abbreviations:* **QOL**, Quality of life; **LBOS**, Low back pain outcome score; **SF-36**, Short form 36; **VAS**, Visual analog scale; **AO**, Arbeitsgemeinschaft für Osteosynthesefragen; **USS**, Universal spine system; **T**, Thoracic spine; **L**, Lumbar spine; **FTF**, Finger-to-floor-distance; **IR**, Implant removal.

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institution (185/10).

87 patients with traumatic vertebral fractures of the thoracolumbar spine were included.

For the interval between primary surgery and interview/examination a minimum of 18 months was considered necessary. Mean interval between accident and follow up was 40.8 months (18–74).

Of 87 patients included, 65 patients had undergone combined anterio-posterior stabilization. In 22 cases, isolated posterior instrumentation using an internal fixator was performed. Initial therapy was established using a titanium internal fixation device (USS®, DepuySynthes, Umkirch, Germany).

Anterior fusion was performed either monosegmentally using an autologous bone graft harvested from the iliac crest, or bisegmentally by implantation of an expandable titanium cage (Obelisc®, Ulrich, Ulm, Germany).

Inclusion criteria were traumatic vertebral fracture, age from 16 to 65 years and a follow-up period of at least 18 months after trauma.

Exclusion criteria included pathological fractures of the spine due to infection or tumoral lesion and lack of consent.

In 44 patients the internal fixator was left in place (group I), 43 patients underwent removal of the internal fixator (group II). Implant removal was performed at an average of 12 months after trauma.

The patients after implant removal were subdivided in patients without anterior fusion (II.1), with monosegmental fusion (autologous bone graft, II.2) and with bisegmental anterior fusion (expandable titanium cage system, II.3). Distribution of patients is shown in Figs. 1 and 2.

Follow up included physical examination, analysis of radiologic findings (mono- and bisegmental Cobb angle) and quality of life survey at the time of examination.

The **physical examination** included range of motion of all levels of the spine. Total flexion of the thoracolumbar spine in bent over position was determined by measuring the distance between ground and the fingers of the patient (finger-to-floor-distance, FTF). A distance of less than 7 cm was considered normal.

Furthermore flexion of the thoracic spine was measured by the lengthening of a 30 cm interval from the spinal process downwards from upright to bent over position (Ott's-test). Flexion of the lumbar spine was measured by the lengthening of a 10 cm interval cranially of the S1-spinal process (Schober's-test). A modified Schober's test was performed by measuring the lengthening of a 10 cm interval with centralized position over the spinal process of L1.

Lateral flexion was evaluated as well as range of rotation.

Active elevation of the head from the ground in supine position was tested measuring the maximum distance between ground and spinal process C7, in prone position the maximum distance between ground and jugulum was measured.

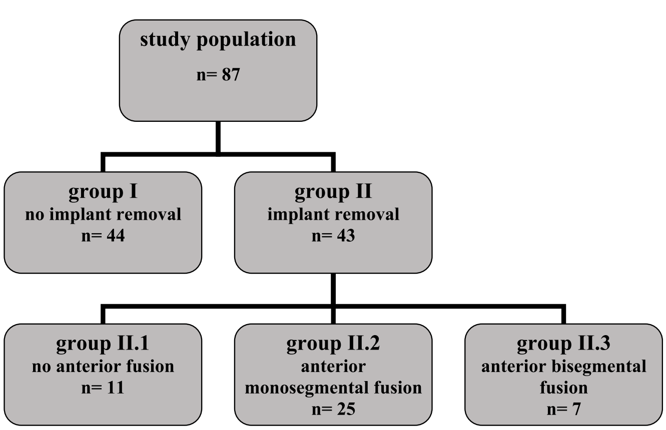


**Fig. 1.** Study population and subgroups: group I: no implant removal; group II: implant removal; group II.1: no anterior fusion; group II.2: monosegmental anterior fusion using autologous bone graft; group II.3: bisegmental expandable cage.

Neurologic symptoms of the lower extremities were evaluated, radicular symptoms including positive Lasègues sign were recorded.

**Radiologic evaluation** included radiographs/CT-scans at the time of the accident, after the posterior stabilization, after anterior fusion if carried out, before implant removal, after implant removal and at the time of examination.

In the lateral projection, endplate angles of the injured vertebra (monosegmental Cobb angle, Fig. 3) as well as endplate angles of the adjacent vertebrae (bisegmental Cobb angle, Fig. 4) were measured, indicating correction postoperatively and loss of correction during follow up.

In the a.p.-projection, the Cobb angle was evaluated indicating posttraumatic scoliosis.

"Correction" determined the improvement of posttraumatic kyphosis by the surgical intervention, while "loss of correction" characterized the recurrence of kyphosis over time.

**Quality of life** was tested by a questionnaire consisting of 89 individual questions that were in turn assigned four scores to determine functional, psychological, social and physical wellbeing (Bombardier, 2000; Bullinger, 1996; Junge and Mannion, 2004). Our survey included the following quality of life-scores: Short form 36 (SF36), Oswestry Disability Questionnaire (Oswestry), Low Back Pain Outcome Score (LBOS) and VAS pain score adjusted for spine patients (VAS).

Statistical evaluation was performed using SPSS, Ver. 17 (SPSS Inc., Chicago, Illinois). Distribution was analyzed using Shapiro-Wilk test and Kolmogorov-Smirnov-test. In cases of Gaussian distribution, we applied student's *t*-test for further evaluation. In other cases, we used Mann–Whitneys *U* test. Multivariate analysis was performed for parametric data using ANOVA, for non-parametric data using Kruskal-Wallis-test. Independence of qualitative data was evaluated using the chi-squared test. In general, a p-value $<0.05$ was considered significant.

