Long-term Functional and Radiological Outcome after Displaced Sacral Fractures

Thesis by

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Preface

During the recent decades, there has been an increase in the rate of pelvic trauma,[1] a decrease in mortality due to improved initial trauma care,[2,3] and an increasing number of elderly patients sustaining high-energy pelvic trauma.[4] In healthy, non-osteoporotic adults, a considerable amount of force is required to disrupt the pelvic ring.[5] The high-energy impact may result in damage, not only to the pelvic bones, but also to other body regions, intrapelvic organs, and neural tissues, that are closely associated with the pelvic bony structures.[1,6,7] Functional sequelae and impairments are common results following these injuries, especially in cases where an unstable sacral fracture is a part of the posterior pelvic ring injury.[8,9] There are several reports on short and medium-term outcome following displaced sacral fractures, reporting considerable morbidity, residual pain, neurologic and functional impairments. However, there is a paucity of information regarding morbidity and functional outcome in a long-term perspective, in terms of changes over time, many years after the initial injury. This is fundamental in order to understand and gain more knowledge about the characteristics of severe sacral fractures. Knowledge about factors that contribute to poor outcome in a long-term perspective can constitute the basis for an improved, and a more focused rehabilitation. In this way, the extent of some impairments may be limited. In addition, as the majority of the individuals sustaining these injuries are young adults in working age, information about their prognosis or final disability may be of a great socio-economic importance at an earlier stage.

Abbreviations

ADL – Activities of Daily Living

AO – Arbeitsgemeinschaft für Osteosynthesefragen

ASIA – American Spinal Injury Association

ASIF – Association of the Study of Internal Fixation

CT – Computer Tomography

IIEF – International Index of Erectile Function

ISS – Injury Severity Score

NBS – Norm Based Scores

OA – Osteoarthritis

OTA – Orthopaedic Trauma Association

PRH – Patient-reported Health

RD – Residual displacement

- CRD – Cephalad Residual Displacement
- PRD – Posterior Residual Displacement

SF-36 - Short form-36

- Pf – Physical functioning
- Rp – Role physical
- Bp– Bodily pain
- Gh – General health
- Vt – Vitality
- Sf – Social functioning
- Re – Role emotional
- Mh – Mental health

SI – Sacroiliac

TLSD – Traumatic Lumbosacral Dissociation

USS – Universal Spine System

VAS – Visual Analog Scale

List of papers

1. Adelved A, Tötterman A, Glott T, Madsen JE, Røise O. **Functional outcome 10 years after surgical treatment of displaced sacral fractures.**
   Spine (Phila Pa 1976.) 2012; 37 (16): E1009-16.

2. Adelved A, Tötterman A, Hellund JC, Glott T, Madsen JE, Røise O. **Radiological findings correlate with neurologic deficits but not with pain after operatively treated sacral fractures. An 11-year follow-up of 28 patients.**
   Acta Orthop 2014; 85 (4): 408-414.

3. Adelved A, Tötterman A, Glott T, Søberg HL, Madsen JE, Røise O. **Patient-reported health minimum 8 years after operatively treated displaced sacral fractures: A prospective cohort study.**
   J Orthop Trauma 2014. In press [Epub ahead of print].

4. Adelved A, Tötterman A, Glott T, Hellund JC, Madsen JE, Røise O. **Long-term Functional Outcome after Traumatic Lumbosacral Dissociation. A Retrospective Case Series of 13 Patients.**
   Submitted.

Summary

Background and objectives

Displaced, unstable sacral fractures are severe injuries resulting in considerable morbidity and functional sequelae. Several authors report neurologic deficits, bladder, bowel, and sexual dysfunction, as well as residual pain and poor self-reported health, in short, and medium-term follow-up studies. However, there is a lack of information on long-term functional outcome following these injures, nor whether any changes occur in functional status many years after the initial injury. The aim of this study was to assess long-term outcome in patients after displaced sacral fractures in a 10-year perspective, focusing on dysfunctions related to the pelvic trauma and the sacral fracture. Also, by comparing the long-term outcome results with the medium-term results, changes over time could be assessed to gain more information on the development of these relatively uncommon injuries. In addition, we aimed to assess the long-term functional outcome in patients with a rare subgroup of sacral fractures, namely traumatic lumbosacral dissociation injuries.

