CT-Guided Screw Fixation of Vertical Sacral Fractures in Local Anaesthesia Using a Standard CT

CT-kontrollierte Schraubenosteosynthese von vertikalen Frakturen des hinteren Beckenringes in Lokalanästhesie

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Abstract

Purpose: To evaluate time efficiency, radiation dose, precision and complications of percutaneous iliosacral screw placement under CT-guidance in local anaesthesia.

Material and Methods: Retrospective analysis of 143 interventions in 135 patients during a period of 42 months. Implant failures could be evaluated in 85/182 screws and bony healing or refracturing in 46/182 screws.

Results: A total of 182 iliosacral screw placements in 179 vertical sacral fractures (105 unilateral, 37 bilateral) took place in 135 patients. 166/179 of the sacral fractures were detected in Denis zone 1, 10 in Denis zone 2 and 3 in Denis zone 3. No screw misplacements including the simultaneous bilateral procedures were noted. The average time for a unilateral screw placement was 23 minutes (range: 14 – 52 minutes) and 35 minutes (range: 21 – 60 minutes) for simultaneous bilateral screwing. The dose length product was 365 mGy × cm (range: 162 – 1014 mGy × cm) for the unilateral and 470mGy × cm (range: 270 – 1271 mGy × cm) for the bilateral procedure. 1 gluteal bleeding occurred as the only acute minor complication (0.7 %). Fracture healing was verified with follow-up CTs in 42/46 sacral fractures after screw placement. Backing out occurred in 12/85 screws between 6 and 69 days after intervention. In 8 patients contralateral stress fractures were detected after unilateral screw placement between day 10 and 127 (average: 48 days).

Conclusion: CT-guided iliosacral screw placement in sacral fractures is a safe tool providing a very high precision. The radiation dose is in the order of a diagnostic CT of the pelvis for both unilateral and bilateral screws. Contralateral stress fractures in unilateral screw placements have to be considered during the first weeks after intervention.

Key Points:
- Sacral fractures are frequent in the elderly and are often only detected in CT or MRI.
- CT-guided screw placement is a precise and time-efficient procedure in non-dislocated vertical fractures of the sacral wings.
- Contralateral stress fractures may occur after unilateral screw placements.

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Zusammenfassung

Ziel: Evaluierung von perkutanen Osteosynthesen sakraler Frakturen unter CT-Kontrolle in Lokalanästhesie hinsichtlich Interventionszeit, Dosis, Präzision der Schraubenplatzierung und Auftreten von Komplikationen.

Material und Methoden: 143 Eingriffe an 135 Patienten aus einem Zeitraum von 42 Monaten wurden retrospektiv ausgewertet. Zur Beurteilung eines Versagens der Osteosynthese lagen für 85/182 Schrauben und zur Beurteilung der Durchbauung oder Auftreten einer Refraktur für 46/182 Schrauben verwertbare Bildgebungen vor.

Ergebnisse: Bei 135 Patienten mit vertikalen Frakturen des Os sacrum (98 unilateral, 37 bilateral) wurden in 143 Maßnahmen (7 zweizeitige Frakturen, 1 Reverschraubung) insgesamt 182 Schrauben transiliakal in Höhe SWK 1 gesetzt. 166/179 der Sakrumfrakturen lagen in Denis-Zone 1, 10 in Denis-Zone 2 und 3 in Denis-Zone 3. Eine Fehlpositionierung fand sich in keinem Fall. Der Zeitbedarf für eine unilaterale sakrale Schraubenplatzierung lag bei 23 Minuten (14 – 52 Minuten) und bei 35 Minuten (21 – 60 Minuten) für bilaterale

Verschraubungen. Das Dosislängenprodukt (DLP) betrug für unilaterale Verschraubungen im Durchschnitt 365 mGy × cm (Schwankungsbreite: 162 – 1014 mGy × cm) und für bilaterale Verschraubungen 470mGy × cm (Schwankungsbreite: 270 – 1271 mGy × cm). Als einzige akute Minorkomplikation trat eine gluteale Einblutung auf (0,7 %). Bei 42/46 verschraubten Sakrumfrakturen konnte ein knöcherner Durchbau objektiviert werden. Bei 8 Patienten wurden nach unilateraler Verschraubung kontralaterale Frakturen in der CT in einem Zeitabstand von 10 – 127 Tagen (Durchschnitt 48 Tage) detektiert.