## 3. Results

### 3.1. Epidemiologic data

The average age of our patients was 45 (16–65). The ratio male to female was 52: 35. With 54.1% fractures of the level L1 were observed most frequently, followed by T12 and L2. Distribution concerning levels is shown in Fig. 5.

77% of our patients suffered from injuries classified as AO type A (77%), followed by type B (19.5%) and C (3.5%). Main cause for the injury was motor vehicle accident (39%).

### 3.2. Physical examination

#### 3.2.1. Trend toward better functional tests in the implant removal group (group II)

The finger-to-floor distance in maximum bent over position (FTF) showed a mean value of 21.3 cm (SD: ±17.3) in group I and of 16.3 (SD: ±15.2) in group II. Best results were achieved in group II.1 with a value of only 8.9 cm (SD: ±10.3). Differences showed no significance.

Schober's sign indicated a trend towards better mobility of the lumbar spine for group II (3.7 cm SD: ±1.4), especially group II.1 (4.2 ± 1.6). Group I showed an average of 3.1 cm ± 1.9. Concerning Ott's sign there were no differences between group I (1.4 cm ± 1.7) and group II (1.5 cm ± 1.0).

*3.2.1.1. Active elevation of the head in supine position.* Mean overall distance between stretcher and spinal process C7 was 13.4 cm (SD: ±7.6) Individuals of group I reached 11.4 cm (SD: ±6.7), whereas the population of group II had better results (15.3 cm ± 7.9).

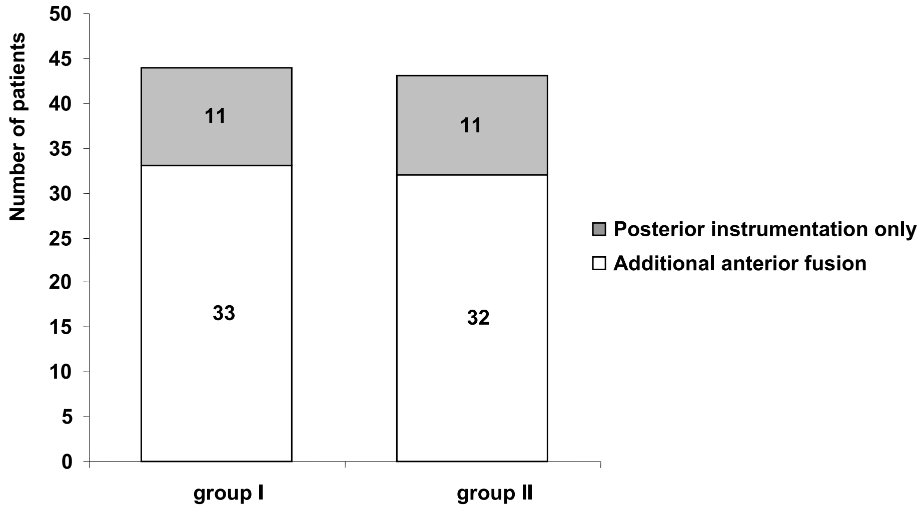


**Fig. 2.** Subdivision of groups concerning additional anterior approach. Group II: removal of implant. Equal distribution concerning injury severity/limited vs. combined surgical approach.