Materials and methods

The present study included two clinical series, one prospective (papers 1-3) and one retrospective (paper 4). The study was conducted at Oslo University Hospital- Ullevaal (OUS-U), where all patients with displaced, unstable sacral fractures were prospectively registered between 1996 and 2001 (papers 1-3). During this period, 39 patients were registered; all of whom underwent operative treatment at OUS-U, with subsequent discharge to a rehabilitation facility at Sunnaas Hospital for the majority of the patients. Tötterman et al followed 32 of the 39 patients, and published the results of functional outcome in a 1-year follow-up. In the present study, 28 of the 32 patients were available for a 10-year follow-up.
Patients with traumatic Lumbosacral Dissociation (TLSD), constituting the material in Paper-IV, were retrospectively identified from the Pelvic Fracture Register at Orthopaedic department, OUS-U, between 1997 and 2006. Out of 21 eligible patients, 15 were available for follow-up, mean seven years post-injury. Seven were treated operatively and eight were treated non-operatively.

All patients were examined and the following data were collected: Neurologic function in lower extremities and perineum (ASIA), bladder function (uroflowmetry, residual urine measurement, and interview), bowel function (interview), sexual function (interview, and IIEF questionnaire in males), pain (VAS), ambulation (interview and observation), ADL and return to work/employment status (interview), and patient-reported health (SF-36). In addition, all patients underwent radiologic assessment with conventional radiographs and CT of lower lumbar spine and the pelvis.

Results

Papers 1-3: All but one patient had neurologic deficits, but only two were wheelchair users. The most commonly affected dermatomes were L5 and S1. No significant changes in neurologic function were noted over time. Nineteen out of 28 had pathologic urinary function, with a significant deterioration noted in 11 since the 1-year follow-up. Eight patients reported bowel dysfunction and 12 had problems associated with sexual activities; none of these parameters was significantly changed from the previous follow-up.

Radiographic assessment revealed that all sacral fractures were united, with residual displacement (RD) in the posterior pelvic ring ≥ 10 mm in 16 patients. Narrowing of one or more sacral neural root foramen was observed in 26 and postforaminal bony encroachment of the L5 nerve in 22 patients. Narrowing of the sacral foramina, as well as postforaminal impingement/ bony encroachment of L5 nerve correlated significantly with neurologic deficits. No significant correlations were found between radiologic findings and pain.

The SF-36 scores among these patients were overall lower than the normal scores (Norwegian population), with no significant changes from the 1-year follow-up. The 10-year SF-36 scores showed significant correlations with pain, sexual, and bowel dysfunction, but not with neurologic deficits or urinary dysfunction.

Paper 4: Only two out of 15 patients had normal neurologic function and both were treated non-operatively. In the remaining 13 patients with neurologic deficits, one patient who was treated non-operatively had no neurologic symptoms initially, but developed secondary motor and sensory deficits bilaterally from L5-S4. Radiologic examination showed massive callus formation around the fracture site at the upper end of the sacrum, with a marked narrowing of the central canal at the S2 level. Eleven had pathologic urinary function, five reported bowel dysfunction, and 10 reported limitations in sexual function, seven of whom complained of pain during intercourse. All but one patient reported pain at follow-up, with the majority having lumbosacral pain combined with radicular pain. All sacral fractures were healed with kyphotic angulation across the fracture. In four cases, there was an increase in kyphosis compared with initial radiographs. Patients with TLSD had significantly lower SF-36 scores than the normal population.

Conclusion

In this long-term follow-up study, we found that patients with displaced sacral fractures had considerable morbidity and disabilities. We found high rates of neurologic deficits, with no significant changes over time, suggesting that neurologic deficits at the time of initial presentation may be permanent if still present one year post-injury. Problems with urogenital functions were common findings; with urinary dysfunction showing a significant deterioration over time, and high rates of sexual dysfunctions were reported. In addition, the patient-reported health was significantly lower than the norms, with no changes over time, and with a significant correlation with pain. These results imply that a special focus on these findings is needed during the rehabilitation period, with longer follow-up period and a multidisciplinary approach across specialties. Pathological radiographic findings were common, including residual displacement in the posterior pelvic ring that did not correlate with lumbosacral pain.