Schlussfolgerung: Die Auswertung belegt eine sehr hohe Präzision und zeiteffiziente Durchführung der CT-kontrollierten iliosakralen Osteosynthesen bei gleichzeitig sehr geringem Komplikationsrisiko. Die Strahlenexposition liegt für uni- und bilaterale Osteosynthesen in der Größenordnung eines diagnostischen Becken-CTs. Als mögliche iatrogene Komplikation können bei unilateralen Verschraubungen kontralaterale Stressfrakturen auftreten.

Kernaussagen:

- Sakrumfrakturen sind in höherem Lebensalter häufig und werden oft erst in CT oder MRT nachgewiesen.
- Nicht dislozierte vertikale Alafrakturen des Os sacrum können präzise und zeiteffizient unter CT-Kontrolle transiliakal verschraubt werden.
- Bei unilateralen Osteosynthesen muss auch mit dem Auftreten kontralateraler Insuffizienzfrakturen gerechnet werden.

Introduction

Fractures of the sacrum in the elderly are mainly due to low-velocity traumas in a mechanically weakened bone and are mostly not or only minimally dislocated [1, 2]. CT and MRI scans have shown that in patients with fractures of the anterior pelvic ring sacral fractures are present in 59 – 97 % [1, 3 – 6]. Furthermore there is an increasing incidence of insufficiency fractures of the sacrum being located far lateral in the sacral wings with increasing age [7 – 9].

Although conservative treatment prevails, invasive interventions are indicated to reduce severe pain and to re-establish stability [1]. Two percutaneous techniques hold promise for pain relief and earlier mobilization in those often multimorbid patients:

- internal screw fixation
- injection of polymethylmetacrylate (PMMA) (i. e. „sacroplasty“)

Bone remodeling may only be promoted by screw fixation. A single posterior iliosacral screw at the S1-level already ensures 70 – 85 % of the axial stability of the pelvic ring, being potentially sufficient for mobilization even when anterior pelvic ring fractures are present, although anterior osteosynthesis promotes stability even further [10, 11]. However, fluoroscopic screw placement using C-arms in the operation theatre even with 2 D/3D-navigation is time-consuming and has a risk of misplacement of up to 8 % [12 – 16].

We report our experience with the internal screw fixation of vertical sacral fractures under local anaesthesia and with mild i. v. analgesia using a standard CT, which provides a more precise anatomy and faster handling compared to intraoperative navigation. Although CT-guided screw placement in the posterior pelvic ring was published as early as 1987 by Ebraheim et al. [17], this technique is still not widely used especially in Europe [18 – 26].

Material and methods

Retrospective evaluation of all percutaneous iliosacral screw fixations under CT guidance from 1 January 2010 – 30 June 2013. The indication for the intervention was put forth by the department of trauma surgery and orthopaedics taking into account overall clinical condition as well as stability of the pelvic ring.

All procedures took place in the CT suite of the radiological department using a Somatom Sensation 40 (Siemens company, Forchheim, Germany) with in-room screen under local anaesthesia with prilocainhydrochloride (Xylonest®; AstraZeneca company, Wedel, Germany) as well as additional i. v. analgesia with alfentanil (Rapifen®; Janssen-Cilag, Neuss, Germany) at a dose of 0,3 – 1 mg. Every intervention was conducted by a team of 1 radiologist and 1 trauma surgeon each. The cannulated 7.0 mm titanium screws were fully threaded and varied in length between 70 and 110 mm in steps of 5 mm (Königsee company, Allendorf, Germany).

