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Review Article

MINIMAL INVASIVE SURGICAL TREATMENT FRAGILITY FRACTURES OF THE PELVIS (FFP): A REVIEW

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ABSTRACT

The incidence of fragility fractures of the pelvis is increasing quickly. The characteristics of these fractures are different from pelvic ring disruptions in adults. Fragility fractures of the pelvis are the consequence of a low-energy trauma which occurs in a patient with an important decrease of bone mineral density. Due to a consistent pattern of alteration of bone mass distribution in the sacrum, other fracture morphologies occur than in younger adults. The leading symptom is immobilizing pain in the lower back, in the buttocks, in the inguinal region and/or at the pubic symphysis. Conventional radiographs and CT will show the presence and localization of the fractures in the anterior and posterior pelvic ring. A new, comprehensive classification system distinguishes four categories of instability. This first criterion is most important, because it also gives hints for the preferred type of treatment. The second criterion, leading to the subtypes in the four categories, is the localization of the instability in the posterior pelvic ring. This criterion points the way towards the type of the surgical procedure to be used. When a surgical treatment is chosen, the procedure should be as minimal invasive as possible. Different techniques for percutaneous or less invasive fixation of the posterior pelvic ring have been developed. Their advantages and limitations are presented: sacroplasty, iliosacral screw osteosynthesis, cement augmentation, transiliac internal fixation, trans-sacral osteosynthesis, lumbopelvic fixation. Fractures of the anterior pelvic ring also need special attention. Retrograde transpubic screw fixation is recommended for pubic rami fractures. Fractures of the pubic body and instabilities of the pubic symphysis need bridging plate osteosynthesis. We do not recommend anterior pelvic external fixation in elderly because of the risk of pin track infection and pin loosening.

Key words: fragility pelvic fracture, classification, treatment, minimal invasive surgery, anterior pelvic ring, posterior pelvic ring.

INTRODUCTION

Thanks to prevention programs, higher quality of life and better medical care, we experience an increasing life expectancy in developed and emerging countries. Simultaneously, there parallel is a steady low birth rate, which leads to an increasing incidence of old and very old persons in our populations. Many elderly remain healthy and independent until high age; others suffer several age-related diseases, which limit their mobility. Osteoporosis is a very common age-related disease, which is characterized by a diminution of bone mineral density due to bone resorption[1]. The consequence is a bony structure, which is more vulnerable in case of traumatic events. Typical osteoporotic fractures are intra and extra capsular hip fractures, vertebral compression fractures, proximal humerus and distal radius fractures. The fragility fracture of the pelvis, abbreviated as FFP, is another typical fracture, which is related to low and very low bone strength[2]. Whereas the incidence of geriatric hip fractures is on the decline since the nineties, the opposite is true for FFP[3]. Data from the United States, Germany, the Netherlands and Finland unanimously show an increase of the incidence of FFP, especially in the population above 80 years of age [4-7]. Although there is large consensus on guidelines of treatment of hip fractures, there is little evidence on optimal treatment of FFP and its influence on outcome.

Specific characteristics:

Pelvic ring disruptions in adolescents and adults are the consequence of high energy trauma. They typically occur in high-speed traffic accidents, crush traumas or falls from great height. Due to massive blood loss, they can be life-threatening [8]. In many patients, there are additional lesions of intra pelvic structures such as the bladder, urethra, and nerves. The primary treatment of pelvic ring disruptions therefore belongs to the resuscitation phase and follows damage control principles. Blood loss and instability are controlled by external compression of the pelvic ring. This is achieved by several procedures, which are applied in different phases of the resuscitation. The pelvic sheet and binder is used in the pre hospital phase, during transport to the hospital and in the emergency room, the pelvic C-clamp is used in the emergency room or operation theatre, external fixation is carried out in the operation theatre only. Other damage control procedures are pelvic packing and arteriography with selective embolization. All these measures are meant to control the hemodynamic instability of the patient, rather than the osteoligamentar instability of the broken pelvic ring. Once the patient survived the resuscitation phase, definitive surgical treatment can be planned. The goals of treatment are different than in the resuscitation phase: reconstruction of a stable and symmetrical pelvic ring, which enables quick mobilization and early rehabilitation[9]. Fragility fractures of the pelvis are the consequence of low-energy trauma such as falls from a standing position. Their major symptom is intense pain in the pubic or inguinal region and/or at the low back or posterior pelvic ring, which restricts mobility and activities of daily life[10]. There seldom is hemodynamic instability. Due to the increasing rate of elderly persons taking antithrombotic drugs for different reasons (coronary bypass surgery, atrial fibrillation, cerebrovascular accident), there must be a high rate of suspicion of continuing bleeding after FFP. We therefore recommend a cardiopulmonary monitoring for at least 24 hours after admission. If an active bleeding is suspected, pelvic CT-scan with contrast is recommended. In case an active arterial bleeding is identified, arteriography and selective embolization seems the best therapeutic option for these patients in danger of life. In all other cases, no damage control procedures are necessary. Patients are admitted in a normal ward and are observed for a short time before decision on definitive treatment is taken[11]. Another characteristic of FFP is the low bone mineral density in the sacrum and innominate bones. Due to the decrease of bone strength, the bone becomes fragile. A "fragility fracture" is defined by the WHO as a fracture that is caused by an injury that would be insufficient to fracture normal bone and is the result of reduced compressive and/or torsional strength of bone[12]. The decrease of bone mass in the sacrum follows a unique and consistent pattern. Wagner et al. calculated the bone mineral density in the sacrum of 92 Europeans above the age of 65 with non traumatized pelvis. They found the most pronounced decrease of bone mineral density in areas lateral to the neuro foramina S1 and S2, sometimes with an additional area of very low bone mineral density in the sacral bodies at the transition of S1 to S2; or between S2 and S3. In the abovementioned areas, the measured Hounds field Units may go down to zero, which means that the bony structure is completely resolved. These areas are defined as "alar voids"[13]. This specific pattern of bone mass in the sacrum of the elderly explains the consistent pattern of fragility fractures of the sacrum. Linstrom et al. described unilateral or bilateral sacral ala fractures, which are incompletely or completely connected to each other by an additional horizontal fracture component between S1 and S2 or between S2 and S3[14]. The patho-anatomy of high-energy pelvic ring lesions does not change over time. The fracture morphology is the result of the amount and direction of the traumatizing force. Whether treatment is conservative or operative, whether fracture fragments further dislocate or not, whether bone healing is uneventful or nonunion develops, the original fracture morphology remains unchanged. This is not the case in FFP. We regularly observe that fracture morphology changes from a fracture form with a lower degree of instability to a fracture form with a higher degree of instability. Additional fractures occur and a creeping implosion of the pelvic ring takes place[10].

Comprehensive classifications:

Due to the abovementioned specific characteristics, many FFP do not fit into the classification systems of Tile, AO/ASIF or Young-Burgess[15-17]. Consequently, we developed a new, comprehensive classification system for this group of fractures. The system provides a framework for the analysis of these lesions and is connected with recommendations for treatment[18]. The classification is based upon the analysis of 245 patients above the age of 65, who were admitted for a FFP in our institution in a 5-year period. All patients had conventional radiographs of the pelvic ring in three views (a.p., inlet and outlet) and a CT-scan. MRI was not part of the diagnostic tools, which were decisive for our classification system. The first criterion, which leads to four different categories, is "loss of stability" or "degree of instability". Instability is invariably connected with pain and with loss of mobility. It is the strongest criterion for the decision on which type of treatment should be chosen. The second criterion, which gives rise to different subtypes in each category, is the localization of the instability in the posterior pelvic ring. The fracture site is determining the type of surgical intervention, if surgery is needed.

- FFP Type I is an anterior pelvic fracture without a posterior pelvic fracture. Most typically, it concerns superior and inferior pubic rami fractures. Pubic bone fractures and pubic symphysis instabilities are also possible.
    - FFP type Ia is a unilateral,
    - FFP Type Ib is a bilateral fracture. In our retrospective analysis, FFP Type I lesions occurred in less than 20% of cases.

  This, upon reversion, means that more than 80% of patients with FFP had a posterior pelvic ring injury. It therefore is recommended that every patient with an FFP receives a pelvic CT-scan so that the severity of the injury is not underestimated[19-21].
- FFP Type II is a non-displaced fracture of the posterior pelvic ring. This category counts for more than 50% of FFP.
    - FFP Type IIa is a posterior pelvic ring injury only,
    - FFP Type IIb is a crush of the sacral ala in combination with a fracture of the anterior pelvic ring,
    - FFP Type IIc is a fracture of the sacral ala, sacroiliac joint or posterior ilium together with a fracture of the anterior pelvic ring.