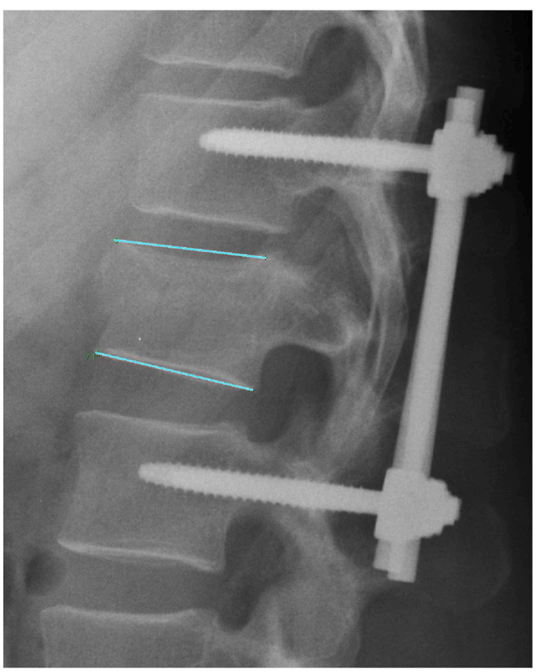

**Fig. 3.** Kyphosis measured by monosegmental Cobb-angle.

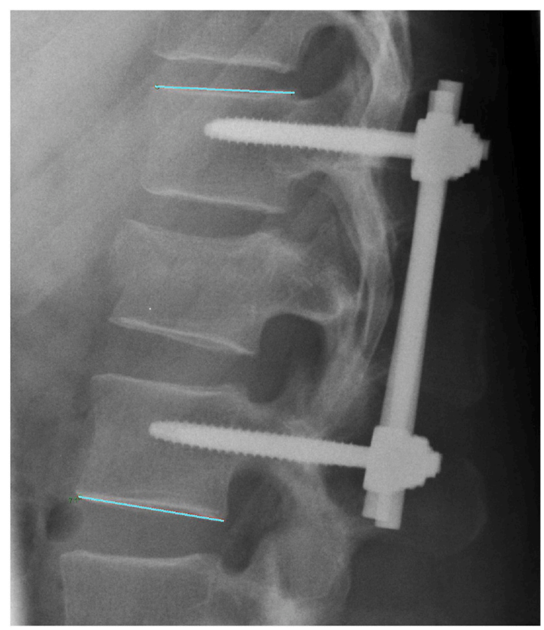

**Fig. 4.** Kyphosis measured by bisegmental Cobb-angle.

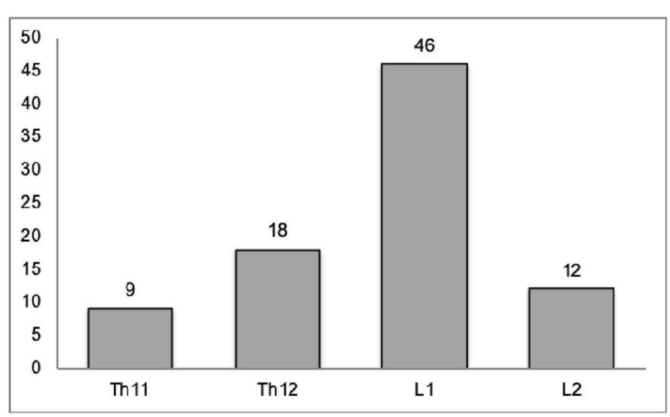


**Fig. 5.** Distribution of fractured levels.

*3.2.1.2. Active elevation of the head in prone position.* Reaching an average value of 8.9 cm (SD: ±5.0) group II shows better values than group I (7.0 cm ± 3.5). The best values were shown in members of subgroup II.2 with 9.5 cm ± 5.3.

Neither Lasègue's test nor evaluation of radicular symptoms showed any differences between groups. ROM determined by lateral flexion and rotation was comparable in both groups.

### 3.3. Radiologic findings

#### 3.3.1. Trend towards higher loss of correction-values in group II

Posttraumatic kyphosis of the fractured vertebral body in the initial period was 12.7° (SD: ±6.8). Patients undergoing implant removal (group II), showed 13.8° ± 5.4, patients of subpopulation I 11.7° ± 7.8.

Initial surgical therapy by internal fixation led to correction by 5° ± 4.8. Postoperatively, patients of groups I and II showed a kyphosis of

7.7° ± 4.7.

In cases of additional anterior fusion, a slight improvement by the second surgical intervention was seen concerning angulation of the endplates of the fractured vertebral body (7.5° ± 3.9).

In group II we recorded in addition the angulation of the Endplates prior to and after implant removal of the posterior instrumentation. Prior to implant removal, we recorded a loss of correction from 2.3° to 9.5° (SD: ±4.0). After implant removal, there was a loss of correction of another 0.7° to the value of 10.2° (SD: ±5.2).

At the time of last follow up, overall loss of correction concerning the fractured vertebral body alone was 8.5° ± 4.3. Group I showed a slight decrease of integrity from 7.8° (SD: ±3.7) to 9° (SD: ±4.7) over time. The measurements in group II showed an improvement from 10.2° (SD: ±5.2) to 7.9° (SD: ±3.8) over the same period.

Additional to the measurement of angulation of the fractured vertebral body itself we examined the bisegmental angulation by measurement of the values between the endplates of the adjacent levels (bisegmental cobb angle). Initial values were 13.5° ± 8.2 in all groups. Analysis of the different groups shows a bisegmental Cobb angle of 14.5° ± 7.7 for group II and an angle of 12.6° (SD: ±8.5) in group I. Patients having undergone implant removal (group II) showed a bisegmental Cobb angle of 15.6° ± 7.2, which was worse than the initial values post-traumatically (14.5° ± 7.7) previous to any surgical intervention. Loss of correction was not prevented by anterior fusion by bone graft or cage implantation. There was an incidence of endplate injury by the expandable cages of 42.9% initially, doubling during follow up to 85.7% after removal of the internal fixator. These endplate injuries and the subsequent migration of the cage into the adjacent vertebral bodies led to a loss of correction in these cases (group II.3) from 5.1° ± 7.6 to 15 ± 4.4 in the last follow up examination.

Overall, we saw an improvement by 7.2°–6.3° ± 7.1 by the initial surgery. Restoration of the bisegmental Cobb angle by reduction and internal fixation was 6.2° to a value of 6.4° ± 7.1 in group I. Group II even showed improvement of bisegmental Cobb angle by 8.3° to a value of 6.2° ± 7.0.

After anterior fusion, decrease of bisegmental Cobb angle to 7.4° ± 7.6 was noted in the overall population. Group I showed a loss of correction of 2.4° to a value of 8.8° ± 8.2). Group II showed a mean bisegmental Cobb angle of 6° ± 6.6 at that point of time.

In group II we were able to record two additional bisegmental Cobb angle values, one directly prior to removal of the posterior instrumentation, (mean bisegmental Cobb angle 9.8° ± 6.4), one afterwards 12.7° ± 5.8, representing a loss of correction of 2.9° by implant removal.

The last CT scan during follow up was the radiologic endpoint of our study. We saw a mean bisegmental Cobb angle of 13.7° ± 8.8) in our population. Group I showed an increasing angle by 3.2° of 12° ± 9.7. Group II had a higher loss of correction of 2.9° to a value of 15.6° ± 7.2. There was no significant difference between groups I and II concerning monosegmental Cobb angle ($p = 0.222$, ANOVA) and bisegmental Cobb angle ($p = 0.439$, ANOVA), respectively.

Radiologic follow-up data are shown in Fig. 6 (monosegmental Cobb angle) and Fig. 7 (bisegmental Cobb angle).

