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Sacral fractures in young and elderly patients. One fracture, two different clinical identities with many treatment options

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ABSTRACT

Sacral fractures have always been a challenging treatment pathology, as they mostly concerned high-energy traumata with several coexisting fractures and injuries. In recent years, however, as the population ages more but remains active, diagnostic options have become more popular and widely used, leading to the appearance of the terms sacral insufficiency fracture or low energy sacral fracture in clinical practice. Although the terms refer to the same bone, the injury mechanism, complications, and treatment options do not overlap with high energy sacral fractures. This article reviews the two different fracture identities and suggests treatment options.

KEY WORDS: Sacrum fracture, insufficient sacrum fracture, spinopelvic dissociation, fragility fracture

Introduction:
Sacral fractures (SF) are a peculiar type of injury with certain problematics. The main issues are the coexistence of other injuries with high morbidity rate, the missed or delayed diagnosis, the lack of an unique classification system with corresponding treatment algorithms and the overlapping fields of specializations of medical professionals (spine-surgeons, neurosurgeons, orthopaedic-surgeons and trauma-surgeons) [1, 2]. Epidemiologically, SF appear in two patient groups: the first group suffers high-energy (HE) trauma, like motor-vehicle-collisions and falls from height and comprises mostly younger patients; the second group comprises either older patients with primary osteopenia which predispose to pathological fractures, or patients with local bone alteration due to radiotherapy or tumor with or without minor trauma (MT) [3, 4].

Diagnosis:
In the HE group isolated SF appears about 5% [5]. Pelvic or abdominal bleeding, significant soft tissue injury (open fractures or Morel-Lavallee lesions) and neurologic deficit (present up to 50%) are common associated injuries that define mortality rate at these patients (17% mortality rate within a year) [5, 6, 7]. Plain radio-

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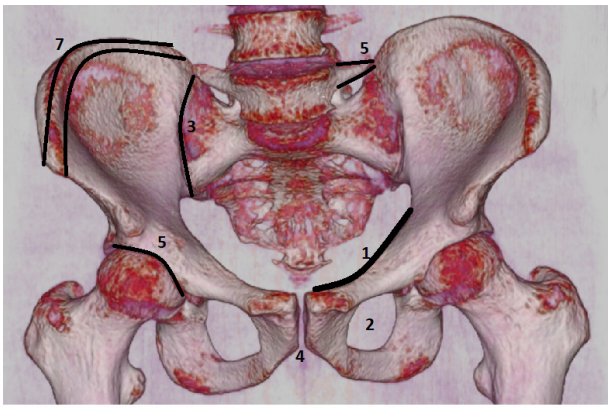
graphs of the pelvis with anteroposterior, inlet/outlet views provide the first information about the fracture severity (Fig. 1) but can be insufficient with up to 50% misdiagnosis. CT-scan remains essential for patients, who are admitted to the ER with a known HE-trauma [8]. Nevertheless MRI can diagnose bone bruises and occult fractures where the cortical bone remains intact, which is even more clinical relevant at the MT group [4]. The sensitivity of CT-scan reaches a 77% compared with MRI with a sensitivity of 96,3% [9].

By the MT group a spectacular trauma is missing and the patients mostly complain about low back pain, radiculopathy and hip/inguinal pain that misguides the clinical diagnosis and leads to misdiagnosis or delayed recognition [10]. The most common diagnostic method to raise suspicion of a sacral insufficiency fracture (SIF) is the lumbar MRI, which leads to further investigation through CT-scan [10]. SIFs are associated with increased mortality rate, which can reach 25.5% at 3 years post event, similar to hip fracture at 5 years follow up [12, 13]. Neurologic deficits can appear approximately at 2% of the MT group, as cauda equina syndrome or L5-S1 nerve root paresis [14]. Continuing bleeding with hemodynamic instability is rare, but could occur in elderly patients who receive an antithrombotic therapy [15]. An isolated fragility fracture of the anterior pelvis with a pubic and/or an ischial rami fracture at the radiograph is rare (3%) and a co-fracture of the sacrum should be excluded with a CT-scan [16].



1. iliopectineal line 2. foramen obturatum 3. iliosacral joint
4. symphysis pubica 5. acetabulum 6. L5 transverse process
7. iliacal crest

Fig. 1: *Pelvic X-ray interpretation:*

Classification:

There are several classifications used, each one of these deals with the fracture from a different point of view:

a. Pelvic ring fractures:

• AO-modified Tile classification does not refer only to SF but to pelvic ring fractures. It divides them into three types: stable, rotationally stable, vertically and posteriorly stable, and rotationally, vertically and posteriorly unstable [17] (Fig. 2).

• Young-Burgess classification also refers to pelvic ring fractures and describes the different displacing vectors: lateral compression, anterior-posterior compression, and vertical shear [18] (Fig. 3).

b. Longitudinal or vertical sacral fractures (90%) [19]:

• Dennis isolated sacrum fracture classification, based on the sacral foramina, defines 3 longitudinal fractures zones at the oblique view. Zone I lies lateral of the sacral foramina, at sacra ala. Zone II goes through the neural foramina and zone III medial of the foramina. The risk for neurological deficit increases from lateral to median from 6%, to 28%, up to 60%. At zone III fractures there is a high rate of 76% for urinary bladder and sexual dysfunction [20] (Fig. 4).