  The overall stability of FFP Type II is lower than FFP Type I [10].
- FFP Type III is a displaced but unilateral fracture of the posterior pelvic ring. In our analysis, FFP Type III counted for less than 10% of FFP.
    - FFP Type IIIa is a displaced fracture of the ilium,
    - FFP Type IIIb is a fracture-dislocation of the sacroiliac joint and
    - FFP Type IIIC is a displaced fracture of the sacrum.

  The posterior pelvic ring fractures are combined with a fracture or instability of the anterior pelvic ring [18].
- FFP Type IV is a displaced and bilateral fracture of the posterior pelvic ring. FFP Type IV was present in nearly 20% of our retrospective analysis, which is equally frequent as FFP Type I.
    - FFP Type IVa is a bilateral posterior ilium fracture,
    - FFP Type IVb a bilateral sacral ala fracture with or without a horizontal fracture component, and
    - FFP Type IVc is a combination of different posterior pelvic ring instabilities. Bilateral fragility fractures of the sacrum (FFP Type IVb) are frequently, but not always combined with a fracture of the anterior pelvic ring.

We hypothesize that FFP Type IV do not occur after one fall. They probably are the result of an evolving process: Due to recurrent falls or triggered by repetitive smaller traumas, an increasing number of bone structures is damaged, leading to more complex fracture patterns and greater instability. Complete collapse of the pelvic ring represents the end of this evolving process [10, 18].

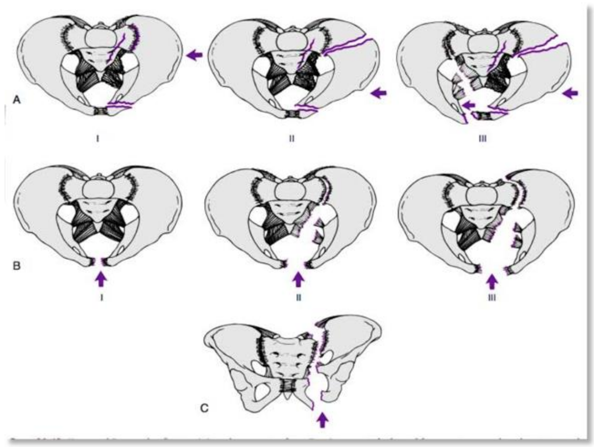


Figure: Different types of pelvis fracture.

Diagnostic Examination:

The patients present with immobilizing pain in the inguinal region and/or in the lower back or posterior pelvic ring. There typically is history of low-energy trauma such as a domestic fall. Some patients cannot remember any trauma. Some of the patients have a history of long-term cortisone intake, irradiation of the pelvic ring for a malignancy, long immobilization due to a concurrent disease or bone grafting out of the posterior pelvic ring for spinal fusion. Most patients are female and suffer from osteoporosis; many of them already had one or several index fractures such as a hip fracture, a compression fracture at the thoracolumbar spine, a proximal humerus or distal radius fracture[10]. Radiological examination starts with an a.p. pelvic overview. When a fracture of the anterior pelvic ring is confirmed or suspected, it is recommended to enhance the conventional radiograph with a pelvic inlet and outlet view. Cortical interruptions and fracture displacement often can better be seen in the oblique views. Nevertheless, conventional pelvic views are not adequate to analyze the posterior pelvic ring[22]. The superposition of soft tissues and bowel content on the one hand, and the rarefication of cancellous bone on the other hand, make recognition of fissures and fractures difficult, even impossible. Overlooking a fracture of the posterior pelvic ring leads to underestimation of the instability, and may lead to inaccurate recommendations for treatment. The pelvic CT-scan is an indispensable examination for thorough analysis of the presence, localization and configuration of fractures of the posterior and anterior pelvic ring. It makes correct classification possible and by this, a correct estimation of the loss of stability is feasible. MRI examination and technetium bone scan are very sensitive for the detection of bone bruise and increased activity. They can explain pain in the posterior pelvic ring, when a fracture cannot be detected in conventional radiographs or CT[23, 24]. In our concept, a pathology, which is detected in MRI only, doesn't give rise to a surgical treatment.