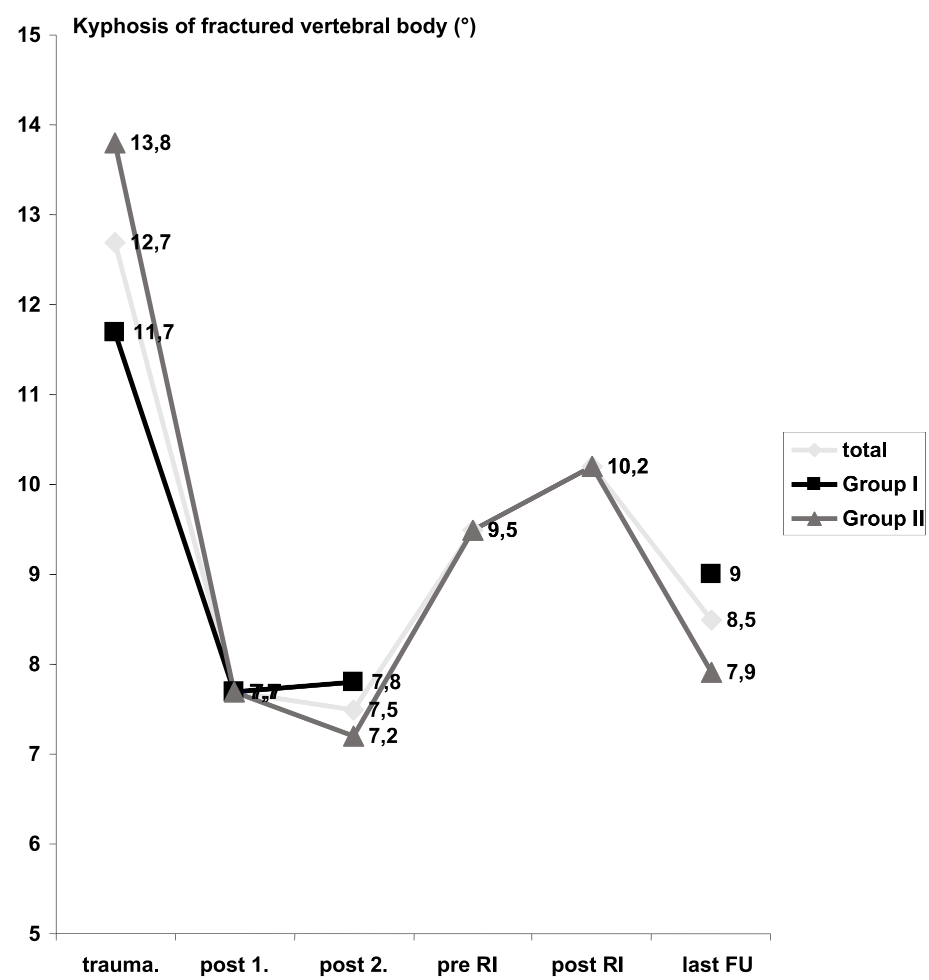


**Fig. 6.** Kyphosis of fractured vertebral body during follow up. RI: removal of implants. FU: followup.

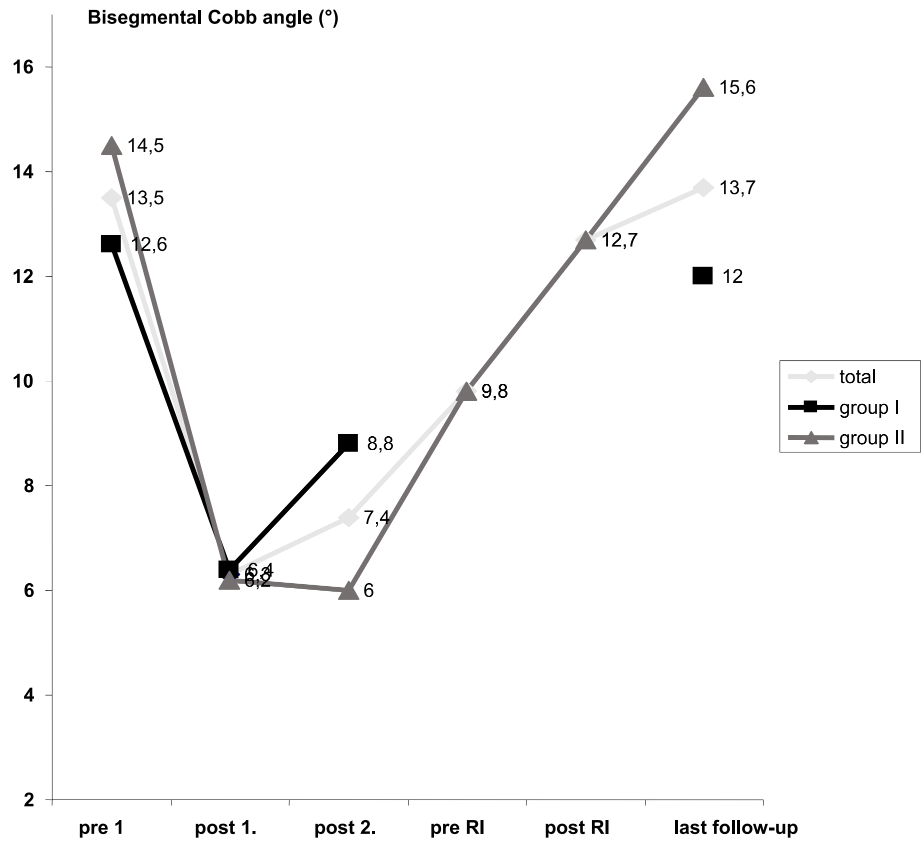


**Fig. 7.** Changes in bisegmental Cobb angle during follow-up. RI: removal of implants.

## 4. Quality of life

### 4.1. SF 36 (score 0–100)

#### 4.1.1. *Trend toward better scores in group II, significant better values for physical function and physical sum scale*

Overall result of the SF 36 evaluation showed a mean value of 52.5 ± 22.5 in group I and of 60.9 ± 22.2 in group II. Further evaluation showed best results in group II.1 (72.6 ± 19.6)

Subgroup analysis revealed differences concerning physical health. Overall physical health after spine trauma was rated 38.3 ± 10.5 in our population. Patients of group I showed a decreased physical wellbeing (35.7 ± 10.7), whereas group II reported better values (40.8 ± 10.2). Physical sum scale was significantly better in group II compared to group I (p = 0.025, *t*-test, Fig. 8).