Apart from 2 female patients who had to be placed in RAO- or LPO-positions due to strong pain, all interventions in the remaining 141 measures were performed in prone position. After a 3-fold skin disinfection with Cutasept G (Bode Chemie company, Hamburg, Germany) and sterile draping, a volume scan at the 1st sacral vertebra with a collimation of 0.6 mm was acquired. The most suitable plane for screw placement was determined from transverse reconstructions with a slice thickness of 5 mm, on which entry point as well as angulation were calculated. After local anaesthesia with up to 20cc from skin down to the iliac periosteum using a 22G Chiba cannula a short incision of the cutis was made. Then Jamshidi bone cannulas (Angiotech, Gainesville, USA) or beveled bone cannulas (Pajunk, Geisingen, Germany) with sizes of 8G were oriented in the direction of the intended screw path between anterior cortex and sacral foramen. When the positioning was considered adequate, the cannulas were advanced manually by turning movements (Jamshidi type) or by a hammer (bevelled type) into the iliac cortex (**Fig. 1a**) and further on across the iliosacral joint. After removal of the mandrin a guide wire with a size of 2 mm was introduced and manually advanced (**Fig. 1b**). This screw path was again verified by a 2nd volume scan and biplanar reconstruction of the wire course. In case of a satisfying path the cannula was removed and a cannulated fully threaded 7.0 mm screw with a plain washer introduced according to the measurements from this scan volume and manually driven down to the cortex (**Fig. 1c**). In case of the wire deviating from the intended path, cannula and wire were repositioned and verified by another volume scan. A final volume scan was performed after placement of the screw(s). Finally, after removal of the guiding wire the cut was closed with a back-and-forth suture. Additional screws in further sacral segments were not placed in either case.

The duration of the intervention was determined from the time visible on the scout view to the time documented on the final volume scan with the screw(s) in place. The overall radiation dose documented in the PACS (dose length prod-

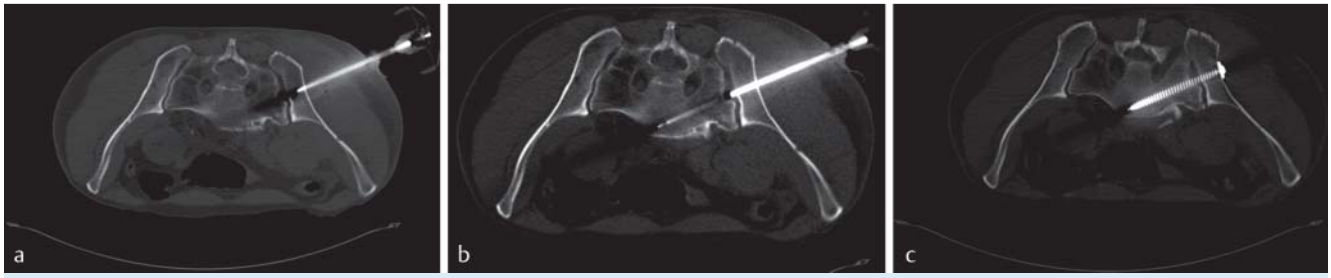

Fig. 1 Procedure stepwise. **a** Alignment of the 8-gauge bone marrow cannula entering the iliac wing according to the desired screw path. **b** Bone marrow cannula advanced beyond the iliosacral joint with guiding wire in place. **c** Cannulated fully threaded screw with plain washer in desired position.

Fig. 2 Coronal view of bilateral screws. The left screw is all the way within the cancellous bone and transpasses the midline (category I). The tip of the right screw has penetrated the cortical bone after slight deviation caudally (category II).

uct DLP) consisted of the sum of the single-shot verifications as well as the sum of the volume sans. Additionally the DLP of the intervention was related to the DLP of the previous diagnostic CT.