• Isler classification deals with Dennis-Zone II fractures, meaning through the neuroforamina, but raises the issue of the L5/S1 facet joint: stable Type I is lateral of the L5/S1 facet joint, unstable Type II is through the joint and highly unstable Type III is medial to the facet [21] (Fig. 5).

c. Transverse SF (3-5%) [22] :

• Modified Roy-Camille classification evaluates transverse fractures and displacement of the upper sacrum in Dennis-Zone III in the sagittal plane. Depending on the kyphosis angle there are 3 types, where the 4th Type is a S1 burst fracture, without any angulation [23] (Fig. 6).

d. Mixed longitudinal and transverse fractures classification (3-6%) [24]:

• They are described by an alphabet letter according to the fracture-morphology, which includes the H, U, λ and the T-form, depending on the shape of the fracture line. They represent fractures of the sacrum complicated with spinopelvic dissociation (Fig. 7) [25].

e. Fragility fracture of the pelvis (FFP) [26]:

• This classification differentiates the MT from the

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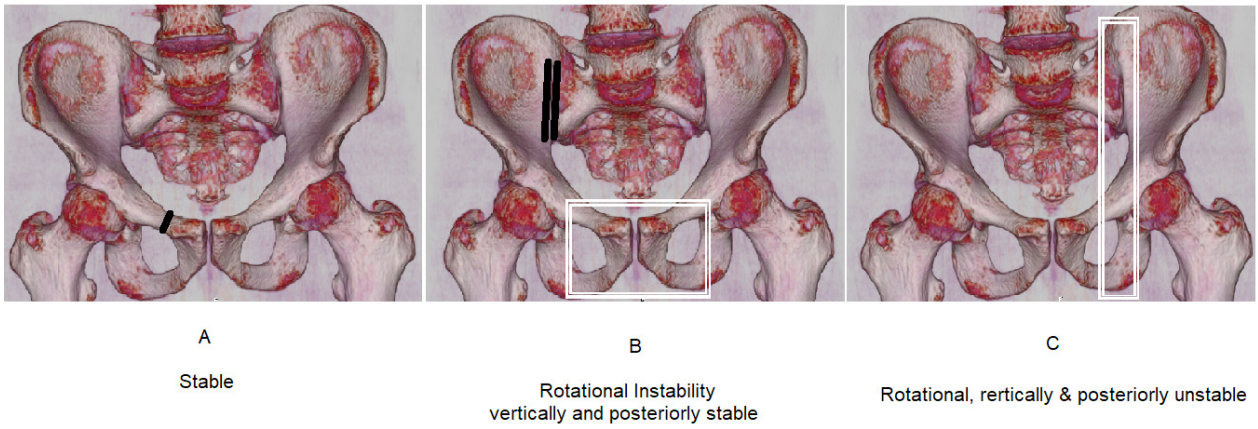


Fig. 2: *The AO/Tile Classification: black lines stand for region with a stable fracture and white frames for region with an unstable fracture*

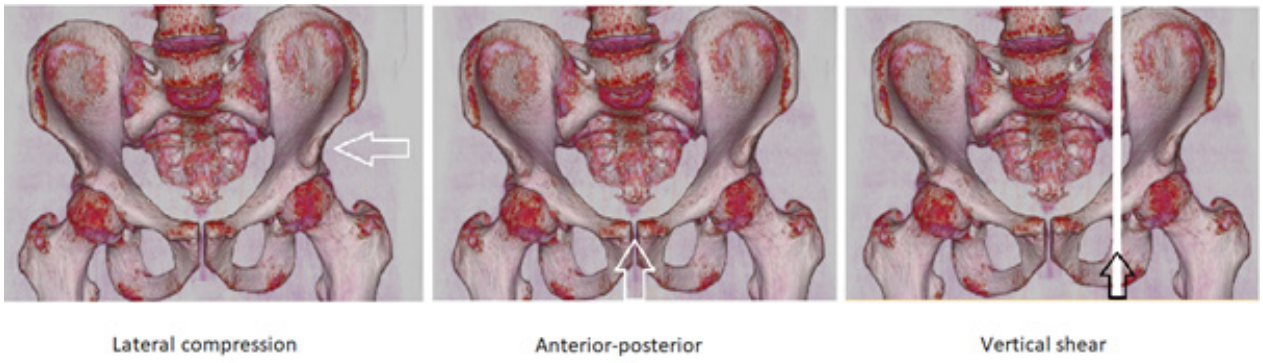
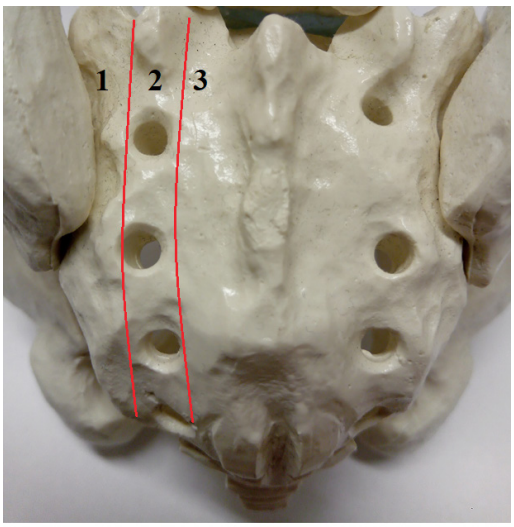


Fig. 3: *The Young-Burgess classification with arrows showing the applying force vector.*

HE sacral and pelvic ring fractures. There are 4 Types described: Type I with isolated fractures of the anterior pelvic ring, Type II with a non-dislocated posterior pelvic ring fracture, Type III with dislocation-fracture of the posterior ring and Type IV with dislocated bilateral fracture of the posterior pelvis ring.

