

# Evaluation Tools and Outcomes after Osteosynthesis of Unstable Type B and C Pelvic Ring Injuries

## Nástroje pro zhodnocení a výsledky po osteosyntéze nestabilního poranění pánevního kruhu – typ B a C

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### SUMMARY

The evaluation of present long-term studies on results after surgical stabilization of the pelvic ring is difficult, as different treatment concepts are used and the majority of these studies are not comparable regarding selected evaluation parameters. Additionally, no standardized measurement instrument exists to analyze the clinical and radiological result after pelvic ring injuries.

Only short-term evaluations with a mandatorily recommended minimum follow-up time of one year are available. Medium-term analyses or real long-term analyses are missing.

Present data show an increase of long-term sequelae from stable type A injuries to completely unstable type C injuries. Concomitant injuries of other injury regions around the body as well as additional injuries to the pelvic region (complex pelvic trauma) seem to influence the overall results. Therefore, in the future it is necessary to develop a sufficient pelvic outcome instrument which addresses these parameters.

Additionally, results of treatment of specific fracture types depend on the chosen stabilization method.

Overall, as single centres have only “limited” experience in treating pelvic ring injuries within a short period of time, and there is a wide range of completely different injury types and different treatment concepts, for future evaluation of long-term results after pelvic ring injuries prospective, multicenter outcome studies are recommended.

### INTRODUCTION

Many reports in the literature are dealing with emergency management and initial treatment, describing several techniques to treat these injuries.

In contrast, there is a lack of adequate follow-up studies on pelvic ring fractures. No clear data are available regarding outcome parameters and instruments in correlation to specific fracture types, stabilization procedures or treatment concepts.

Especially in completely unstable type C injuries results after conservative treatment are unacceptable. Approximately 40–60% of the patients report on persistent pain and only half of the patients reach their previous working level (13, 17, 21, 36, 45, 58, 59).

Therefore, during the last decade, several reports were published regarding outcome evaluation after stabilization of vertically unstable type C injuries of the pelvic ring, whereas type B injuries were of minor interest.

Therefore, the aim of the present evaluation was first to describe well accepted outcome measurement instruments for pelvic ring injuries, and second to present general data on functional and radiological outcome following these injuries including pain, return to work, urogenital complaints, neurological complaints and prognostic factors leading to inadequate long-term results. Third, an additional attempt was made to analyze the outcome of specific fracture types and stabilization concepts.

## ACCEPTED OUTCOME INSTRUMENTS

Traditionally, evaluation of long-term results after bony injuries have focused on radiologic outcomes or nonvalidated measures of pain and function that did not facilitate comparison of results from one report to the next (23). With the advent of validated measurement instruments, deficits in physical, social, and emotional function subsequent to injury and disease now can be consistently quantified (24).

Several non-validated and validated outcome measures are used in describing the long-term result after pelvic ring fractures.

Most authors use the validated 36-item short-form health survey SF-36 (63) or the Musculoskeletal Function Assessment (MFA) (11, 35). Their main disadvantage is that they capture relevant impairments of the overall quality of life, but the individual importance of these limitations, localized to the pelvis, can not sufficiently be analyzed (47).

Therefore, other rating scales, especially to describe problems focussed to pelvic ring are still used by many authors: the Majeed score (32), the outcome instrument of the German Multicenter Study Group Pelvis (POS) (43, 44), and for analysis of unspecific posterior pelvic complaints the Oswestry Lock Back Pain Scale (12).

### SF-36

The SF-36 is the most common used validated outcome instrument and is used for subjective self-assessment of mental health, physical and social aspects (63). It is a meaningful measurement instrument for evaluating the overall quality of life. A potential disadvantage is that relevant impairments of quality of life are captured, but the relative individual importance of these limitations is not sufficiently analyzed. Scores range from 0 to 100, with higher scores indicating a better health state.

Eight different parts are analyzed: physical functioning (PF), role limitations due to physical health (RP), body pain (BP), general health perceptions (GH), vitality (VT), social functioning (SF), role limitations due to emotional problems (RE), and general mental health (MH). Of these PF, RP, BP and GH are summarized to measures of physical (PCS) and VT, SF, RE and MH to mental (MCS) health.

### Musculoskeletal Function Assessment (MFA)

The MFA is a validated 101-item, self-reported health-status questionnaire to detect differences in the functional status of patients who have a broad range of musculoskeletal disorders (11, 35). Its short version (SMFA) is a two-part, forty-six-item, self-reported health-status questionnaire, which also can be used for clinical evaluation of impact of treatment in individual patients or patient groups after an injury (55). The main items are analysis of daily activities, general injury-related daily impairments, injury-related impairments in daily activities including working abilities and social status. As with the SF-36 an individual analysis of pelvic ring related

impairments cannot be made and therefore only general functional impairments can be clearly distinguished.

### Oswestry low back pain disability questionnaire

The Oswestry low back pain disability questionnaire as a region-specific validated score measures the patient's permanent functional disability in the lumbosacral region (12). The score consist of 10 items with score values from 0–10%. The analyzed items are: pain intensity, general personal care (washing, dressing etc.), weight lifting, walking ability, impairments while sitting, standing or sleeping, sexual impairments, social life and travelling. The score rates the disability into five categories: minimal disability: 0–20%, moderate 21–40%, severe 41–60%, crippled 61–80% or >80% (bed bounded or symptom exaggerating).

### Majeed score

The Majeed score is a non-validated self developed pelvic fracture specific functional assessment instrument with a maximum of 100 points for patients working before injury or 80 points for patients not working before injury (32) (Tab. 1). The score items are pain (30%), return to work (20%), sitting disturbances (10%), sexual impairments (4%) and walking ability (36%). The latter is subdivided into use of walking aids (12%), analysis of unaided gait (12%), and the walking distance (12%).

A score of 100 points or 80 points is defined as the best result. Patients who worked before injury are graded as excellent with a score >85, good with a score of 70–84, fair with a score of 55–69 and poor with a score <55. Patient who did not work before injury are graded into excellent, good, fair and poor with score values of >70, 55–69, 45–54 and <45, respectively.

The disadvantage of the Majeed score is, that neurological impairments, which have relevant prognostic influence, are not integrated and it measures exclusively the functional component of the long-term pelvic injury.

A modification of Majeed score has been used by Lindahl et al. (29, 31). Ability to work was separated from this assessment giving a maximal total score of 80 points for each patient in order to compare the outcome of different types of fracture and subgroups. The total score for the functional outcome was also modified specially to take account of the outcome after the pelvic injury. The functional outcome was graded as: excellent, 78 to 80 points; good, 70 to 77 points; fair, 60 to 69 points; and poor, less than 60 points.

### Multicenter Study Group Pelvis Outcome Scale (POS)

The POS is a non-validated scale and consists of three items: clinical, radiological and social integration criteria (43, 44) (Tab. 2). Clinical criteria include the sub-items pain, functional impairments (limping, walking assistance), and persistent neurological and urogenital impairments. Radiological criteria focus on the reconstruction of the posterior pelvic ring and to a less relevant part on the integrity of the anterior pelvic ring. The social reintegration considers working ability, leisure ac-

Table 1. Majeed score for functional evaluation after pelvic ring injuries

Pain		Gait unaided	
intense, continuous at rest	0–5	cannot walk or almost	0–2
intense with activity	10	shuffling small steps	4
tolerable, but limits activity	15	gross limb	6
with moderate activity, abolished by rest	20	moderate limb	8
mild, intermittent, normal activity	25	slight limb	10
slight, occasional or no pain	30	normal	12
Work		Walking aids	
no regular work	0–4	bedridden or almost	0–2
light work	8	wheelchair	4
change of job	12	2 crutches	6
same job, reduced performance	16	2 sticks	8
same job, same performance	20	1 stick	10
		no stick	12
Sitting		Walking distance	
painful	0–4	bedridden or few meters	0–2
painful if prolonged or awkward	6	very limited time and distance	4
uncomfortable	8	limited with sticks, difficult without; prolonged standing	6
free	10	1h with a stick, limited without	8
Sexual intercourse		1h without sticks, slight pain or limb	10
painful	0–1	normal for age and general condition	12
painful if prolonged or awkward	2		
uncomfortable	3		
free	4		

Table 2. The POS for clinical, radiological and social evaluation after pelvic ring injuries