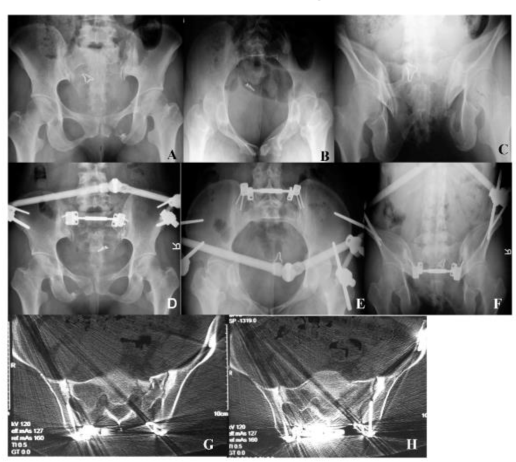
Treatment Objectives:

Once a FFP has been detected and classified, decision on treatment has to be taken. The goals of treatment are nor precisely the same as in adolescents and younger adults. The ultimate goal is giving back the best mobility and highest degree of independence possible to these elderly patients. This can only be reached by efficient pain relief and early out of bed mobilization. Anatomical fracture reduction and restoration of pelvic symmetry are less important. When surgery is needed, the procedure should be as less invasive for the patient as possible. Long surgeries with significant blood loss imply high stress for the cardio-vascular system and may involve dangerous conditions such as hypothermia and coagulopathy. They are associated with prolonged recovery and higher risk of wound healing problems and infection. Consequently, percutaneous procedures are preferred whenever they can achieve adequate stability for early mobilization[25, 26]. Conservative treatment consists of hospital admission for a short time, hemodynamic monitoring for at least 24 hours, pain relief with analgesics and mobilization as tolerated. Mobilization exercises start from day one with exercises in bed. They are followed by sitting at the edge of the bed, standing and short transfers. Monitoring of the pain intensity with the visual analogue score helps confirming an efficient pain control while exercising and mobilization. The velocity of the mobilization is defined by the patient him- or herself. Exercises never should be forced as they carry the risk of increasing the instability by the occurrence of new fractures[27]. Additionally to the short term symptomatic treatment, bone metabolism must be analyzed and deficiencies corrected. The general condition of the patient and especially the reason for falling should be investigated and ameliorated, if possible. The management of these patients optimally is coordinated in a multidisciplinary team of orthopedic trauma surgeons, geriatricians, pain therapists and physiotherapists [28].

1. **Conservative treatment** is recommended for FFP Type I and FFP Type II lesions. Whereas a good outcome can be expected in FFP Type I, conservative management may be more cumbersome in FFP Type II due to the posterior pelvic ring fracture. It should be clear within one week if conservative treatment is going to be successful. If pain intensity does not decrease or even increases, or when mobilization is apparently difficult, surgical options should also be considered as a valid treatment alternative. Moreover, conventional radiographs and pelvic CT-scan should be repeated to rule out further fracture displacement or exclude the existence of additional fractures. If the last is the case, surgical stabilization becomes inevitable[19]. FFP Type III and FFP Type IV lesions need operative treatment. It cannot be expected that displaced fractures heal spontaneously. Long term immobilization will lead to complications such as pneumonia, urinary infection, and muscle atrophy or pressure ulcers. Percutaneous procedures are to be preferred above open reduction and internal fixation, when an adequate stability can be obtained [26].
2. **Minimal Invasive stabilization procedure**