General treatment:

The management of SF depends on the patient group. In the HE group the mortality rate can reach up to 40% for patients with a hemodynamic unstable pelvis fracture [27]. Initially ATLS and institution specific protocols provide cardiopulmonary and hemodynamic stability. If an active bleeding is suspected an external pelvis stabilization should be placed either with a sheet, a binder, a pelvic C-clamp or an external fixator in order to decrease the pelvic volume and minimize the blood loss. In addition, an urgent angiography and



Foramina Sacralia separate sacrum in 3 fracture Types:
Type I, medial of the foramina
Type II, through the foramina
Type III, lateral of the foramina

Fig. 4: *The Dennis classification has 3 fracture zones*

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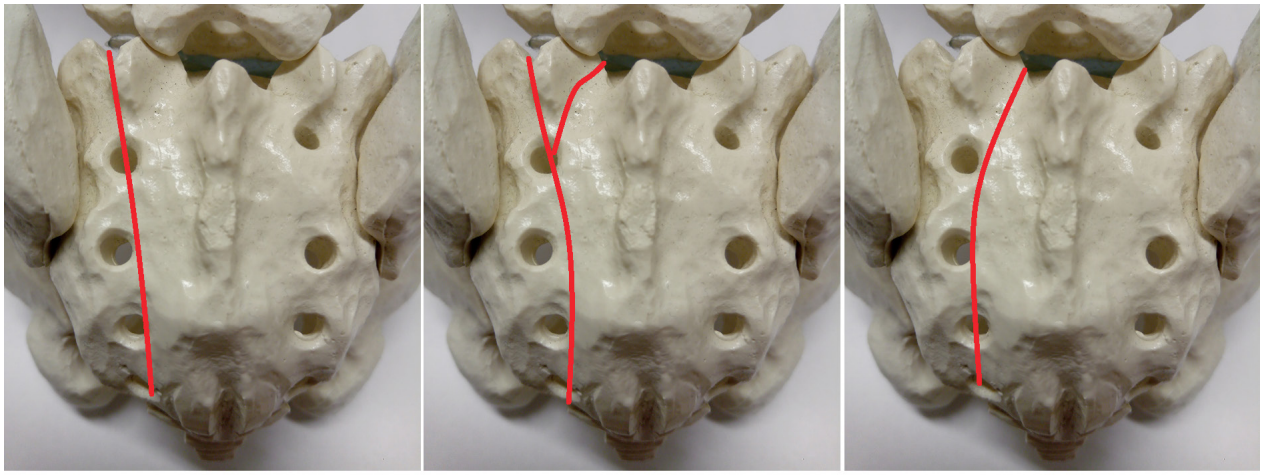

Fig. 5: *The Isler classification considering the L5/S1 facet joint*

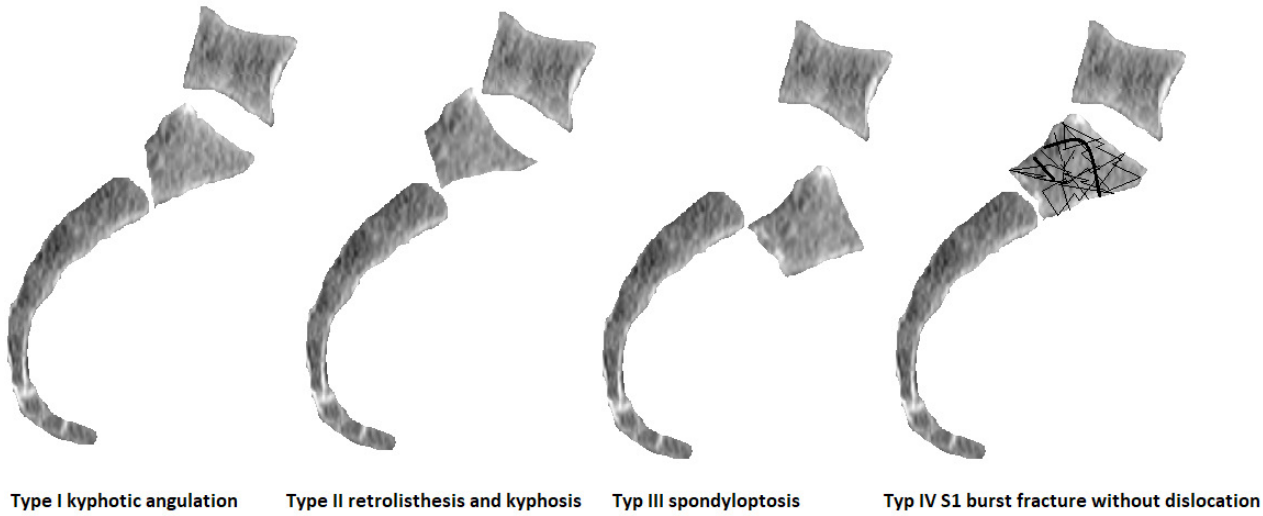

Fig. 6: The modified Roy-Camille classification:

embolization should be performed [28]. Additional specialists should also be counselled if hematomas or active bleeding are present at the urogenital tract or the rectum [29]. If the patient is conscious, a short neurological examination is essential.