Clinical result	
4 points	no pain, no neurological or urological impairment, no functional limitation
3 points	pain only after severe effort, no analgesics required slight functional impairment (occasional limping) slight neurological disturbance, not subjectively distressing
2 points	invariably pain after effort, occasional analgesics required significant impairment of function (limping, walking-stick required) impairment of motor nerve function not regarded as a handicap and/or extensive sensory disturbance without loss of protective reflexes micturition disturbances without residual urine in bladder and/or partial erectile impotence, or other disturbances of sexual function not regarded as distressing
1 point	continuous pain, pain at rest, analgesics frequently required permanent use of crutch or wheel chair required because of pelvic injury handicapped impairment of motor nerve function and/or sensoric deficits with loss of protective reflexes micturition disturbances, impotence/disturbances of sexual function, urinary or faecal incontinence
Radiological result	
3 points	posterior anatomical reconstruction residual displacement of the pubic symphysis < 5 mm and/or maximal residual displacement of the pubis/ischium < 10 mm
2 points	maximal posterior residual displacement 5 mm and/or residual displacement of the pubic symphysis 6–10 mm and/or maximal residual displacement of the pubis/ischium 10–15 mm
1 point	maximal posterior residual displacement > 5 mm and/or residual displacement of the pubic symphysis > 10 mm and/or maximal residual displacement of the pubis/ischium > 15 mm
Social reintegration	
3 points	same profession as before sports and free-time activities unchanged social activities unchanged
2 points	limited employment in previous profession retraining being undertaken or completed reduced sporting activities occasional external support required
1 point	unable to work owing to accident or employment as handicapped person significantly reduced free-time activities, no sport social life significantly limited or socially withdrawn frequent external assistance required

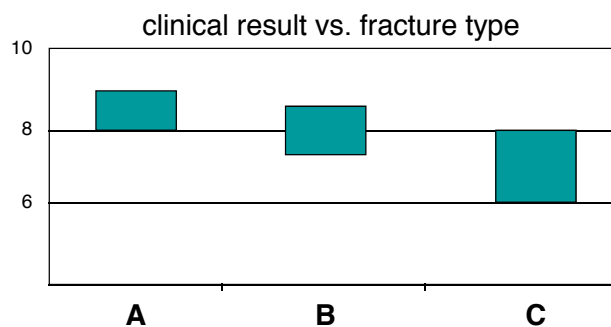


Fig. 1. Average values of excellent and good clinical results dependent on the fracture type showing a decrease of optimal results from type A to type C injuries.

tivities, sporting activities, social activities and necessity of external assistance.

To estimate the total result of the pelvic injury, the radiological (3 points) and clinical results (4 points) are summarized and the resulting 7 point scale assesses the result of the pelvic injury as follows: 7 points for an excellent result, 6 for a good result, 4 and 5 for an adequate result and 3 or 2 for a poor result.

### Basis of outcome evaluation of pelvic ring injuries

The main question when describing the prognosis of pelvic injuries or comparing treatment options is at which follow-up time a long-term result should be recorded.

Majeed et al. noted that patient function improved over the first 18 months and then stabilizes (33), whereas Kreder identified a functional plateau between 6 months and 1 year post injury (23).

**Therefore, it is imperative that follow-up studies for pelvic ring injuries have at least a minimal follow-up evaluation of one year.**

Comparable analyses of type B and C injuries showed confusing results. Several reports showed, that type C injuries have the worst prognosis (9, 19, 31), whereas others stated that no difference exists between these fracture groups (40). In contrast, even type B1 fractures can be associated with the greatest degree of disability, followed by type C fractures, whereas type B2 and B3 fractures demonstrating the lowest degree of disability (23).

Therefore, a detailed outcome analysis should focus on fracture type specific results, results of injury regions, and on the type of osteosynthesis in these different regions or the fracture type.

In a recent multicenter analysis clinical results were excellent or good according to the Majeed score in 85%. A decrease of these results was observed with increasing pelvic ring instability from type A to type C injuries. Neurological long-term sequelae increased with the type of pelvic ring injury with 4% after type A, 11% after type B and 17% after type C injuries. Urological and sexual sequelae were both present in 8%, with highest rates after type C injuries (each 14%). Additionally, patients

with less than 5mm residual displacement showed best functional results with a Majeed score of >90, whereas with increasing displacement significantly lower scores were observed (10).

Pavelka et al. found comparable results in their single center analysis. Excellent and good clinical outcomes according to the Majeed score were seen in 83% after type B and in 70% after type C fractures. The radiological results was excellent (<5mm residual displacement in 83% and 61%, respectively (41).

**The stability of the pelvic ring influences the long-term result, with type C injuries showing worse results than type B injuries.**

Therefore a detailed analysis of these fracture types is and there subgroups is presented.

### TYPE B INJURIES

The classification of type B injuries includes anterior-posterior compression injuries ("open book" injuries, B1, B3) and lateral compression injuries (B2). The latter seem to be less unstable (31) and therefore potentially have a better long-term result with fewer patients complaining of pain (43).

Additionally, as type B1 injuries can be associated with functional results more in line with type C fractures (23) or even worse (18), inclusion of type B2 and B3 injuries in the overall group of type B injuries can make it difficult to clearly analyse the overall result. Analyses of the type B group must therefore distinguish between these subgroups of fractures.

An overview is given on long-term results after unselected type B injuries as well on specific fracture types.

### Outcome after unselected type B injuries

Only few reports are available on long-term results after isolated type B injuries. There are some data on SF-36 analysis after these injuries.

In 11 patients with type B injuries at a mean follow-up of 2 years with a non constant treatment, a reduced physical component score of 68.7 and a reduced mental component score of 72.2 was reported, which represents approximately 12% and 4% impairment compared with the U.S. normal population, respectively (40).

Long-term results in 32 type B injuries, which were treated by different treatment concepts including non-operative treatment and several stabilization concepts, showed a mean physical functional value of 75.8 and a pain value of 69.8 (4). This a reduction according to the normal U.S. population (in: (40)) of 10.3% and 7.6%, respectively.

Additionally, the results of 31 patients with type B injuries treated by external fixation in 60% and by non-operative means in 40% with a follow-up of more than 5 years were within 2 standard deviations from established American populations norms (37) and therefore showed no significant difference.

**Accoding to a validated outcome instrument (SF-36), there are only minor impairments after type B injuries compared to the normal population.**

Some reports used non-validated outcome instruments to analyse the long-term result after type B injuries.

In a multicenter analysis in Germany, the POS was used in 87 patients after isolated type B injuries without additional acetabular fractures. No consistent treatment concept was documented and follow-up evaluation was performed at 2 years posttrauma. 79.3% of the patients reported none or slight pain in the pelvic region (43). Pain localization was reported to be solely anterior in 4.6% (symphyseal/pubic region), whereas 34.5% reported on single posterior pain and 16.1% suffered from both ventral and dorsal pain. Functional limitations, analyzed with the Merle d'Aubigné score showed a mean value of 17 points, and 83% of the patients had bilateral identical scores or differences of a minimum of one point. Leg length differences were exclusively the result of accompanying lower extremity injuries. Radiological follow-up evaluation (at least an a.p. x-ray) was available in 78 patients (89.6%). Posterior anatomic healing was observed in 90%, whereas in 28% some anterior mal-healing occurred. A total of 88.5% of the patients offered a positive or neutral subjective assessment of their condition. Overall, 87% of the patients were still able to work. 74% continued in their previous profession or remained in the same training program. 14% were at least partially able to work, and 13% of patients were unable to work as a result of the injury. 69% reported that their sporting activities had not been altered by the accident, and further 11% had only slight limitations. 90% had no or only slight limitations regarding hobbies. The total clinical result was assessed as excellent or good in 83.9% of the patients. A poor total clinical result was due to permanent urological and neurological disturbances or significant pelvic pain.

Overall pelvic outcome assessment stated that 77.5% of the patients achieved a good or very good result after a type B injury (43).

The non-validated 100 point Iowa pelvic score (IPS), which includes activities of daily life (20%), return to work (20%), pain (25%), limping (20%), pain by visual analogue scale (VAS) (10%) and cosmesis (5%), where 100 points is a perfect result was used

to analyse the result in 31 type B injuries treated by external fixation in 60% and by non-operative means in 40% with a follow-up of more than 5 years (37). No data on neurological and sexual dysfunction are integrated in this scale.

75% of patients returned to their previous occupation, 73% had identical previous sexual activities, 88% had an identical recreational level in light work and 62% in heavy work compared to the uninjured situation. Additionally, 27% suffered from sexual disturbances and 35% reported significant persistent pain in the pelvic region. Overall, only 32% had no functional impairments (37).

In an analysis of a mixed group of B1 and B2 injuries after ORIF of the anterior ring with a plate at least one year after trauma (12–84 months) full ambulation was possible in 96% but only 69% of these patients were pain-free. 27% had pain with strenuous activity and overall, 83% returned to work within one year after trauma and 75% returned to their original jobs (60).

Recently, an analysis of 27 patients with type B injuries, all treated with ORIF, used the Majeed score for functional evaluation and showed 81% good and excellent results. But only 48% of these patients were completely pain-free at follow-up (34).