1. INTRODUCTION

Anatomy of the sacrum and the pelvis

The pelvic ring is formed by the connection of the two innominate bones (*Latin*, *Innominatus,* meaning unnamed or nameless due to its shape that does not resemble any known object) with the sacrum wedged in between them posteriorly (Figure 1). Anteriorly, the innominate bones are connected together at the pubic symphysis with an interpubic fibrocartilaginous disc, and the superior, the posterior and the arcuate pubic ligaments[10] The innominate bones are in turn formed by the fusion of three separate ossification centers, namely the pubis, the ischium and the ilium, with complete fusion during the early teens.[11-13]

The sacrum arises from the bony fusion of 5 separate vertebrae, the ossification process of which starts in the distal end approximately at 18 years of age, proceeding in the proximal direction, and is completed at approximately 25-33 years of age[14,15] . The sacrum is the most caudal part of the spine, which with its triangular shape connecting to the innominate bones, also connects the spinal column to the pelvis. In the standing position, the sacrum is tilted forward approximately 45-60°, however considerable variations in inclination have been described.[16] It has a kyphotic shape, concave at the anterior surface, with a sagittal angulation varying from 20° to 90°, although most commonly ranging from 40° to 60°. It has four articular surfaces; at the distal end, it articulates with the coccyx, the lateral surfaces of the two lateral masses articulate with the iliac bones forming the sacroiliac (SI) joints that extend distally to the S-2 level. Proximally, it is connected to the 5th lumbar vertebral body (L5) with 2 facet joints and an intervertebral disc.[17]

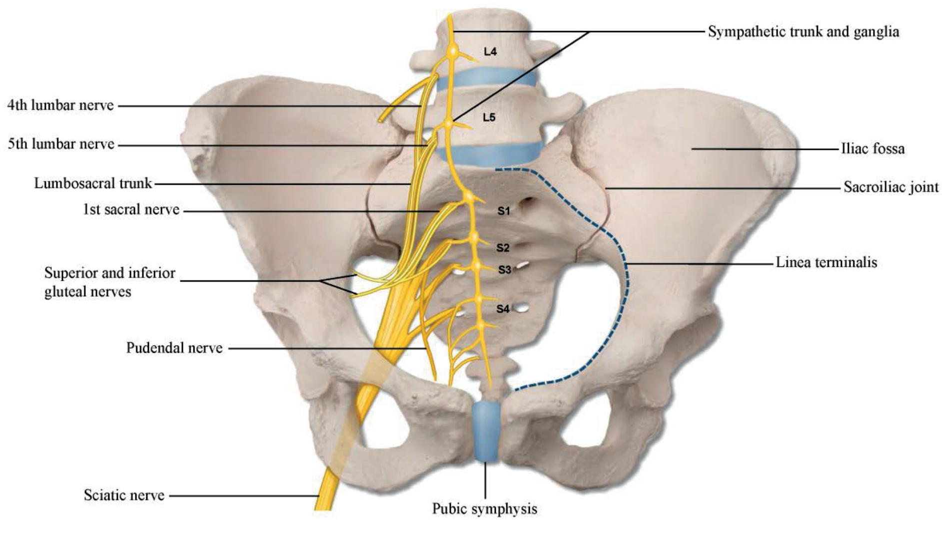

Figure 1. An overview of the pelvic ring, with the lower lumbar and sacral nerves, including the main branches.

Biomechanics: The load transfer from the lower extremities to the spine takes place through the posterior column of the hip joints to the sacroiliac joints and the sacrum.[18] The three pelvic bones have no inherent bony stability and are completely dependent on ligamentous connection and stabilization. The ligamentous structures primarily responsible for sacropelvic stability are the sacroiliac interosseous ligaments, the strongest ligaments of the body, and the anterior and posterior sacroiliac ligaments (Figure 2).

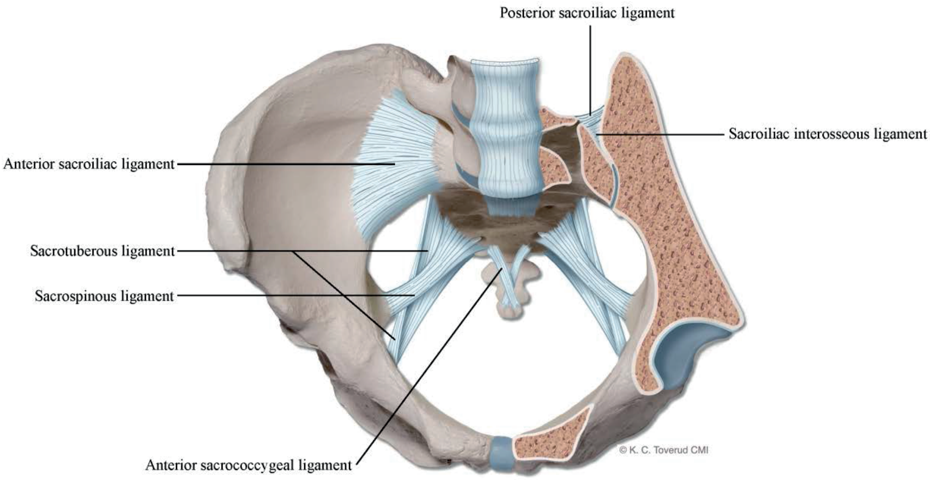

Figure 2. The ligaments of the pelvic ring, inlet view.