Group II.1 showed best results in the analysis of physical functioning (46.6 ± 7.3). Differences in the subgroup analysis were significant (p = 0.007, Fig. 9; Fig. 10).

Concerning psychological wellbeing, overall rating was 46.4 ± 12.6. Subpopulation analysis showed less diverse results, group I reached 45.9 ± 12.2, group II 46.9 ± 12.9. Best results were seen in group II.1 (49.7 ± 11.1).

### 4.2. LBOS (score 0–75)

#### 4.2.1. *Trend towards better values in group II*

The study population reached a mean value of 44.9 ± 17.3. Group I showed a mean 40.9 ± 17.9, whereas group I reached higher scores (48.8 ± 15.7). Highest score was reached by group II.I (54.7 ± 12.4). Differences were not significant.

### 4.3. Oswestry low back pain disability questionnaire (score 0–100)

#### 4.3.1. *Trend towards better scoring results in group II, significantly better results in subgroup II.1*

Overall we saw a mean value of 23.9% ± 18.6. Group I showed higher levels of disability (28% ± 19.1) compared to group II (19.9% ± 17.1). The best scoring results were seen in group II.1 (9.8% ± 12.7). This difference showed to be significant (p = 0.046, *U* test Mann/Whitney, Fig. 11).

Subgroup analysis showed a trend towards better results in Oswestry in group II-patients concerning pain intensity (28% ± 32 vs. 32% ± 32), everyday-life activities (18% ± 16 vs. 30% ± 20) and social activities (20% ± 20 vs. 28% ± 26).

### 4.4. Questionnaire concerning implant removal: subjective wellbeing after surgery

#### 4.4.1. *Improvement of symptoms in group II.1 and II.3, worsening of symptoms in subgroup II.2!*

68.8% of group II-patients reported an improvement of their complaints after implant removal. 18.8% did not notice any change concerning their complaints. In 12.4% of patients the complaints were aggravated due to implant removal. Patients suffering from worsening were all members of group II.2.

72.8% of Patients of group II would choose implant removal again as an option to improve quality of life.

## 5. Discussion

Implant removal is a widely used therapy in different fields of orthopedic surgery. In the era of inert implants made of titanium alloys, benefit of these procedures remains controversial. Especially in spine surgery, implant removal should be indicated with care. In general the