The placement of the cannulated screws was graduated in 3 categories according to the final volume scan (**Fig. 2**):

- I: path solely within cancellous bone crossing the midline without penetrating the cortex
- II: path within cancellous bone, but no crossing of the midline or penetration of the screw tip into the cortex
- III: screw perforation into foramen, through endplate into disc space L5 / S1 or perforation of the anterior cortex of the sacrum

As the evaluation was not done prospectively, no standardized grading of the pain before and after the intervention was available. Thus, the clinical effect of the screw placement was not investigated. Follow-up imaging with a time span of at least 3 months was available in 32 patients on plain films (39 screws) and in 36 patients by CT including the pelvic region (46 screws). Thus, adequate imaging for evaluation of screw insufficiencies was available in 85 out of 182 screws and for evaluation of bone fusion and refracturing in 46 screws. 5/32 of the plain films and 23/36 of the CT scans were carried out for other medical reasons. In another 24 patients without imaging documents of the pelvis, other imaging studies were found indicating further treatment without indications for symptoms from the pelvic fracture.

Results

During the evaluation period 182 iliosacral screws were placed in 143 procedures in 135 patients (120 women and 15 men; age range 20 – 94 years; average 77 years) with vertical sacral fractures (98 unilateral, 37 bilateral). In 37 bilateral fractures and 2 unilateral fractures with contralateral iliosacral instability the screws were placed simultaneously. In 8 patients contralateral fractures were detected on CT scans 10-127 days (average 48 days) after unilateral screw placement. Thus, in 7/8 cases a contralateral screw was additionally placed. After removal of a screw having backed out in a unilateral fracture a new screw was placed. Thus, in total there were 104 unilateral procedures and 39 simultaneously bilateral interventions. The length of the cannulated fully threaded screws varied from 70 to 110 mm in steps of 5 mm (median: 95 mm).

166/179 of the sacral wing fractures were located in Denis zone 1, 10 in Denis zone 2 und 3 in Denis zone 3. According to patient history and the presence of an anterior pelvic ring fracture 75/104 of the unilateral screws patients had a significant trauma, 28 were considered insufficiency fractures and 1 case could not be classified. From the 39 patients with bilateral screw placements 17 suffered a trauma, 19 were considered insufficiency fractures and in 3 cases no classification could be made.

Precision of screw placement

According to the final volume acquisition on CT 175/182 screws were classified as category I. Category II was attributed in 7 cases. No category III screw positions could be found, especially not in the 39 patients with simultaneously bilateral screw placements.

Time required and radiation dose

The mean time from scout view to screw in place was 23 minutes (range: 14-52 minutes) for unilateral and 35 minutes (range: 21-60 minutes) for bilateral screws. The mean dose length product (DLP) was 365 mGy*cm (range: 162 – 1014 mGy*cm) for unilateral and 470mGy*cm (range: 270 – 1271 mGy*cm) for the bilateral procedure. The DLP ratio to the previous diagnostic CT of the pelvis was 0.95 (standard deviation: 0.33) for the unilateral and 1.10 (standard deviation: 0.19) for the bilateral approach.

Bone union

36 follow-up CT scans including the pelvis showed bone healing in 42/46 fractures (**Fig. 3**). Non-union was proven in 4 fractures. In a 90-year-old female with a traumatic fracture, a CT scan for persistent pain 45 days after unilateral screw placement showed non-union with resorptions besides a little backing out of the screw as well as a new insufficiency fracture on the contralateral side (**Fig. 4**). The same findings were made in a 72-year-old woman after 3 months where the initial screw was placed in an insufficiency fracture. In a 81-year-old woman with an insuffi-