**In unselected patients with type B injuries, approximately 30% of patients suffer from long-term problems (pain, functional limitations) with an overall rate of 75–80% acceptable results.**

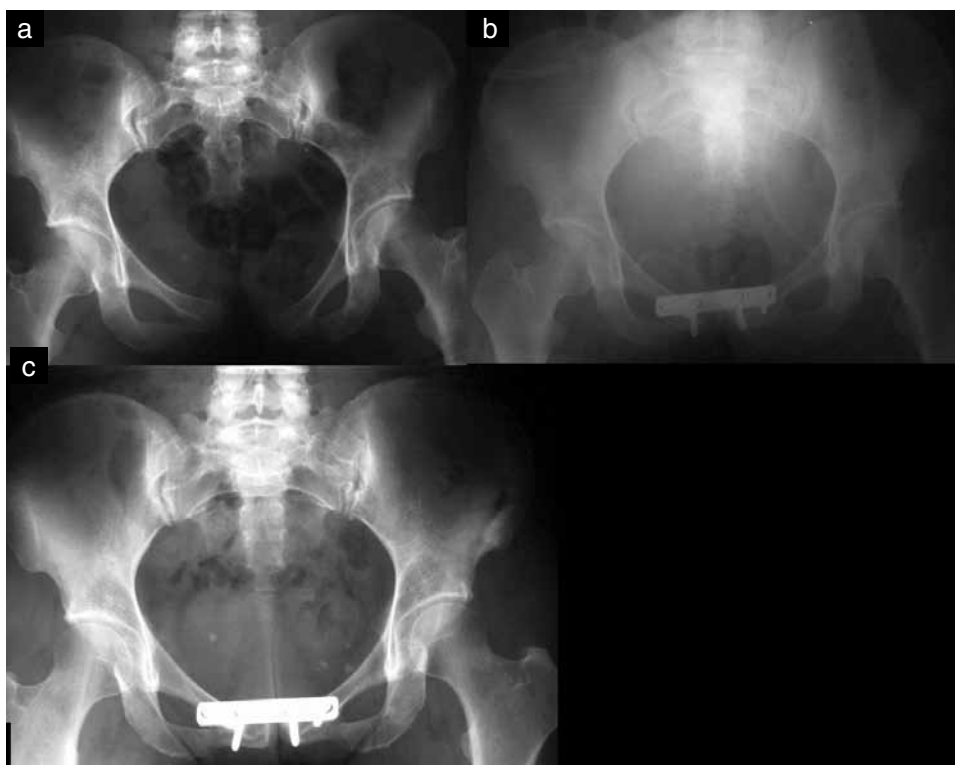


Fig. 2. 43-year-old woman after motorcycle accident. The pelvic x-ray shows symphyseal disruption and anterior widening of the left SI-joint (type B1 injury) (a). Symphyseal plating with a small 4.5mm DC-plate was performed on the day of injury (b). The 3-year result showed anatomic healing (c). The patient refused implant removal, as she had no complaints.

### B1 “open book” injuries

As already mentioned, type B1 injuries are supposed to be the most severe type B injuries with a potential risk of permanent disabilities. Different outcome instruments were used, making comparison of the results nearly impossible. Therefore, only relative recommendation can be stated.

In an analysis of nine patients with B1 injuries after ORIF using the Sickness Impact Profile (SIP) with a minimum follow-up of one year following injury the mean SIP score was 12.4, indicating a moderate disability ( $<10$  = slight disability,  $10-30$  = moderate disability;  $>30$  = severe disability) (18). The total physical score was 11.1 with worst values for ambulation (20.2 points). The mean psychosocial score was 10.9 with emotional disability of 17 points. Sleep (16.6 points), working (25.7 points), home management (17.2 points) and recreation (24 points) showed moderate impairments.

In a further analysis by this group, the Ostwestry back pain score (OBPS) was evaluated for the same study group. There was minimal to moderate disability related to low back pain (19).

22 patients which were treated with symphyseal plating and were analysed at least one year posttrauma (range 1–9 years) using the POS (65). Overall 41% of these patients reported some pelvic pain, even after anatomical reconstruction of the pelvic ring.

In 15 patients after plate osteosynthesis of open-book injury without additional complex pelvic trauma re-eval-

uation was performed 14 to 49 months postoperatively (42). Using POS 93.3% of these patients had an excellent or good functional result and all patients had anatomical healed pelvis. 73% were completely pain-free.

Using the Majeed score eight patients with open book injuries were analysed after a mean of 4.1 years (1–11 years) (31). All patients were treated with an anterior external fixation alone. Six of eight patients had a fair or poor radiological results at follow-up with  $>11$ mm displacement at their injury site. Three of these patients had significant pelvic pain and the functional results was graded fair or poor in 50%.

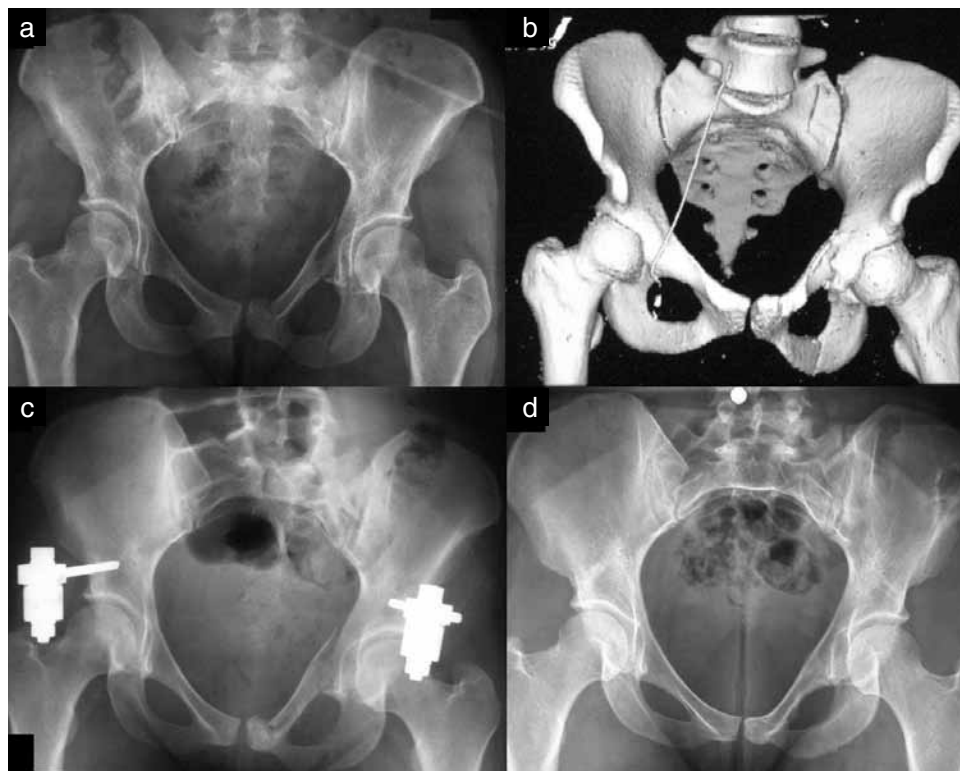
In an analysis of 31 patients with B1 injuries which were treated by several stabilization techniques including external and ORIF techniques good or excellent functional results were observed in 74% of these patients (48, 49). Significant permanent pain was reported in 29% and 36% of these had moderate to severe pelvic pain. In contrast, anatomical bony healing occurred in 93%.

Recently, the functional outcome of 32 patients with open book injuries after a median follow-up time of 84 months using the SF-36 and the Majeed score was analysed (62). All patients had initial anterior ring stabilization and in approximately one fourth of the patients an additional iliosacral screw was applied.

All values of the different SF-36 categories were lower compared to uninjured German and U.S. patients. The median level of physical functioning was 95%, no patient

had role limitations and the median pain level using the VAS was 10%. Interestingly, patients which were treated by additional posterior iliosacral screw fixation showed a trend to worse results compared to patients with symphyseal stabilization alone. The average Majeed score was high with 95.7 points.

**After B1 injuries moderate disability and 30–40% relevant persistent pain can be expected, despite a high rate of anatomical healing. The overall functional result is graded excellent and good in 70–90%, when symphyseal plating is performed. Single external fixation seems to lead to worse results.**



*Fig. 3. 25-year-old woman sustaining a car accident. Pelvic a.p. x-ray (a) and 3D-CT (b) show lateral compression injury of the left sacrum and left anterior pelvic ring fracture (type B2 injury). Initial stabilization was performed by simple supraacetabular external fixation (c). The 5 year results showed uneventful bony healing (d). The patient was completely pain free without any functional disturbances.*

### B2 lateral compression injuries

In the analysis of 62 patients with lateral compression type B2 injuries

treated by external fixation alone with a mean follow-up of 4.1 years (1–11 years) using the Majeed score 32.2% of these patients had a fair or poor radiological result with >11mm displacement at their injury site but only 6.4% reported on significant pelvic pain. The functional result was graded fair or poor in 25.8%. Especially, when vertical pubic ramus displacement was >10mm, significant more patients had persistent pain or a worse functional result (31).