In case of stable pelvis fracture, lack of neurological deficit and limited soft tissue injury conservative treatment is indicated with better functional, emotional and mental results [30]. FFP Type IIa fractures could be treated conservatively with painkillers and early mobilization and only in case of pain resistance, operation should be reconsidered. Treatment of the primary disease, in most occasions osteoporosis, with Vitamin D, bisphosphonates and teriparatide, not only prevents further fractures but improves pain relief and enhances the fracture healing [31, 32]. Unstable fractures with or without neurological deficit require an operative treatment [33]. Such are displaced AO-Tile Type B and C, displaced vertical, transverse Roy-Camille Type II-IV, U-shaped fractures as well as dislocated lateral compression injuries (<10mm) [34-38]. FFPs Type III-IV are also considered unstable and a surgical fixation is mandatory [32]. Neurological deficits can be treated either indirectly by reducing the fracture or directly by

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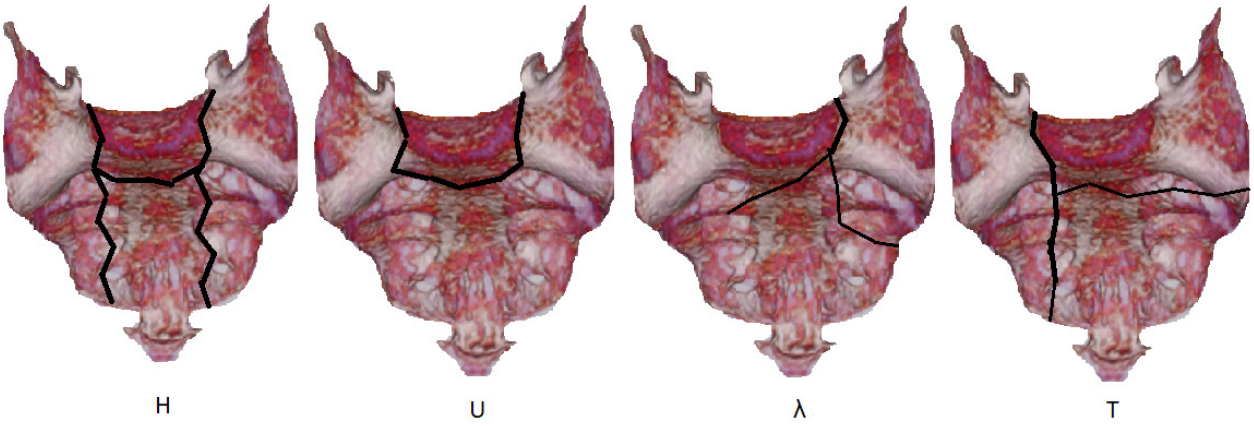

Fig. 7: *The alphabetic fracture classification of the sacrum:*

decompression and laminectomy within 24-72 hours, with controversial outcomes [39, 40].

Surgical treatment:

If conservative treatment fails or in case of fracture instability, surgical intervention is advised, either minimally invasive/percutaneously (MIS) or with open reduction and internal fixation (ORIF).

MIS procedures are:

a. Sacroplasty with or without balloon kyphoplasty
b. Transiliac sacral screws (TIS)
c. Indirect sacral fixation with iliac screws or
d. Minimally invasive plating
e. Sacral bars
f. Percutan spinopelvic fixation

For fragility fractures of the pelvis such methods are preferred in order to reduce the risks of cardiovascular and lung complications, as well as infection and wound healing problems. FFP Type I and IIa fractures are primarily treated conservatively, however the latter could end up needing an operative treatment because of posterior ring instability. If mobilization under painkillers fails, CT imaging should be performed in order to exclude a fracture displacement [41].

For Type IIa fractures, sacroplasty with or without balloon is a minimally invasive method of preference for stabilization of the fracture and significant pain relief. The patients can be mobilized early and regain their quality of life. The procedure can be performed under fluoroscopy or CT-guided in a prone position [42, 43]. Complications like cement leakage have been described, however major complication rate was reported at 0,3% [44]. There are two recommended techniques: the short and the long axis technique. With the short axis technique the needle is placed over the S1 and/or S2 ala, lateral of the neuroforamina and median of the iliosacral joint. With the long axis technique the needle has a caudocranial direction, entering the sacrum between the inferior margin of the iliosacral joint and the S3 neuroforamen (Fig. 8). Advantages of the long axis technique are better cement distribution and decreased chance of anterior cortex violation [45]. Preoperatively the landmarks of the anatomic relationships have to be studied in order to avoid false positioning of the needles (Fig. 9).

TIS is an established method for treating the posterior pelvic ring fracture, not only for FFP Type II fractures but also for HE trauma as vertically unstable pelvic fractures and U-shaped SF with simple fracture pattern [41, 46]. The screws are placed under fluoroscopic imaging with the patient in prone or supine position. One or two distally-threaded screws are inserted in S1 or one in S1 and a second screw in S2 body [46]. The use of a washer at the screw head reduces the iliac cortex perforation [47]. Using cement augmentation through the cannulated screws can reduce the risk of screw loosening (Fig. 10), even combined with balloon kyphoplasty [48, 49, 50]. Correct positioning of the screws demands proper study of the individual anatomy of each patient at the preoperative CT-scan [51]. Intraoperative use of fluoroscopy with lateral, inlet and outlet pelvic views and identification of the sacral safe zones are mandatory elements of the procedure (Fig. 11) [52].