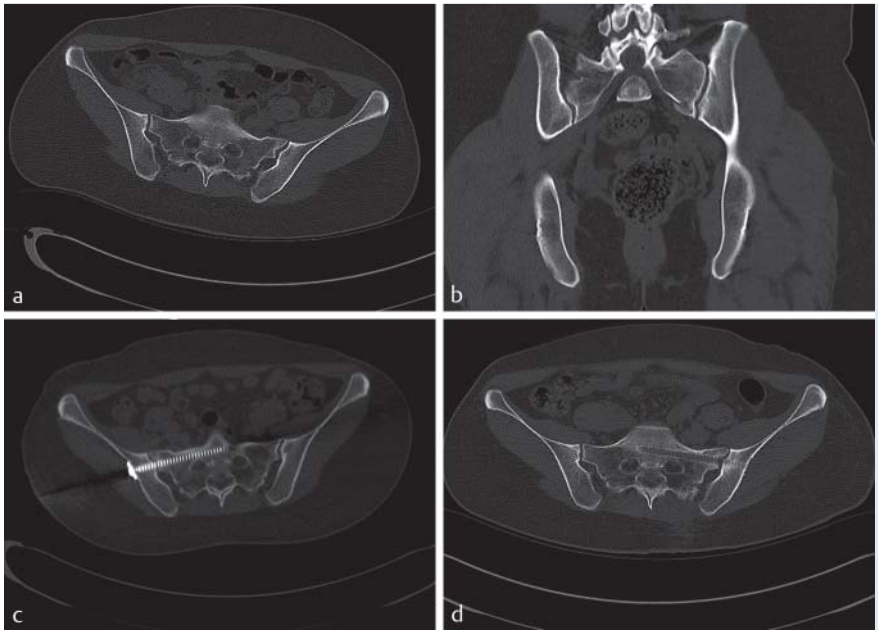

Fig. 3 Regular bone remodeling in a 41-year-old female. **a, b** Sligthly dislocated fracture in Denis zone 1 of the left sacral wing. **c** Screw from left with bulging of the anterior cortical bone due to fracture. **d** Smoother cortical outline after removal of the screw 6 months later.

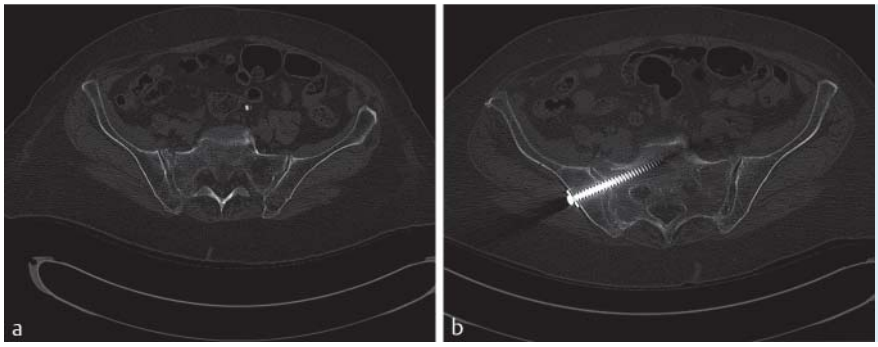

Fig. 4 Non-fusion after screw placement in a 90-year-old female without signs of screw loosening. Note contralateral insufficiency fracture. **a** Fracture in Denis zone I on the right in severe osteoporosis. **b** 3 months later increasing resorption around the fracture on the right. and new fracture in Denis zone I on the left.

ciency fracture in a chronic stage further resorptions and non-union occurred. Among the 2 patients with fractures as sequelae of radioosteonecrosis in 1 woman bony healing could be verified on CT after 7 months; the male patient developed non-fusion with an extended granulation reaction. In all 4 patients the screws were removed. In 32/99 patients with a plain film follow-up from 3 to 38 months after screw placement signs of a non-union were not seen.

Screw failure

Backing out of the screws was seen in 12/85 screws (all females) on follow-up images (plain film and/or CT) between 6 to 69 days after screw placement. In 6 cases the backing out was graded as insignificant (< 3 turnings) and did not progress over time. In 1 woman there was a simultaneous non-fusion and the screw was removed. Another screw was removed since the bone had healed. In 6 cases the backing out was considered significant and required removal. 3/6 fractures were fused at the time of removal. In 1 patient another screw was placed after removal under CT-guidance as the fracture was not yet fused. In the other 2 cases no new screws were placed despite non-fusion. A screw fracture was not detected.