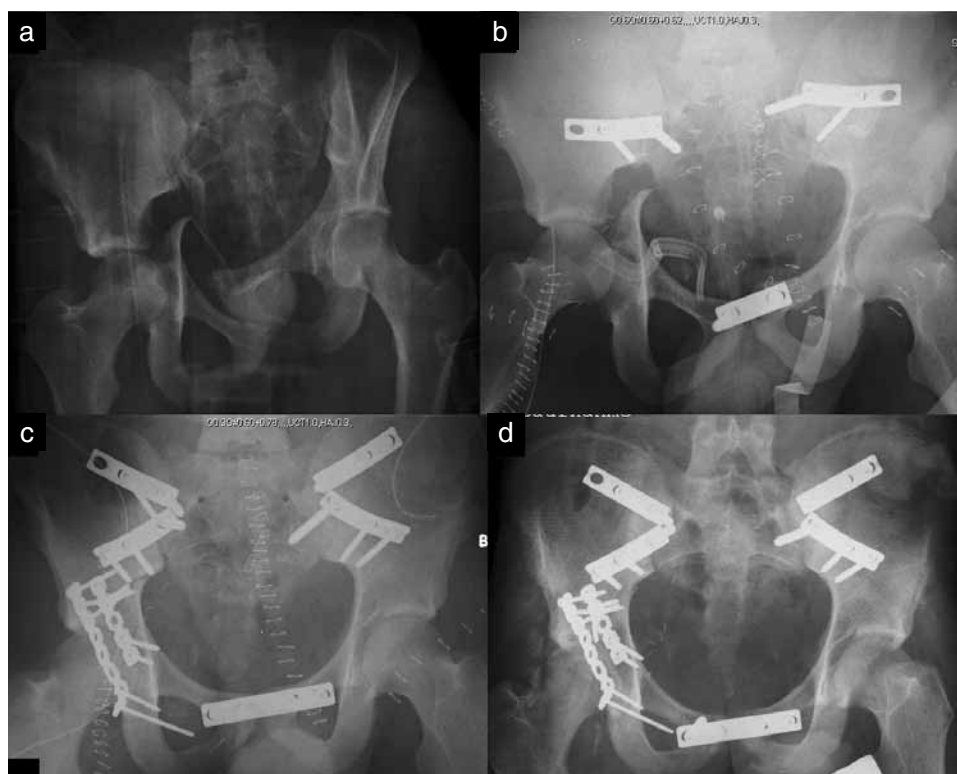
In a recent analysis of 30 patients with lateral compression pelvic ring fractures with extension into the anterior acetabulum, treated conservatively in the majority of patients, follow-up was performed after a mean of 4.2 years (2 to 6 years), using the MFA (Musculoskeletal Function Assessment) and the SF-36 (25). At follow-up, 93.3% of the pelvis showed a maximum residual displacement of <10mm. Functional deficits were observed for mental and social function in the SF-36 compared to B1 and C injuries.

**After lateral compression type B2 injuries a low rate of permanent pain (5–15%) can be expected, despite anatomical healing of the pelvis in only 70–75%. An excellent or good overall functional result was observed in 75–90%.**

**In conclusion, as expected, type B1 injuries lead to more worse results than type B2 injuries. The major problem today in these analyses is the usage of different outcome parameters, different outcome measurement instruments, integration of different treatment concepts and amount of persistent pelvic ring displacement, making comparison of these results extremely problematic. Future research should focus on these problems with standardization of these topics before acceptance for publication.**

## TYPE C INJURIES

The majority of reports in the literature are dealing with completely unstable pelvic ring injuries, disrupting



*Fig. 4. 18-year-old man after roll-over injury with severe hemodynamic instability. Pelvic a.p. x-ray (a) showed bilateral SI-joint dislocations, symphyseal disruption and right transverse acetabular fracture (type C3 injury). After emergency stabilization of the pelvis with non-anatomic plate osteosyntheses of the symphysis and both SI-joints, pelvic packing was performed (b). After hemodynamic and physiological stabilization definitive treatment was performed on day 10 with bilateral anterior SI-joint plating and symphyseal plating in combination with acetabular reconstruction via Kocher-Langenbeck approach (c). After one year, he was pain free with an excellent function of his hip. Only a moderate right peroneal nerve injury was still present. Bony healing was anatomic (d).*

the anterior and posterior pelvic ring structures. Several reports are describing results of study groups with different types of type C injuries not distinguishing between classification, fracture types, fracture location or treatment modalities (26, 56, 64).

It is expected, that these injuries lead to the worst results.

## Outcome after unselected type C injuries

Several reports are dealing with results of treatment after type C injuries, not distinguishing between the type of posterior lesion and the applied treatment concept.

There are some data on SF-36 analysis after these injuries.

In 24 patients with type C injuries at a mean follow-up of 2 years with a non consistent treatment, a reduced physical component score of 62.6 and a reduced mental component score of 69.3 was reported, which represents approximately 20% and 7.8% impairment compared with the U.S. normal population, respectively (40).

Long-term results in 34 type C injuries, which were treated by anterior and posterior stabilization techniques showed a mean physical functional value of 68.9 and a pain value of 60.1 (4). This a reduction according to the normal U.S. population (in: (40)) of 12% and 16.8%, respectively.



Additionally, of 24 patients with type C injuries treated by external fixation in 60% and by non-operative means in 40% with a follow-up of more than 5 years, 81% returned to their preinjury occupation level, but 42% had disturbances of their sexual activity (37). These patients had the lowest rates of returning to their preinjury level of recreation. Persistent pain was present in 25% and 21% had a limited activity. Overall, only 17% showed no functional impairments.

Distinguishing between posterior complete iliac fractures (type C.1.1), complete SI-dislocations (type C.1.2) and unilateral type C sacral fractures (type C.1.3), after anterior and posterior stabilization of the pelvis, mean SF-36 physical functional values of 63.8, 71.1 and 72.6 were reported, respectively and the mean pain values were 54.5, 62.2 and 63.5, respectively. As complete iliac fractures and SI-dislocation are more uncommon than sacral fractures, the long-term sequelae after unilateral sacral fractures seem to be better compared to other unilateral type C injuries (4).

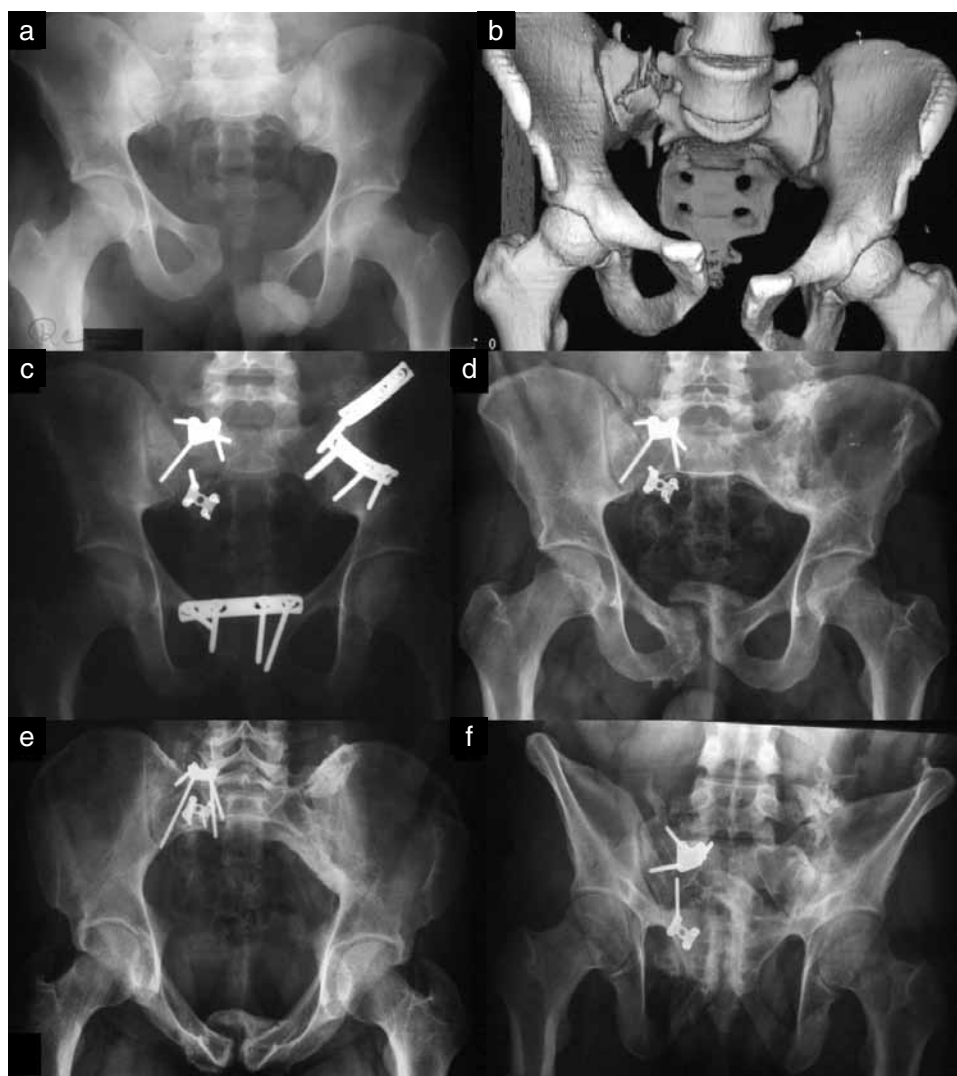
**According to a validated outcome instrument (SF-36), there are relevant impairments after type C injuries compared to the normal population. Operatively treated sacrum fractures showed better results than after pure SI-joint dislocation.**

The majority of reports are dealing with non-validated outcome instruments to analyse the long-term result after type C injuries.