   Several less invasive techniques for internal fixation of the anterior and posterior pelvic ring in FFP have recently been developed. They use different stabilization principles. There is not enough evidence in literature showing the superiority of one procedure above the other. Only case series have been reported, which ultimately recommend the described procedure. Although more clinical and biomechanical work is needed to identify the optimal stabilization procedure for the different types of FFP, the developed procedures clearly demonstrate a shift from open reduction and internal fixation (using rigid plate and screw osteosynthesis) towards closed internal fixation (using bridging and splinting). Sacroplasty is a technique, which is derived from vertebro- and kyphoplasty. A small amount of cement is injected into the fracture area. No further implant is inserted. Through interdentation of the cement with the trabecular bone, stability is restored and pain relief is significant. Contradictory results have been reported in literature. The ratio of cement leakage varies between less than 1 and 27%. Some authors use the technique for "fractures", which are visible in MRI but not in CT, others perform sacroplasty in complete sacral ala fractures, which are clearly visible in CT[29, 30]. It remains unclear which type of FFP profits the most of sacroplasty. The injected cement may hinder fracture healing and be an obstacle for iliosacral screw osteosynthesis, when additional fracture stabilization is needed. Iliosacral screw osteosynthesis is a well accepted stabilization procedure for sacral fractures and sacroiliac dislocations in high energy pelvic trauma[31]. One or two large fragment cancellous screws are inserted from lateral towards medial through the lateral and medial cortex of the posterior ilium, through the iliosacral joint, through the sacral ala and end in the sacral body of S1 or S2. The corridor of S1 is larger than this in S2, the narrowest parts being the isthmus or "vestibule", which is the passage between the sacral ala and the sacral body. The vestibule of the S1 corridor is located just superior to the neuroforamen S1. The vestibule of the S2 corridor is situated between the S1 and the S2 neuroforamen[32]. Two iliosacral screws obtain a higher stability than one, longer screws a higher stability than shorter ones. When the thread of the screw is located on the medial side of the fracture, then tightening of the screw will create some inter fragmentary compression. When a cancellous screw with a continuous thread is used, the implant has the function of a positioning screw and does not create compression. The procedure can be performed with the patient in supine or prone position[33, 34]. It is of utmost importance to analyze the morphology of the upper sacrum before surgery. In dysmorphic sacra, the direction of the iliosacral screw will be oblique in two planes: from posterior to anterior and from inferior to superior. In non-dysmorphic sacra, the direction of the iliosacral screw can be transverse (in the coronal plane) and horizontal[35]. Hopf et al. present good results and high patient satisfaction in their series of 30 patients[36]. Accuracy of screw placement is very high in experienced hands: Gardner had no neurologic complications in 106 screw insertions[37]; Osterhoff needed 4 revisions (4.8%) in 83 screw placements[38]. Accuracy is the highest when using 2D-or 3D-image based navigation, but this procedure needs the availability of an expensive navigation system in the operation theatre [39, 40].