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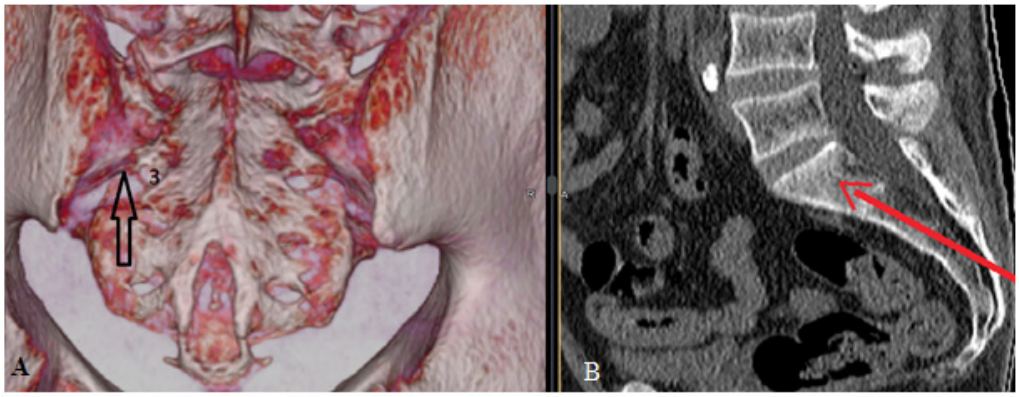
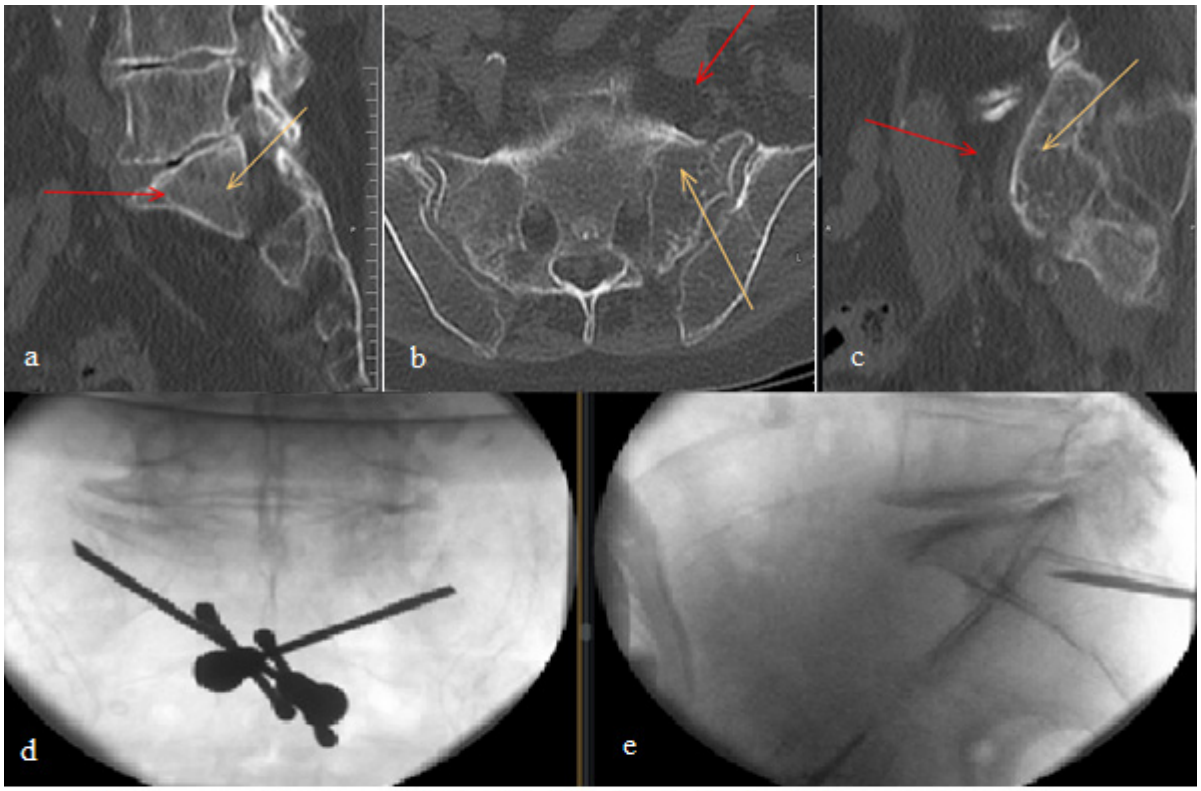


(A) Entry point is between S3 neuroforamen and the iliosacral joint (ap view),
(B) Aiming posteriorly of S1 centre (lateral view).

Fig. 8: *Landmarks for needle placement at the long axis technique:*



a-c: CT-scan compating correct (yellow) to false (red) placing of the cement-needle: The needle should not be targeting for the promontorium at the lateal view, otherwise it will end up too far anteriorly, in the small pelvis.

d-e: Intraoperative needle placing using the short axis, aiming at the lateral view just posteriorly of the S1 center.