52 patients with different unstable posterior pelvic ring injuries and operative treatment of the posterior pelvic ring were followed at 36 months (range 5–74 months). 98% showed bony union. In 88% the posterior pelvis healed within a maximal displacement of 5mm. The pain level during rest using a VAS Scale was 28% on average and 41% for the ambulation pain score. An additional lumbosacral plexus injury leads to higher pain values. The overall rate of urinary complaints was 37%. 30%

of the male patients had signs of erectile dysfunction. The working status was identical to the preinjury level in 65% and 11% were partially integrated. The mean self developed pelvic outcome score was 29 points. 28.8% had functional deficits related to associated injuries (6).

In a further analysis of ORIF of with 46 patients with different unstable posterior pelvic ring injuries after at least one year after (mean 44 months, range, 12–101 months), 45.5% of the patients with sacral fractures were completely pain-free, and further 18.2% had only slight pain, giving acceptable pain levels in 63.7%. A persistent nerve deficit was present in 54.5% of these patients. 63.7% returned to their previous jobs. Despite a good radiological reduction several patients reported on pain, indicating, that the soft-tissue injury possibly contributes to the long-term clinical status. After pure sacroiliac dislocations 61.5% had no and



*Fig. 5. 23-year-old man sustaining a car accident. Pelvic a.p. x-ray (a) and 3D-CT (b) show a displaced right transforaminal sacral fracture (type C), an open book injury of the left SI-joint (type B) and a symphyseal disruption (type C2 injury). Definitive pelvic reconstruction was performed on day 4 with localized sacral plating and symphyseal plating. Two days later, anterior SI-joint plating was performed to allow full weight bearing on the left side (c). The 5-year results showed uneventful bony healing with anatomic pelvic ring healing in the a.p. view (d), the inlet (e) and the outlet view (f). Heterotopic ossification developed posterior to the pubic symphysis.*



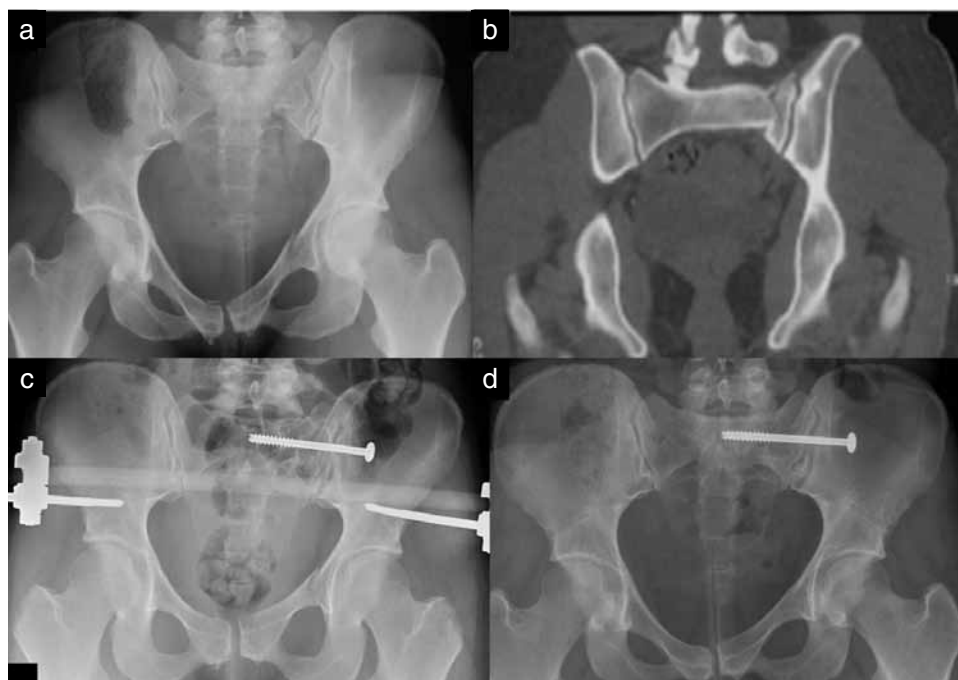
7.7% had slight pain, (69.2% acceptable pain level). Overall, 61.5% had a permanent lumbosacral plexus lesion. Previous occupational status could be reached by 46% of the patients. After sacroiliac fracture dislocations 45.8% of patients were pain-free and 12.5% had mild pain. After this injury type the lowest rate of acceptable pain levels (58.3%) were reported. A persistent nerve deficit was seen in 12.5% of the patients. The majority of patients (79.2%) was able to return to their previous jobs (61).

In 40 patients treated with only anterior external fixation and type C injuries, the Majeed score was used during follow-up after a mean of 4.1 years (1–11 years). 95% had a fair or poor radiological result. 47.5% reported on significant pelvic pain and the functional results were graded fair or poor in 85%. Posterior displacement of >10 mm was a bad prognostic indicator for functional impairments (31).

In an analysis of 67 patients after type C injuries treated by different stabilization techniques including anterior and posterior techniques, the long-term functional results were graded excellent or good in 71.6% of the cases. Pain was frequent with 54% of patients having persistent pain. A permanent neurological deficit was observed in 13.4% (48).

101 patients with type C injuries treated by posterior fixation techniques in 98 patients, additional anterior fixation in 78 patients and single anterior fixation in 3 patients had follow-up analysis at least one year after trauma with a mean of 23 months (range 12–85 months) (29). The long-term radiological results was graded excellent (<5mm residual displacement) in 65%, and good (5–10mm residual displacement) in 24.8%. The Majeed score was graded excellent or good in 83%. Despite this, late pain problems were common in 33.7% of patients, with the majority complaining of posterior pelvic pain. There was a strong correlation between the radiological and clinical result. Additional analysis with the POS showed 80.2% good and excellent results for combination of the clinical and radiological result (29).

In a recent analysis of 11 patients with type C injuries, treated posteriorly with ORIF, the functional results was as good and excellent in 73%, whereas 63.6% of these patients were completely pain-free at follow-up (34).



*Fig. 6. 26-year-old woman sustaining a car accident. Pelvic a.p. x-ray (a) shows a lateral compression injury of the left sacrum with bilateral anterior pelvic ring fractures. CT scan (b) reveals complete sacral fracture (type C1 injury) leading to pelvic ring stabilization a simple supraacetabular external fixator and percutaneous iliosacral screw fixation (c). The one year result showed uneventful bony healing (d). The patient was completely pain free without any functional disturbances.*

**In unselected patient groups with type C injuries, approximately 30–50% of patients suffer from significant persistent pain and have sexual or urogenital disturbances. An excellent or good overall functional result can be expected in 70–80%. The local soft-tissue injury at the posterior pelvis may influence the clinical long-term result.**

**A rate of 65–90% healing with residual displacement <5 mm was observed, depending on the type of pelvic ring stabilization. Single external fixation is inadequate for treating these injuries. These studies support the concept of anterior and posterior stabilization in type C injuries.**

#### **Analysis of results of type posterior osteosynthesis in unstable type C injuries**

Few consecutive epidemiological data are available regarding treatment options of type C posterior pelvic ring injuries.

The best data are available for unstable sacral fractures. In the early 90ies one third of patients with sacral fractures were treated by iliosacral screw fixation, one fourth had sacral plate osteosynthesis, ilio-iliacal stabilization techniques were performed in approximately 10% and sacral bar fixation in 17% (43).

Unpublished data from the 2<sup>nd</sup> German Multicenter Study on pelvic fractures still observed that iliosacral screw fixation is the most common stabilization method in approx. 45%, followed by lumbo-pelvic fixation concepts in 32%. 15% had some type of ilio-iliacal stabilization and only 7% were stabilized using direct plating techniques.