The most important drawback of iliosacral screw osteosynthesis in FFP is the low bone stock for screw anchorage. As already mentioned, there is a consistent decrease of bone mass in the sacral ala and sacral body in elderly people. Due to lower screw anchorage, there is a higher risk of screw loosening with recurrent instability in the posterior pelvic ring[41] To enhance screw anchorage in the trabecular bone of the upper sacrum, cement augmentation of the iliosacral screws has been described[42]. The technique is different from sacroplasty, where the cement is applied in the fracture gap. Here, the cement is applied in the sacral body through several screw perforations near to the screw tip[43]. Cement application is done under fluoroscopic control. Special care should be taken to avoid cement leakage into the sacral canal, the neuro foramina or through the anterior sacral cortex. Biomechanical studies have shown that stability of iliosacral screw fixation in FFP is significantly higher with cement augmentation than without[44, 45]. Clinical experience is still small, but results are promising[42, 43]. The posterior pelvic ring can also be stabilized with a bridging construct, which is applied between the left and right posterior ilium behind the sacrum. A specific angular stable plate has been developed for this procedure[46]. The left and right posterior iliac crests are exposed through two small vertical incisions and a subcutaneous tunnel is created between the left and right posterior iliac crest. The plate is carefully inserted in the tunnel and fixed with several screws to the posterior ilium. Instead of a plate, a transiliac internal fixator can also be used[47]. Two pedicle screws of a diameter of 7 or 8 mm are inserted from the left and right posterior superior iliac spine in the direction of the anterior inferior iliac spine using the corridor between the inner and outer cortex of the ilium. The screw heads of the pedicle screws are countersunk in a small defect, which is created by osteotomy in the posterior iliac spine, and are connected with a transverse bar, which is inserted in the subcutaneous tunnel [48]. There is a high stability thanks to the good anchorage of the pedicle screws in the ilium. In case of severe osteoporosis, the tip of the screws can be augmented with cement[49]. The construct can also be enhanced with iliosacral screws[50]. The transiliac internal fixator is inserted minimally invasive; only two short incisions at the posterior superior iliac spines are needed. Unilateral and bilateral fractures of the sacrum can be bridged with this technique, but there is no compression at the fracture site. An alternative stabilization technique is the trans sacral bar osteosynthesis[51, 52]. A 5 to 6 mm threated bar is inserted through the sacral corridor of S1. On both sides of the bar, a washer and nuts are inserted. Tightening the nuts creates a compression on the lateral cortex of the posterior ilium. The stability of the construct does not depend on the strength of the trabecular bone of the sacrum, but rather on that of the cortex of the posterior ilium. There is no risk of loosening as the bar is tightened with nuts on both sides. Unilateral and bilateral sacral fractures and fracture dislocations of the iliosacral joint can be treated with this construct[52]. In case the trans sacral bar is used for a unilateral fracture, the osteosynthesis can be regarded as stabilization, which prevents an additional fracture on the contralateral side. Thorough preoperative planning is needed, the morphology of the upper sacrum differs considerably, in patients with a dysmorphic sacrum, a transsacral corridor may not be available[53]. To enhance rotational strength, the trans sacral implant can be combined with unilateral or bilateral iliosacral screw osteo-synthesis . Lumbo pelvic fixation is a stabilization procedure, which may be used unilaterally or bilaterally. One pedicle screw is inserted into the pedicle of L5, alternatively of L4. Another pedicle screw is inserted in the posterior ilium, as described for transiliac internal fixation. The two pedicle screws are connected with a vertical rod. When used on both sides, a transverse connector may connect the left and right construct. Iliosacral screws may be inserted additionally. This configuration is called triangular osteosynthesis[54]. The pedicle screws can be inserted through small incisions, the rods and connector then being inserted percutaneously. The construct controls vertical instability, but locks the motion segment L5-S1 or L4-L5 and L5-S1. The best indications for lumbopelvic fixation are U- or H-shaped sacral fractures with intrusion of the lumbosacral spine into the small pelvis[55-57]. The construct will prevent further displacement, which ultimately leads to neurological deficits such as urine or fecal incontinence. When the posterior pelvic ring needs surgical stabilization, attention should be paid to the fracture(s) of the anterior pelvic ring as well. Fixation of the broken posterior pelvic ring only will not close the pelvic ring, when it is also broken anteriorly. Residual instability may cause high stresses on the osteosynthesis and lead to early implant loosening or failure. Also may the broken anterior pelvic ring not heal due to continuing motion in the fracture site. The type of fixation at the anterior pelvic ring is depending on the localization of the fracture, the amount of displacement and the presence of bone gaps or defects. Pubic rami fractures at the obturator foramen are the most frequent, followed by pubic body fractures near to the pubic symphysis and fractures at the anterior lip of the acetabulum. When non- or minimally displaced, we prefer a retrograde transpubic screw osteosynthesis for pubic rami and more lateral fractures. The screw is inserted percutaneously through the superior pubic ramus in the so-called anterior column corridor and can have a length of up to 130 mm. It passes the acetabular cavity medially and superiorly and ends at the outer cortex of the ilium [58]. It splints the fracture rather than fixing or compressing it. The procedure is performed bilaterally in case of bilateral pubic rami fractures. When the fracture is severely displaced or located near to the pubic symphysis, retrograde screw osteosynthesis is not possible. An open reduction and internal fixation through a suprapubic midline or a Pfannenstiel incision is necessary in these cases. The plate bridges the fracture and must have a least two screws with excellent purchase on each side of the fracture. Plate osteosynthesis has a higher stability than screw osteosynthesis[59]. The approach may be extended into a modified Stoppa approach with the plate being placed below the pelvic brim and screws inserted above the acetabulum[60, 61]. External fixation is a minimally invasive bridging osteosynthesis of the anterior pelvic ring. Two long Schanz' screws are inserted from the anterior inferior iliac spine towards the posterior superior iliac spine. The screws may have a length of up to 100 mm in the supra acetabular bone. The screws are connected to a bowed carbon rod with ball joints[62]. We do not recommend this technique, as it is combined with serious drawbacks and limitations. The most important are pin loosening, pin track infection, necrosis of the skin margins around the pin, and lack of comfort due to direct pressure of the connecting rod(s) on the abdominal wall and because of limited flexion of the hip joints due to mechanical conflict of the upper thigh with the fixator frame.



Figures: X-rays on treatment of pelvis fracture.

CONCLUSION

Fragility fractures of the pelvis deserve our specific attention as their incidence is growing importantly and because they show a complicated course in many cases. The characteristics of fragility fractures of the pelvis differ in many aspects from pelvic ring disruptions in adolescents and adults. They are the consequence of a low-energy trauma and do not need emergency treatment. Immobilizing pain in the low back, in the gluteal region, in the groin or at the pubic symphysis is the leading symptom. A new classification system comprises different degrees of instability, specific morphologies and localizations of fractures. When a surgical treatment is needed, the surgery should be as less invasive as possible. Different techniques for stabilization of the posterior and anterior pelvic ring have been developed, which use the principles of compression, bridging and splinting. Literature data do not deliver sufficient evidence until now, to answer the question which procedure(s) are the most beneficial for the patients with fragility fractures of the pelvis. More clinical and biomechanical work is needed to shed light on the optimal management of this emerging pathology.

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