Fig. 9: *The short axis technique:*

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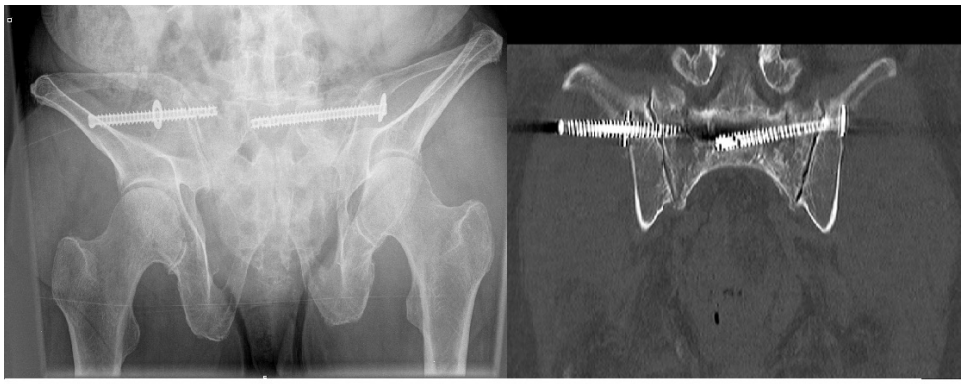
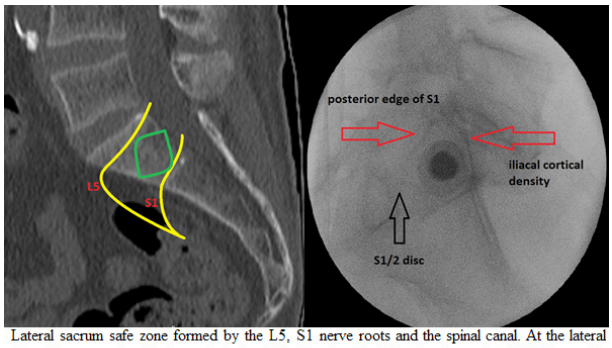


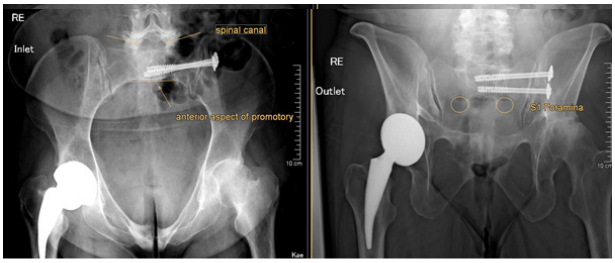
X-ray and CT-scan of a 82years old female patient, showing screw loosening on the right side, 2 months after TIS-treatment

Fig. 10: *Complication after treatment with TIS screws:*



Lateral sacrum safe zone formed by the L5, S1 nerve roots and the spinal canal. At the lateral view, the screw should stay posteriorly of the iliacal cortical density, above the S1/2 disc and in front of the posterior edge of S1 vertebra.

Fig. 11a: *TIS screw placement: lateral view*



1) Inlet view with spinal canal (A) and anterior aspect of promotory (B). 2) Outlet view with S1 foramina

Fig. 11b: *TIS screw placement: inlet and outlet view:*

Other MIS techniques are bridging constructs, which connect the iliac bones bilaterally, posteriorly of the sacrum but do not provide compression at the fracture zone. These procedures can be used at unilateral and bilateral fractures of the sacrum regardless of bone density because of the good anchorage provided by the iliac screws (Fig. 12) [53, 54]. The iliac screw can be inserted posteriorly through the skin, by targeting for the teardrop landmark at the obturator outlet view, over the foramen ischiadicus major at the lateral view and over the acetabulum at the anteroposterior view (Fig. 13). The use of a 5 to 6mm threaded transsacral bar has also been described. It is inserted percutaneously through the S1 body and provides compression at the fracture site by tightening the nuts bilaterally [54]. Both the bridging as well as the transsacral bar technique could be combined with TIS screws for additional rotational stability [47, 56].

When spinopelvic dissociation, vertical instability or complex fracture patterns are addressed, the use of spinopelvic fixation reaches better biomechanical stability. It is recommended for FFP Type III and IV, but also for U and H-shaped fractures (Fig 14) [46, 57, 58]. The construct bridges with screws the lower lumbar spine with the posterior ilium over a vertical rod. The screws can be inserted minimally invasive, uni-or-bilaterally. A S2-Alar-Iliac screw can alternatively be used instead of an alar iliac screw with similar biomechanical features [59]. Spinopelvic fixation combined with a TIS screw for accessorial rotational stability is named triangular osteosynthesis.

Residual instability at the anterior pelvic ring can cause pseudarthrosis and implant failure posteriorly. Depending on the fracture's characteristics, MIS retrograde transpubic screw insertion or ORIF by plate or screws is recommended (Fig. 15) [60, 61].