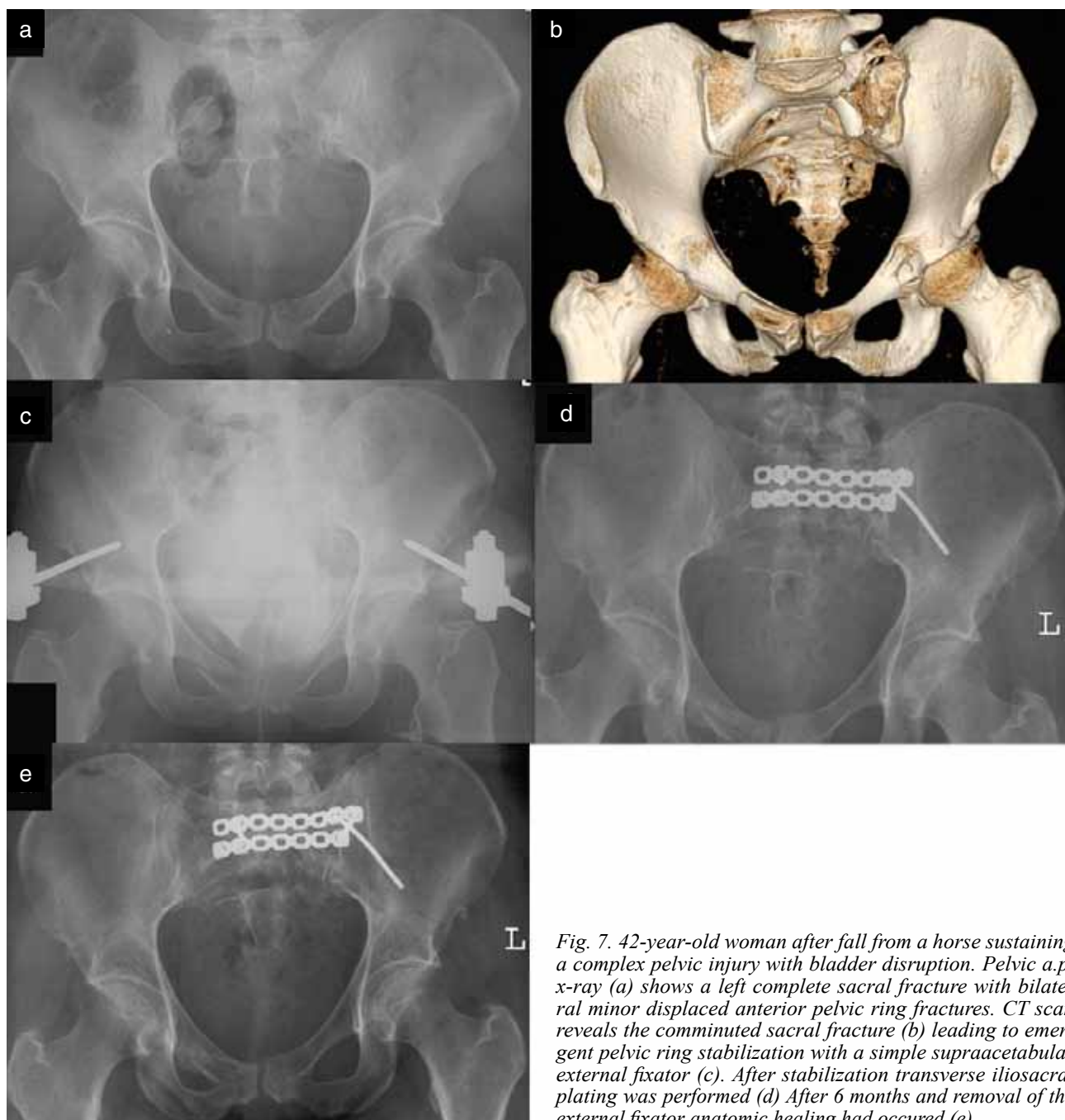


Fig. 7. 42-year-old woman after fall from a horse sustaining a complex pelvic injury with bladder disruption. Pelvic a.p. x-ray (a) shows a left complete sacral fracture with bilateral minor displaced anterior pelvic ring fractures. CT scan reveals the comminuted sacral fracture (b) leading to emergent pelvic ring stabilization with a simple supraacetabular external fixator (c). After stabilization transverse iliosacral plating was performed (d). After 6 months and removal of the external fixator anatomic healing had occurred (e).

Therefore, it is of interest to analyse the results of different posterior pelvic ring stabilization techniques in type C injuries.

#### Long-term results after iliosacral screw fixation of the posterior ring

Despite increasing reports on conventional and navigation assisted techniques in stabilization of unstable sacral fractures, these studies predominantly focus on quality of reduction, safety of screw positioning, radiation exposure and perioperative parameters. Only few reports focus on long-term results after this procedure.

In an analysis of 21 patients after iliosacral screw fixation, with a mean follow-up time of 31 months, only 33.3% of these patients had excellent or good clinical

results in the POS. Removal of the screw(s) lead to an improvement of the functional results in 10 of 12 patients (66).

In a recent follow-up analysis at least one year postoperative (mean 32 months) of 71 patients with 10 type B and 61 type C injuries and pure SI-dislocations or sacral fractures, 69 (97%) showed a satisfactory healing with a displacement <10mm. In 21% degenerative changes of the involved SI-joint was seen at final follow-up (52). The Majeed score was used to grade the long-term functional result in 68 patients. 91% of these patients a good or excellent result. Bad results were observed in patients with complex pelvic trauma or permanent lumbosacral plexus injury. 86% of patients returned to their preinjury occupation and recreation level.

The long-term result after iliosacral screw fixation of posterior pelvic instabilities can not clearly be expected presently. The functional result is potentially influenced by additional trauma to peripelvic soft-tissues (urogenital, lumbosacral plexus etc.). Secondary implant removal should be considered to optimize the result.

#### Long-term results after anterior plating of the unstable SI-joint

Ragnarsson et al. were the first to analyze 21 patients with 23 type C injuries of the SI-joint (OTA C1.2) (46). In three patients no anterior ring stabilization was performed (14%). At follow-up after a mean of 5 years (2–8 years) 47.6% of these patients were completely pain-free, 14.3% reported on slight pain and 9.5% on severe or disabling pain. 19% of these patients had moderate or severe limping, in 14.3% walking support using a cane was necessary. Additional 19% of the patients reported on problems while sitting, 14.3% had pain during sexual activity and one patient had erectile dysfunction. 38% of these patients had persistent lumbosacral plexus injury. 71% of the patients were partially or fully integrated in their previous occupation. According to the Harris hip score the functional result was graded good or excellent in 85.7%. Only one patient showed breakage of a plate screw. All others had identical x-rays compared to postoperative evaluation with anatomical healing in 81%. Overall, 57% of these patients showed relevant functional disability.

An own analysis only analyzed the radiological long-term result. 16 patients after anterior plating of a C1.2 injury were evaluated after a mean of 63.2 months (range 1–14 years). Anatomical healing was observed in 81%. The other patients showed some malalignment of 2–4 mm. In ten patients with a follow-up CT scan, only one patient showed a “normal” SI joint. All others had changes in the SI-joint (periarticular osteophytes, degenerative changes, and ankylosis) (16).

**Anterior plating of the completely disrupted SI-joint as part of a type C injury results in anatomical healing in 80%. Overall, approximately half of these patients can have relevant functional limitations.**

#### Long-term results in type C injuries after ilio-iliacal stabilization techniques

Several techniques are described for posterior ilio-iliacal stabilization of unstable pelvic ring lesions. These include sacral bar stabilization (extra- and intraosseous), application of an ilio-iliacal internal fixator, and transiliac plate osteosynthesis. No study is available for long-term results after sacral bar stabilization.

In 14 patients with unstable sacral fractures transiliac reconstruction plate osteosynthesis was performed and no loss of reduction was observed. Overall, 57% of these patients reported pain (1).

A comparable percutaneous technique with subfascial ilio-iliacal plate osteosynthesis technique was analysed in 25 with different posterior pelvic ring injuries after a mean of 17 months. Radiological analysis with criteria of the POS showed 64% anatomic reconstructions of the

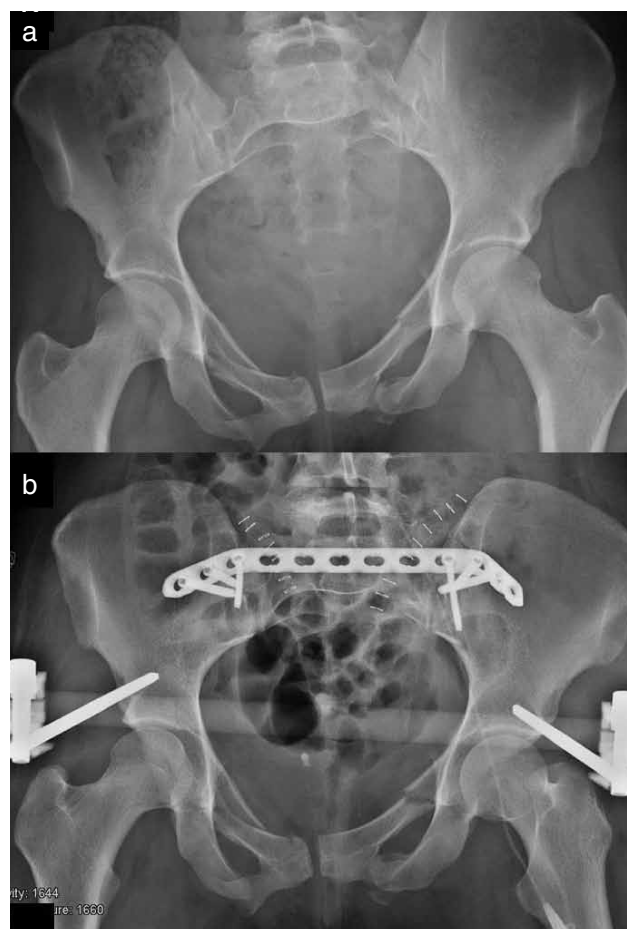


Fig. 8. Example of a type C injury with bilateral anterior ring fractures and a left transforaminal sacral fracture (a), stabilized by a simple supraacetabular external fixator and an ilio-iliacal plate osteosynthesis (b).

posterior pelvis (maximal displacement of the posterior pelvic ring < 5 mm) and 32% with a good result (displacement 5–10 mm) (8).