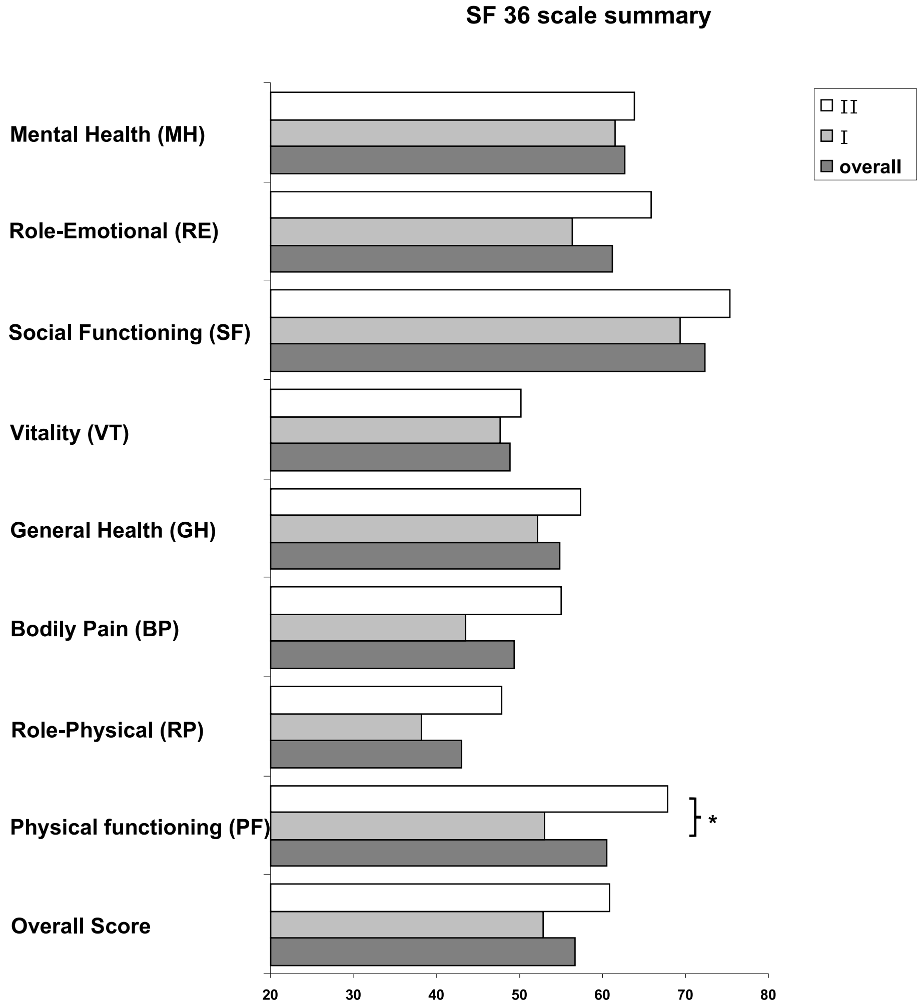


**Fig. 8.** Improvement of SF 36 PF scale by IR (p = 0.007, *t*-test), trend toward improvement in all other scales.

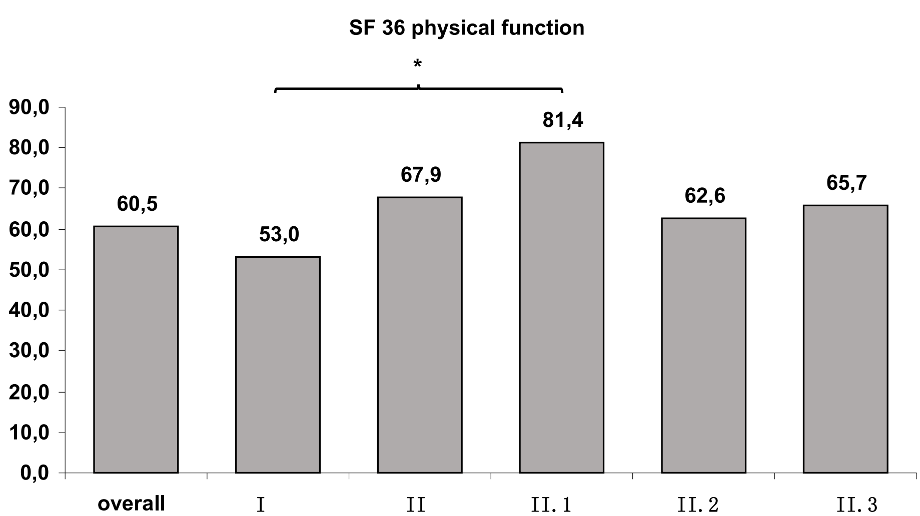


**Fig. 9.** Improvement of SF 36 PF scale by IR (p = 0.007, *t*-test).

extent of the posterior approach, the risk of vertebral compression fractures, wound infection, muscle damage and even neurological or large vessel complications have to be taken into consideration (Stavridis et al., 2010; Vanichkachorn et al., 1997; Waelchli et al., 2002). In cases of posterior stabilization only or combination of bisegmental posterior stabilization with anterior monosegmental fusion by bone graft, implant removal is recommended to prevent loosening or failure of the construct. In cases of anterior bisegmental fusion, there is no need to remove the internal fixator from this point of view (Knop et al., 1999a).

Only a limited number of studies deal with implant removal after

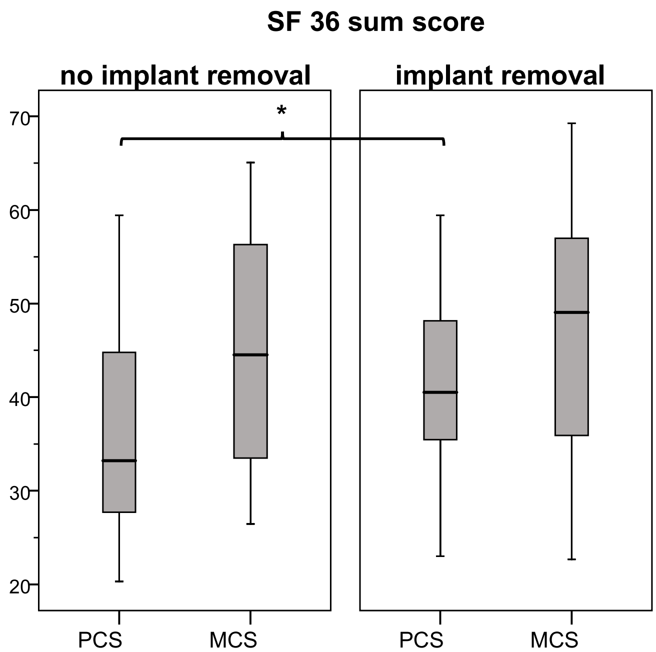


**Fig. 10.** Significant improvement of SF 36 Physical Health Component Summary Score after IR (PCS, p = 0.025, *t*-test) in contrast: No improvement of SF 36 Mental Health Component Summary Score after IR (MCS, p = 0.712).

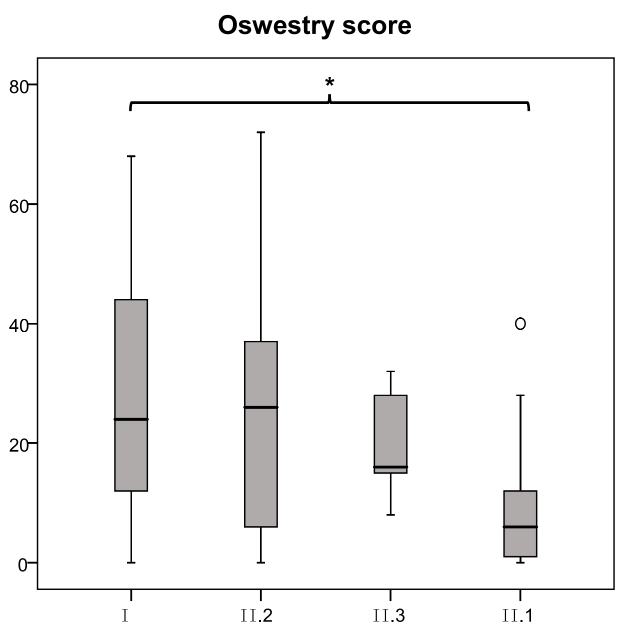


**Fig. 11.** Oswestry score: significant better results group II.1 towards group I (p = 0.046, u-test Mann/Whitney).

spine surgery and its impact on QOL, pain, and function as well as loss of correction in the course.