Conclusions:

SF used to be a concern at trauma center hospitals,

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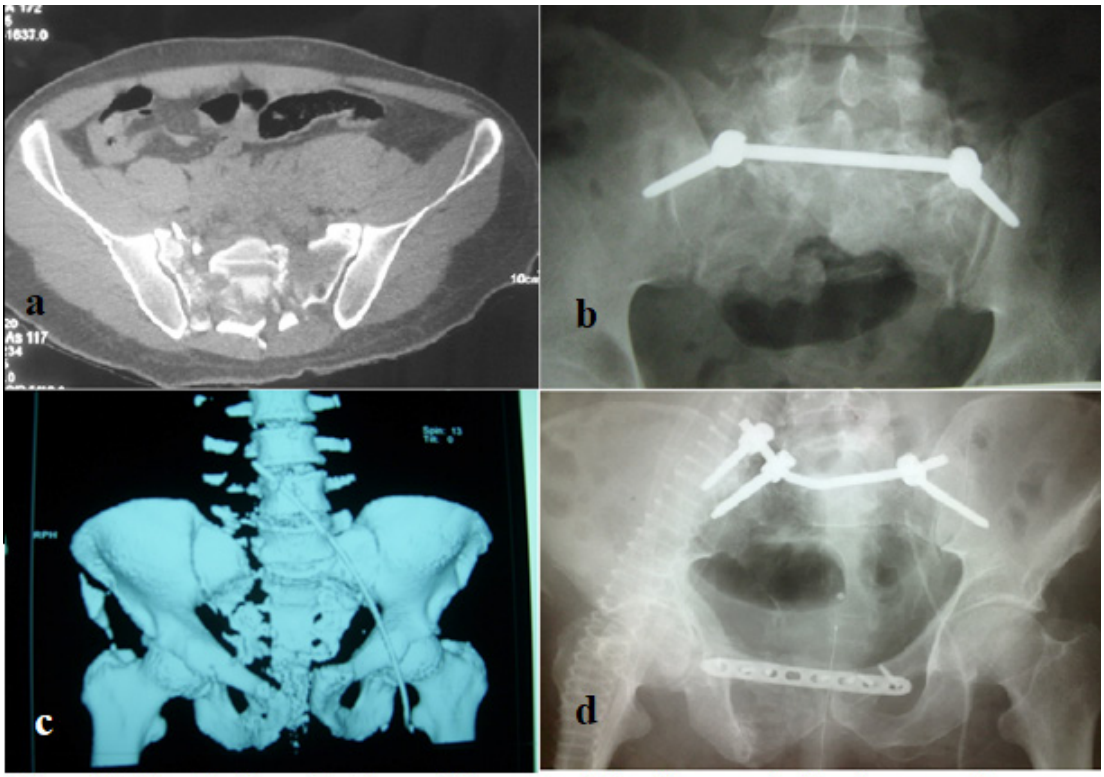
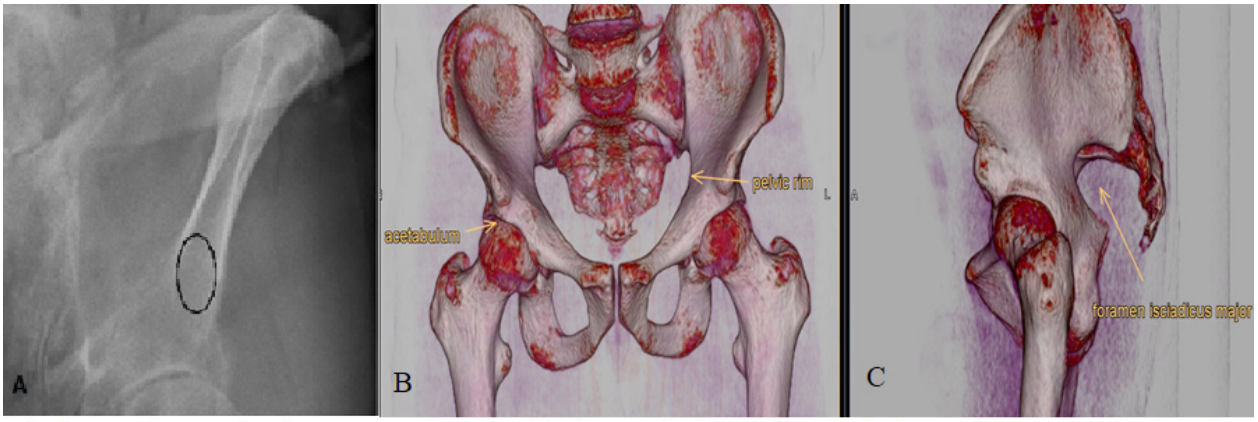


Bilateral (a+b) and unilateral (c+d) sacral fractures stabilized by posterior iliacal screw-rod system

Fig. 12: *Bridging iliac screw-rod constructs for unstable sacral fractures*



a) The teardrop at the obturator outlet view b) the acetabuli and the pelvic rim at the anteroposterior view c) the foramen ischiadicus major at the lateral view

Fig. 13: *Landmarks for placing iliac screws:*

where high-energy injuries were admitted. Nowadays, the clinical entity of the fragility fractures of the pelvis raises the necessity that also medical specializations such orthopedic- and neurosurgeons be acquainted with the treatment of SF as well.

AOSpine/Trauma concluded that a new global classification should be generated [62]. Lehmann et al. proposed a scoring system for evaluating injury severity and developed an algorithm for clinical decision making and surgical management [63].