The same group reported the clinical results and the social reintegration in 23 after an average of 20 months (range 7–57 months) (22). The clinical outcome (POS) was graded excellent or good in 73.9% of cases. 39.1% of the patients were complete socially integrated, further 43.5% had incomplete integration. A trend for better clinical results was seen with good bony reconstructions. The presence of lumbosacral plexus lesions and permanent urogenital complaints was associated with worse clinical results. The initial presence of polytrauma lead to a worse social integration, for the clinical result only a trend could be observed.

Stabilization of comminuted sacral fractures in 18 patients with ilio-iliacal plate osteosynthesis showed 72.2% of the patients rated excellent or good using the Majeed score with a mean score of 78.5 points. Radiographically, healing with displacement <5mm occurred in 50%, and healing with displacement 5–10 mm in 38.9%. A persistent neurological deficit leads to significant lower scores (53).

Results in 28 patients with SI dislocations or sacral fractures treated with a percutaneous technique of an

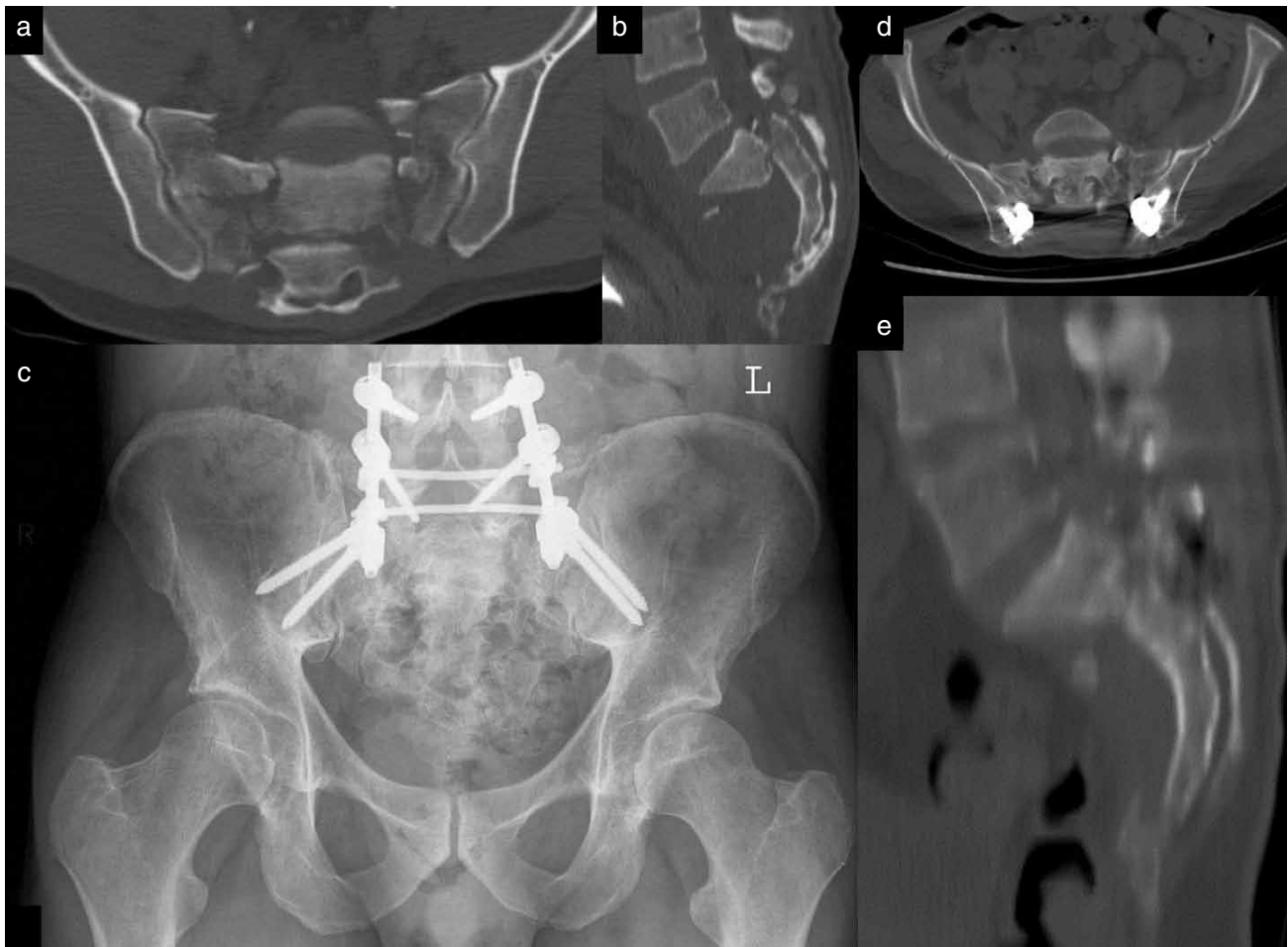


Fig. 9. 37-year-old male fell from the fourth floor sustaining H-shaped sacral fracture-dislocation with spinopelvic instability; cauda equina injury and bilateral L5-S1 nerve root injuries (a-b). Operative reduction, segmental lumbopelvic fixation and sacral decompression was carried out once the patient was stabilized hemodynamically. The end radiological and functional results were good (c-e). The patient returned to work, but he changed the job.

ilio-iliacal internal fixator showed after a mean of two years postoperative an overall rate of 62.5% excellent or good clinical results according to the POS. All but two patients had posterior reconstructions with a residual displacement < 5 mm. Patients with an additional pelvic complex trauma (2) showed worse clinical and radiological results and their social integration was impaired.

**The long-term result after percutaneous posterior ilio-ilacal plating in type C injuries shows a rate of 70–75% good to excellent clinical results. Healing with displacement <5mm was recorded in 50–80%. Better radiological results were observed with the TIFI, but no comparable data were available regarding primary displacement. Additional peripelvic soft-tissue injury (complex pelvic trauma) lead to worse results.**

#### **Long-term results in type C injuries after lumbo-pelvic fixation**

Lumbo-pelvic or spino-pelvic stabilization techniques are of increasing popularity during the last years. Several different techniques are well described in the literature. The basic concept is a connection of an internal fixator fixed in the distal lumbar spine pedicles to the sacrum

and/or posterior ilium. Modifications include additional plate or iliosacral screw fixation.

A triangular lumbo-pelvic technique was used in unstable sacral fractures with complemented iliosacral screws or an ilio-iliacal plate. 34 patients had a follow-up examination at an average of 19 months postoperatively (range 8–52 months). All patients had unstable sacral fractures. No loss of reduction was observed, but clinical data were missing (51).

Using the same technique in 18 patients with SI-dislocations and sacral fractures stated, that after a mean follow-up time of 23 months (range 4–48 months) using the POS no patient was completely pain-free. 66.7% had slight or occasional pain, 22.3% had moderate pain and 11.1% had permanent severe pain. 11.1% of these patients required walking assistance (cane), and 61.1% had a normal gait (57).

A modification of the triangular technique was used in 20 patients with unstable sacral fractures and follow-up was performed at a mean of 23 months (range 7–48 months). 90% showed healing with a displacement of the sacrum <5mm. The overall clinical result was graded excellent or good in 65% using the POS (39).

**Unselected long-term results after lumbo-pelvic fixation in type C injuries show good to excellent clinical results in only 65% of these patients. The fixation concept shows adequate stability with low rates of loss of reduction.**

#### **Long-term results in spino-pelvic fracture dissociation injuries after lumbo-pelvic fixation**

As a special subgroup of type C injuries, spino-pelvic fracture dislocation (dissociation) or “suicidal jumper’s fractures” were evaluated by several authors. These injuries are extremely unstable as typically a longitudinal or oblique sacral fracture is associated with a transverse sacral component leading to flexion or extension displacement of the vertebral column with some part of the sacrum into the small pelvis.

The majority of these injuries are presently stabilized with a spino-pelvic fixation construct. Only in minor displaced injuries, bilateral iliosacral screw fixation or even non-operative treatment was recommended by some authors.

17 patients were treated with ORIF, sacral nerve root decompression, and lumbopelvic fixation. A bilateral lumbo-sacral-iliac internal fixator connected with a transverse bar was used. 26% had wound complications. Follow-up was performed after at least 12 months. The kyphotic deformity could be reduced from an average of 43° to 20°. No loss of reduction was seen. Neurological recovery was observed in 83%, with full recovery of bowel and bladder function in 47% (50).

In a first analysis of 15 patients 67% good and excellent pelvic results using the POS and 67% good and excellent functional results using a modified Majeed Scale were stated (27). An on-going analysis of now 22 patients with this injury found that sacral kyphosis was reduced from 43° to 21° with no secondary loss of reduction until latest follow-up examination. The functional outcome according to the modified Majeed score was excellent or good in 62% with a primary lumbosacral plexus involvement in 95% of these cases. In this series, only 1 wound complication was observed (4.7%) (28).

**Spino-pelvic dissociation treated with lumbo-pelvic stabilization concepts show a high rate of adequate bony pelvic reconstructions. Typically, no loss of reduction is observed and nerve root decompression leads to acceptable rates of recovery. The functional result show excellent and good results in <70%, possibly due to the permanent nerve injury and a high pain rate, potentially due to permanent soft-tissue pain by the injury itself.**

#### **Results after specific posterior pelvic injury types**

The classical unilateral injuries to the posterior pelvic ring are complete iliac fractures (type C1.1), pure sacroiliac dislocations (SI-dislocation, type C1.2), and sacral fractures (type C1.3). Only few data are available for analyzing these specific injuries.