There are few studies dealing with the functional improvement or the clinical outcome after degenerative spine surgery. Impact of implant removal after traumatic vertebral fractures concerning outcome remains unclear.

Aim of our study was the evaluation of implant removal in clinical and radiological outcome in patients with traumatic fractures of thoracolumbar spine.

Our epidemiologic data are comparable to previous studies. Mean age at the time of trauma was 45 years which is in accordance with the German multicenter-study on spine trauma MCSII that showed a mean age of 44 years (Reinhold et al., 2009b). Other studies showed mean ages ranging from 37 to 45 years. Gender ratio of approximately 60:40 (male: female) showed no difference to previous results (Knop et al., 1999a; Eysel et al., 1991; Eysel and Meinig, 1991; Gertzbein and Scoliosis Research Society, 1992; Kaneda et al., 1997; Knop et al., 1997; Knop et al., 2001a; Lindsey and Dick, 1991).

Localization of the fractured vertebral body showed a preference of L1 in 54%, followed by TH 12 and L2. Knop et al. reported involvement of L1 in 49.3% of cases. Several studies have shown this kind of distribution similarly (Eysel et al., 1991; Eysel and Meinig, 1991; Gertzbein and Scoliosis Research Society, 1992; Kaneda et al., 1997; Knop et al., 1997; Lindsey and Dick, 1991; Knop et al., 2001b; Knop et al., 1999b; Katz et al., 1988; Scalea et al., 1986).

According to the Magerl/AO classification (Magerl et al., 1994) our results are quite consistent with epidemiologic data published previously.

Concerning trauma mechanism, we saw a higher rate of motor vehicle accident (MVA) associated injuries (39%) in our population compared to other groups. Reinhold et al. found MVA-associated injuries in only 25% of the cases (Reinhold et al., 2009b). This might be caused by the geographic location of our trauma center surrounded by several highways with a high number of commuters as well as the demographic changes of the last decades leading to less work-associated injuries.

Downfall from relevant height was seen in 32% of cases in our population similarly to the studies of Reinhold (Reinhold et al., 2009b, 2010), whereas other studies reported higher numbers (Knop et al., 1999a). In 29% of cases we saw fractures related to sport- or working-related accidents.

Radiologic evaluation showed an initial height restoration of the fractured vertebral body by posterior reposition and stabilization. This led to a reduction of postoperative traumatic kyphosis that is comparable to previous studies (Knop et al., 2000, 2001a; Reinhold et al., 2009a, 2009c, 2010). We measured the kyphosis angle of the fractured vertebral body itself as well as the bisegmental Cobb angle in the sagittal plane. Angulation of the endplates of the fractured vertebral body showed correction by initial surgical intervention, followed by a loss of correction during follow-up. There were no significant differences between the subgroups. The fact that we saw an improvement of this angle from 10.2° to 7.9° in group II shows either a certain amount of inaccuracy of the measurement comparable with previous studies (Eysel et al., 1991), especially if anterior fusion with destruction of the integrity of at least one endplate was performed. We saw a considerable loss of correction even in subgroup II.3 before and after IR. Previous studies showed better radiologic results in combined procedures with additional anterior approach but without impact on function or QOL (Reinhold et al., 2009b, 2009c, 2010).

There was a trend towards higher loss of correction rates after implant removal in our series, although these differences failed to be significant. Highest rates were seen in group II.1: Bisegmental Cobb angle 17.0 ± 7.7 at the final examination. The subgroup II showed a nonlinear worsening of the angle by the last surgical intervention. This is discordant to the results of Reinhold, who saw no change in the sagittal profile due to removal of the posterior instrumentation (Reinhold et al., 2009c).

The removal of the internal fixation, if performed 12 months after initial trauma, leads to an increased load bearing of the anterior column with danger of subsequent loss of height of the injured segments.

There were no significant differences in the functional results, although there was a trend in all tests towards better functional results in group II concerning ROM of the lumbar and thoracic spine as well as the ability of active elevation of the ground in prone and supine position. Knop et al. reported similar findings with a decreased range of motion in patients with internal fixator in place (Knop et al., 2001a). Improvement of functional parameters was reported elsewhere. Oh et al. saw a restoration of ROM after implant removal of 4.1°, which was "not as much as he had expected". He concluded from his study that implant removal is preferably performed no later than 12 months after initial surgery to prevent stiffness (Oh and Seo, 2019).

There is a wide range of interindividual differences in the healthy population as well as a certain amount of inter-observer variability (Reinhold et al., 2009b; Knop et al., 2001a; Radoschewski and Bellach, 1999), differences of 0.6 cm between subgroups for Schober's/Ott's sign should be interpreted cautiously. On the other hand the trend to better functional outcome as suggested by functional testing was concordant to better QOL-results in our cohort.

Our study included only patients that underwent open surgery for posterior stabilization. There are data available that MIS patients with percutaneous pedicle screw administration might even benefit more than open surgery patients from consecutive (percutaneous) implant removal due to less soft tissue compromise (Ntilikina et al., 2017; Charles et al., 2017).

In a study performed by Lee et al., patients after implant removal showed better QOL-results than without implant removal. In this study, an abbreviated health related quality-of-life-outcome score derived from SF-36 called SF-6D was used. The authors postulated not only better clinical outcome but cost effectiveness from a health care point of view up to 2 years after initial surgery (Lee et al., 2017).

In our opinion the relevance of minor gains in ROM remains doubtful.

### 5.1. Quality of life

All used questionnaires/QOL-scores found wide implementation in follow-up studies concerning traumatic vertebral fractures (Knop et al., 2001a; Reinhold et al., 2009c, 2010; Gaul et al., 2008). The short form-36 item health survey score is a well-established means to determine the quality of life dependent on health (Knop et al., 1999a; Radoschewski and Bellach, 1999; Ware and Sherbourne, 1992).