Contralateral stress fractures

Contralateral vertical fractures of the sacral wings were detected on CT in 8/96 cases (7 female, 1 male) after unilateral screw placements (**Fig. 5**). The time interval to the intervention was between 10 and 127 days (average: 48 days). In 6 cases the initial fracture was considered traumatic, in 2 cases due to insufficiency. 7/8 of the fractures were also subject to percutaneous screw placement.

Further complications

Iatrogenic inflammation did not occur and a misplacement of screws was not found. In 1 patient stronger gluteal bleeding occurred which could be stopped by compression but the intervention had to be postponed to the following day.

Discussion

The placement of iliosacral screws under CT-guidance in vertical sacral wing fractures under local anaesthesia with mild i. v. analgesia may reliably avoid misplacements of the screws in non- or only minimal dislocated fractures and is not prone to complications. This is also true for the simultaneous bilateral screw placement, which has a documented higher rate of malpositioning under C-arm navigation [13].

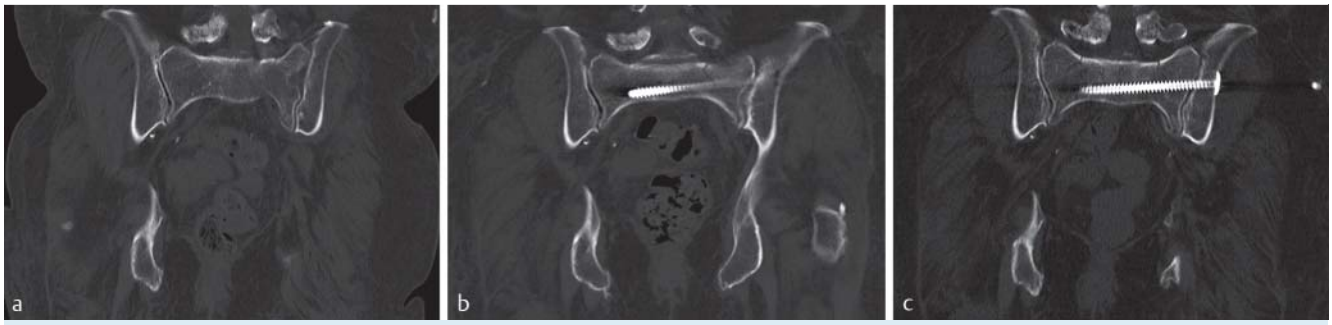

Fig. 5 Contralateral fracture after unilateral screwing in a 72-year-old woman. **a** Fracture in Denis zone II on the left 16 days after a fall. **b** Screw placement 3 days later. **c** New fracture in Denis-Zone II on the right with sharp margins and no adjacent osteopenia 16 days after screw placement while the initial fracture still being visible. No backing out of the screw.

Depending on the surgeon's training, malplacements and insufficient screw lengths are reported in 3 to 8 %, half of which are associated with neurologic deficiencies [12 – 16, 25]. Clinically inapparent malpositions are generally only detected by CT [13, 16]. The malpositioning of screws may possibly be avoided with the latest navigation techniques matching preoperative CT scan data with intraoperative fluoroscopy (27).

Time required

23 minutes for unilateral and 35 minutes for bilateral screw placements correspond to the results of other studies [20, 21, 24]. The time needed is probably less for experienced staff as 40 % of the unilateral screw placements took less than 20 minutes. Considering another 10 minutes each for positioning and sterile draping as well as the final suture and dismissal of the patient, it is realistic to assume that the CT suite is occupied for 35 – 45 minutes when performing unilateral screwing. The time needed for the procedure in the operating theatre with C-arm navigation is at least 60 minutes [13]. When general anaesthesia is performed, a doubling of the time requirement has to be calculated [22].

Radiation dose

The dose for uni- or bilateral screw placements is in the order of a diagnostic CT of the pelvis. A direct comparison to the placement under C-arm navigation is not feasible due to the different exposure. However, it has to be considered that a postoperative CT after C-arm placement is mandatory to rule out malplacement. No conclusions concerning pain reduction and faster mobilization can be drawn from this evaluation as there was no prospective standardized evaluation of the patients available.