#### **Complete iliac fractures (type C1.1)**

Cole et al. treated four of these injuries by plate osteosynthesis. When comparing patients with different poste-

rior fracture pattern, no statistical difference on outcome could be observed in this specific fracture type (6). Another analysis using the SF-36 showed physical functional values of 63.8, and mean pain value of 54.5 indicating lower values than for the general population (4).

In conclusion, no clear data can be presented for this specific fracture type.

#### **Pure SI-dislocations (type C1.2)**

After ORIF of pure SI-dislocations none or only slight pain was reported in 69.2%. The previous occupational status could be reached by only 46% of these patients (61).

Comparable results were found in 21 patients after anterior plating of the SI-joint with none or slight pain in 61.9%. Additionally, 19% of these patients had moderate or severe limping, in 14.3% walking support using a cane was necessary. 19% of the patients reported on problems while sitting, 14.3% had pain during sexual activity and one patient had erectile dysfunction. 38% of these patients had persistent lumbosacral plexus injury. 71% of the patients were partially or fully integrated in their previous occupation. Overall, 57% of these patients showed relevant functional disability. Anatomical healing occurred in 81% (46).

Thus, between 30–40% of patients after ORIF of the SI-joint report on persistent pain, and half of these patients have relevant functional impairments.

#### **Sacral fractures (type C1.3)**

After ORIF of 11 unstable sacral fractures, follow-up at least one year after the injury showed that 45.5% of the patients were completely pain-free, and further 18.2% had only slight pain. 63.6% returned to their previous jobs (61).

Ilio-iliacal reconstruction plate osteosynthesis in 14 patients showed no loss of reduction but 57% of these patients reported on pain (1).

The same technique was used in 18 patients in comminuted sacral fractures showing 72.2% excellent or good functional results with a mean Majeed score of 78.5 points. Bony healing with residual displacement <5mm occurred in only 50%. A persistent neurological deficit leads to significant lower scores (53).

Triangular stabilization in 20 patients resulted in bony healing with a displacement of the sacrum <5 mm in 90%. The POS showed excellent or good results in 65% (39).

Overall, more than 50% of patients after ORIF of sacral fractures report some pain at follow-up with an expected excellent or good functional result in 65–75%.

#### **PROGNOSTIC FACTORS OF WORSE LONG-TERM RESULTS**

Several prognostic factors of worse clinical and functional outcome after pelvic injuries are well described in the literature:

- residual displacement
- persistent nerve injury
- additional pelvic soft-tissue injury (complex pelvic trauma)

### **Influence of residual displacement**

A correlation between persistent vertical displacement of the posterior pelvic ring and body pain after treatment of unstable sacral fractures was recorded (38). The amount of displacement is potentially relevant. Better functional results were found with residual posterior displacement <5mm in type C injuries (9), whereas Tornetta et al. showed no difference in pain levels comparing patients with less or more than 4mm posterior displacement after ORIF (61). In contrast, a higher rate of urinary complaints was noted when more than 5mm displacement persisted at the posterior pelvis (7).

**Optimal results should be expected only in patients with a residual posterior displacement of ≤5mm.**

### **Influence of persistent neurological deficits**

Many outcome analyses could confirm that a permanent lumbosacral plexus lesion is responsible for a worse clinical or functional result (6, 8, 22, 52, 54). Even after type B and more often after type C injuries, persistent nerve deficits can be observed. Most severe nerve lesions were found in type C injuries, whereas after type B injuries only minor sensoric deficits were observed (29, 44, 45). In a recent analysis on late nerve deficits, the lumbosacral plexus injury was one of the most common reason for an unsatisfactory functional result (30). In a recent analysis on a late nerve deficit analysis, the lumbosacral plexus injury was identified as the mainly involved neurologic injury after pelvic trauma which has severe long-term implications regarding pain and gait outcome (5).

Recent data show acceptable rates of neurologic recovery between 30% and 70%. Especially, unstable sacral fractures have the highest rates of additional nerve injury.

**The combination of unstable sacral fractures or spino-pelvic dissociations in combination with a lumbosacral plexus injury is of major prognostic value.**

### **Influence of additional pelvic soft-tissue trauma (complex pelvic trauma)**

Complex pelvic trauma is defined as a pelvic ring injury in combination with a significant peripelvic soft-tissue injury, e.g. open fractures, Morel-Levallé lesions, additional urogenital or pelvic bowel injury as well as neurovascular injuries (2).

The relevance of an additional lumbosacral plexus lesion was already stated.

Open pelvic fractures lead to reduced physical function scores and role physical scores of the SF-36 (3). In a further analysis nearly half of the patients with open pelvic injuries had long-term impairments in daily activities (14).

Urogenital long-term sequelae are of additional relevance. In a comparable study of type B and type C injuries, higher rates of incontinence were observed after type C injuries, whereas after type B injuries a higher rate of micturition disturbances was observed. 12.5% of men had permanent erectile dysfunction after type C injuries (43, 44, 45). In women a 19% incidence of dys-

pareunia was reported (6). In a literature overview a rate of erectile dysfunction between 11% and 30% for all patients depending on the type of diagnostics and a rate of up to 42% in patients with additional injury to the urethra was found (20).

The relevance of the overall additional soft-tissue trauma could be confirmed as it was associated with decreased functional results, when a significant pelvic soft-tissue trauma was present (15, 61).

Analysis of the German Multicenter Study Group Pelvis identified patients with severe pelvic pain as having a higher injury severity, a higher rate of unstable pelvic ring injuries and additional complex pelvic trauma and a higher rate of neurological and urological long-term disturbances. Additionally, in patients with a poor clinical outcome more frequently additional peripelvic soft tissue injuries were present (43).

**Therefore, an additional injury to relevant pelvic soft-tissues including pelvic organ injury influences the clinical and functional long-term result.**

### **CONCLUSION**

For further analyses of long-term results after pelvic ring injuries, a minimum follow-up time of one year is mandatory. Presently, only short term evaluations are available, in the majority of studies with a mean of two years after sustained injury. Medium-term analyses or real long-term analyses are missing.

Present analyses state, that there is an increase of long-term sequelae from stable type A injuries to completely unstable type C injuries (Fig. 1). Concomitant injuries of other injury regions around the body as well as additional injuries to the pelvic region (complex pelvic trauma) seem to influence the overall result. A disadvantage of present studies is, that no consequent treatment strategies were followed, and therefore the outcome after pelvic ring injuries can additionally be influenced by the treatment concept itself.

No standardized measurement instrument exists to analyze the clinical result after pelvic ring injuries.

The currently most commonly used scoring systems are the SF-36, the MFA, the Majeed score and the POS from the German Multicenter Study Group Pelvis.

Validated scores (SF-36, MFA) only scale the difference in disability compared to a normal population. The individual pelvis-dependent outcome can not be measured with these instruments. It can only be measured how much percentage difference in disability exists compared to "normal".

In an attempt to analyze pelvis-related long-term impairments, the Majeed score and the POS and some other scorings tried to integrate appropriate parameters. These include analysis of pain (including low back pain), pelvic and hip function, walking analysis, impairment while sitting, and disturbances of fracture-related concomitant lesions of the lumbosacral plexus and pelvic urogenital organs (sexual, bladder dysfunction etc.).



Therefore it is necessary to develop a sufficient pelvic outcome instrument and an expert group should focus and agree on parameters which should be integrated in such a clinical scoring system. Additionally, they should focus on the different strength of these parameters and therefore their clinical importance.

For pain analysis, we propose a subjective evaluation by the patients with the visual analog scale (VAS), as results of the German Multicenter Study Group Pelvis showed a good correlation between the subjective and objective (by physician) pain rating.

From the practical standpoint, a grading of the mentioned parameters into four categories can be helpful.

The radiological outcome is additionally of major importance. It is well known that a residual displacement of >5mm at the posterior pelvis is associated with poorer clinical outcomes. Therefore, agreement is necessary how to evaluate the posterior pelvic ring radiographically at follow-up (by conventional x-rays, or even CT-scans).

Some studies already showed, that there is a correlation between the clinical and radiological result. Therefore, it can be stated that the radiological results influence the clinical result.

Thus, a single clinical or functional evaluation is of reduced value and a combined scoring of the clinical and radiological result can be a solution to get an overall pelvic result. The German Multicenter Study Group Pelvis tried to develop such a scoring system to get a pelvic outcome score. Again, this should be discussed in expert rounds as adequate scientific data on this topic are missing.

Overall, as single centres have only "limited" experience in treating pelvic ring injuries within a short period of time, and there is a wide range of completely different injury types, which cannot be compared, and different treatment concepts are used to treat these injuries, for future evaluation of long-term results after pelvic ring injuries prospective, multicenter outcome studies are recommended using a more standardized treatment concept and integration of a standardized outcome parameter analysis.

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