Patients after removal of the posterior instrumentation (group II) had a trend towards better scores in all different types of tests used in our study.

There were significantly better results concerning the physical sum tests ($p = 0.025$) and physical function ($p = 0.007$) in the SF36 as well as in Oswestry score ($p = 0.046$) for group II.1 compared to group I.

Differences in the mental/psychological sum scale of SF36, psychological wellbeing and social function were less obvious as were social contacts in Oswestry. Best results were achieved in group II.1. LBOS showed a trend towards better results in group II. Evaluation of differences of QOL between group II.2 and II.3 revealed better results for II.3 in LBOS, VAS and Oswestry, whereas II.2 had better scoring in SF36. There was no statistical significance in this subgroup analysis.

Previous studies suggested the superiority of limited surgery (isolated posterior instrumentation) compared to combined approaches in the trauma population. While there are higher rates of loss of correction in limited approaches, they often show better functional results and less complications (Reinhold et al., 2009b, 2009c, 2010).

In our study population, we saw the best results after IR accordingly in limited surgery cases (group II.1).

71.8% of the population of group II said, they would choose again to undergo surgery for implant removal. Previous studies reported a rate of 63% (Stavridis et al., 2010).

68.8% of the patients reported improvement of symptoms after implant removal. These two simple questions reveal a subjective impression of improvement and support the findings of the established QOL–tests.

In 12.4% of patients, implant removal lead to a worsening of symptoms and complaints. All patients who had no benefit of implant removal belonged to subgroup II.2. In our opinion this is underlining the necessity of strict indications for surgery. A rate of missed fusion of the bone graft might be taken into account for this interesting effect in this subgroup.

Smits saw similar numbers in his population concerning QOL. He reported worsening of symptoms in 11% and some kind of benefit in 74% of cases. He was not able to show any correlation between Cobb angle increase, treatment modalities or fracture type with outcome (Smits et al., 2017).

Comparison of the radiologic findings and the QOL-results revealed that there was no correlation between loss of correction or posttraumatic kyphosis and QOL in our population. It was postulated that kyphosis leads to functional deficit and pain. In our study, the best clinical outcome concerning QOL was seen in group II.1, these patients had less functional problems or pain but the highest bisegmental Cobb angle of 17°. Further studies with long-term results with a follow up period of approximately 10 years will show whether these results are only short-/mid term effects. Kyphosis might lead to degeneration of adjacent levels leading to long-term complications and functional impairment.

In our clinical setting, we recommend implant removal in cases of posterior instrumentation without anterior surgery (group II.1), if there are no contraindications.

IR will be scheduled 9–18 months after initial surgery. We do not insist on the necessity of this procedure if the patient is frightened by additional surgery.

In cases of bisegmental posterior instrumentation with anterior monosegmental spondylodesis (autologous tricortical pelvic bone graft) implant removal is recommended to prevent implant failure, There is special focus on the risk of exacerbation of symptoms after IR in the pretreatment consultation concerning informed consent. Due to inferior results in this subgroup (pre and post IR) we almost completely abandoned the monosegmental bone graft technique at our institution.

In patients who underwent combined anterioposterior surgery using a bisegmental distractable cage we do not consider implant removal necessary. In selected cases (very slim patient, back pain due to soft tissue affection by protruding implants), IR can be helpful and indicated.

In patients with higher perioperative risk or age >65 years, IR is recommended only in cases of implant-related complications.

### 5.2. Limitations

We were able to include a respectable number of patients in our single-center-observation. One disadvantage of our study design is the fact that we included injuries of different severities (Magerl A1.3, A3.1, B, C; AO A1, A3, A4, B, C). A prospective multicenter study with a higher number of patients differentiating injury severity in patients with or without implant removal might provide more detailed results in this regard. Although the number of patients in our cohort is comparable to previous studies (Stavridis et al., 2010; Oh and Seo, 2019; Ntilikina et al., 2017; Charles et al., 2017; Lee et al., 2017), results might be more reliable in larger populations. Our combination of functional tests, radiologic findings and a selection of established QOL-tests is considerable in our point of view. Finally, the determination of loss of correction is subject to a certain measuring inaccuracy. Interpretations of functional results have to be discussed with caution due to relevant interindividual differences even in a population without spinal injury. There were no significant differences in function as determined by physical examination and range-of-motion-tests. So it remains unclear whether implant removal has an effect on function (by improving range of motion) or on local soft tissue. The psychological role of "coping with the injury" and finally overcoming the residual trauma effects by implant removal seems to play a more significant role than functional improvement in a number of cases. Nevertheless, there are skinny patients suffering from local irritation of the implants who have an anatomical benefit by implant removal surgery.

## 6. Summary and conclusion

Our data suggest that patients do benefit from implant removal of the posterior instrumentation after traumatic fractures of the thoracolumbar spine concerning QOL.

In the short term follow up of 18 months we saw better results in different types of QOL testing, especially in the physical sum scale of SF 36, in physical function of SF 36 as well as in Oswestry. There was a positive trend in all other tests; only members of group II.2 did report increasing symptoms after implant removal.

There was a loss of correction in all cases during follow up. Posttraumatic kyphosis at the end of follow up was worst in group II.1, which had the best QOL scoring and the best outcome concerning functional tests. There was no correlation between radiologic findings and QOL.

We postulate that implant removal has a positive effect on clinical outcome/QOL in our study population. Whether there will be an impairment of QOL or functional testing in the long run due to kyphosis has to be evaluated.

## Statement of the corresponding author

The manuscript has been read and approved by all authors and there are no conflicts of interest.

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