Summarizing, cement augmentation or TIS should be considered for FFP Type II fractures. For Type

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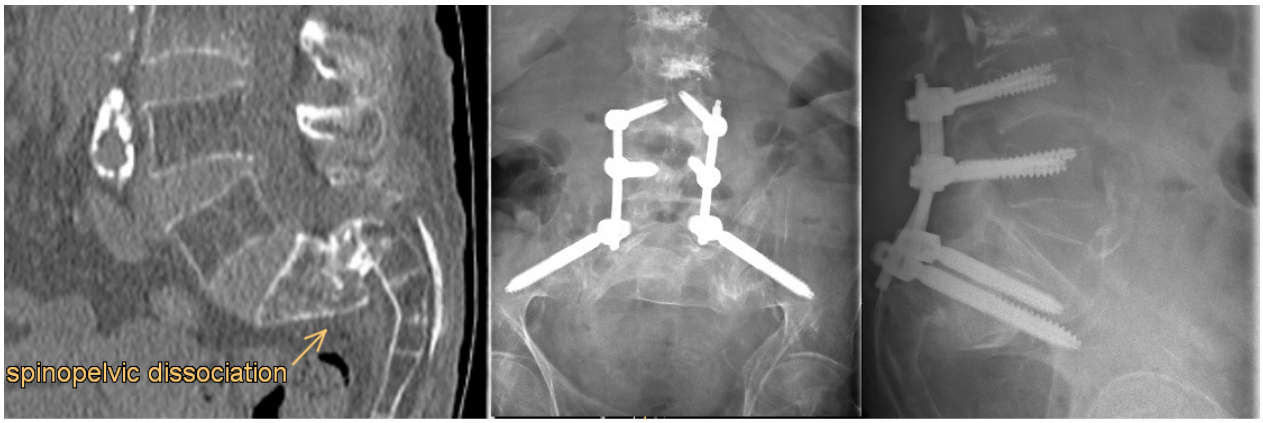
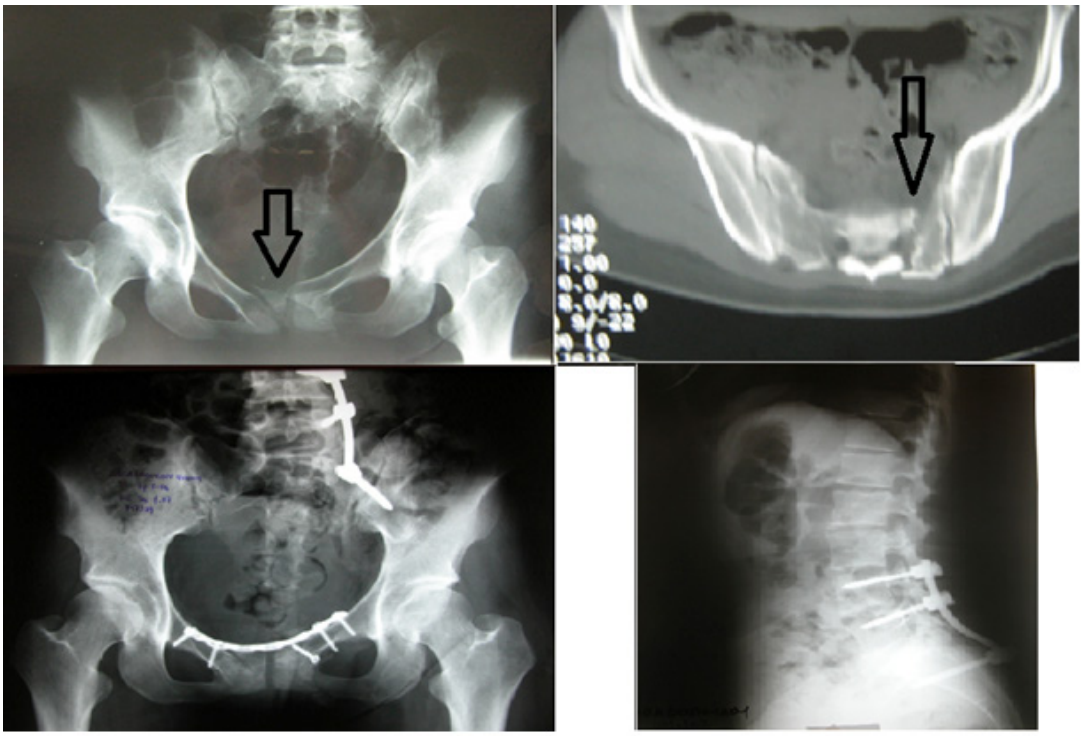


Treatment of spinopelvic dissociation with percutaneous fixation: L4, L5 and S2-Ala-Iliac screws.

Fig. 14: *Treatment of spinopelvic dissociation*



Combination of spinopelvic fixation with plating at the pubic symphysis

Fig. 15: *38years old female patient with motor vehicle collision: fracture of the symphysis pubis and unilateral vertical sacral fracture on the left side*

III lesions open surgical reduction will be needed in most cases. In Type IV fractures spinopelvic fixation is required [61]. Simple vertical fractures could be treated with TIS, where complex ones are more suitable for triangular fixation. Unstable transverse fractures and spinopelvic dissociation as may occur at U-and H-fractures demand more rigid osteosynthesis, which involves iliolumbar fixation [64, 65, 66].

Conflicts of Interest

The authors declare that they have no conflicts of Interest.

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