Acute complications

The evaluation proves that the placement of iliosacral screws under CT-guidance is a safe procedure even with varying staff. The detailed anatomy provided by CT helps to reliably avoid cortical perforations with vascular or neurologic complications as well as insufficient screw lengths. One gluteal bleeding could be stopped by compression and did not require surgery, but the intervention had to be postponed.

Delayed complications

Although bearing in mind that the evaluation is limited due to the fact that only in 68/135 patients (50 %) follow-up imaging was available, the limitation due to the lost cases is mitigated because all images from the 3 county hospitals and the 2 out-patient institutions are collected in the same PACS and could be scrutinized. While other studies report bone fusion in all treated cases [18, 21 – 23] in this evaluation 4 cases of non-fusion occurred. Presuming that in all cases without follow-up no further non-fusions occurred, this would correspond to a rate of non-fusion of at least 2 %. As the non-fusion in all 4 cases became evident without significant backing out of the screw, and other studies without non-fusion included almost only traumatic fractures in significantly younger patients (Ziran et al.: 42 years; Taller et al.: 41 years; this study: 77 years, [21 – 24]) old age with osteoporosis may be considered the major risk. This presumption is also backed by the fact that in our evaluation 93 % of our treated fractures were located in Denis zone I as according to a study by Waites et al. fractures in the sacral wings occur under vertical shearing forces in 87 % lateral to the sacral foramina when osteoporosis is present [9].

The backing out of screws was considered clinically insignificant in half of the cases. Only in 1 patient the backing out was associated with non-fusion and may have played a role. A symptomatic backing out in 6 patients warranted screw removal. As the follow-up images including the pelvis for other reasons did not show further cases of significant backing out, it seems unlikely that there were more cases with symptomatic backing out. Nevertheless the rate might be higher as e. g. Osterhoff et al. had to perform reoperation in 2/38 patients (5 %) [12]. There may be a correlation between the rate of osteoporosis in our study and the risk for backing out as well.

Spontaneous contralateral fractures after unilateral sacral wing fractures due to pain-related unequal loading occur [7, 8] and subtle fissures may have gone undetected on the diagnostic CT scans due to the lower sensitivity for fractures of CT compared to MRI [6]. However, all patients with newly detected contralateral fractures after screwing returned to the hospital with new complaints after an interval of little or no pain and showed sharply delineated fractures lines without adjacent reactive demineralization as should be expected in fracture several weeks old (**Fig. 5**) Therefore, 8 fractures in the contralateral sacral wing during the first weeks after screw placement could not be recognized on the preoperative scans even in retrospect put forth the question of a causality. Increased shearing forces may occur in the contralateral sacral wing due to the altered biome-

chanics after unilateral screwing of the iliosacral joint and may lead to stress fractures (28). This phenomenon has so far not been described in the orthopaedic literature. Whether this is due to the lower age of patients in previous studies having internal screw fixation or due to the rare use of CT in follow-ups has to be clarified. 6 out of 8 patients with contralateral stress fractures in our evaluation were beyond 80 years of age and 2 women also showed non-fusion of the initial fractures. The risk for contralateral fractures could be even higher than about 8 % as there was a CT follow-up only in 36/96 unilateral fractures with screw placements. However, all affected women became symptomatic and returned to the aftercare of the hospital. Further studies to evaluate the risk profile for contralateral fractures seem to be necessary. In cases with an increased risk a prophylactic screw placement of the contralateral side may be considered. An early removal of a screw is no prophylactic option as all those fractures occurred within the first weeks before remodelling of the initial fracture.

Conclusion

The placement of iliosacral screws in vertical fractures of the sacrum can routinely be performed under local anaesthesia with i. v. analgesia in a CT suite. The high precision of CT-guidance renders re-interventions unnecessary due to malpositioning even in simultaneous bilateral screw placements.
The onset of contralateral pain during the first weeks after intervention should warrant a CT scan to check for a contralateral stress fracture after unilateral screw placements.

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