Of the sacroiliac ligaments, the posterior ligaments are by far the most robust, with the anterior ligaments contributing much less to overall stability.[10,18] Additional sacropelvic stability is achieved by the sacrospinous and sacrotuberous ligaments and spinopelvic stability by the iliolumbar and lumbosacral ligaments. All of the ligaments of the posterior pelvic ring form the posterior tension band of the pelvis, binding the skeletal elements together to resist deforming forces[18] (Figure 3). Any disruption of these ligamentous structures will result in instability of the posterior pelvic ring, depending on the direction of the impact and which ligament that is affected. The interosseous and the posterior sacroiliac ligaments resist internal rotational forces, while the anterior sacroiliac, and the sacrospinous ligaments, and the pubic symphysis resist external rotational forces. All of the ligaments of the posterior pelvic ring complex also contribute to vertical stability, and in case of vertical shear injury, all may disrupt resulting in complete instability of the affected hemipelvis.[19]

The anterior pelvic ring structures, with the pubic symphysis acting as a strut, withstand rotational forces, but isolated disruptions in the anterior structures have little effect on the overall stability of the pelvic ring.[19]

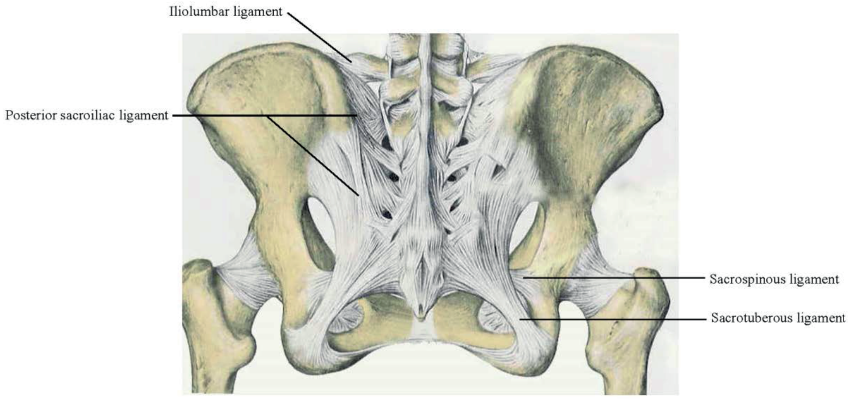

Figure 3. A posterior view of the pelvis, showing the posterior sacroiliac ligaments.

The pelvic cavity (*Latin, Pelvis,* meaning basin) is divided into two parts; the false pelvis, which is formed by the sacral ala, the pelvic brim (ilio-pectineal line), and the iliac fossa (Figure 1). The true pelvis is the cavity below the sacral promontory and linea terminalis, including the ilio-pectineal line. It contains the bladder, rectum, and the internal reproductive organs, as well as blood vessels and neural structures. It is limited laterally and antero-posteriorly by the pelvic bones, and inferiorly by the sacrospinous and the sacrotuberous ligaments and the pelvic floor musculature formed by levator ani muscle and the bulbospongiosus, bulbocavernosus and ischiocavernosus muscles.[15] The urinary bladder lies in the anterior pelvic cavity in close proximity to the pubic symphysis anteriorly, and the rectum posteriorly. In males, the internal genital organs lie inferior and posterolateral to it and in females; the space between the bladder and the rectum is occupied by the uterus and the vagina. The rectum lies in the posterior end of the cavity, along the anterior curvature of the sacrum.[20]

The pelvic floor is perforated by the urethra, rectum and vagina. The levator ani muscle has a visceral support function as well as having an important role in the mechanism of defecation and urination.[21]

The sacral nerves exit the sacrum via eight pairs of neural foramina, four pairs at the posterior/ dorsal aspect and four pairs at the anterior/ ventral aspect (Figure 1). The anatomy of the neural elements changes within the sacrum with termination of the dural sack at approximately the S2 level. In the central canal, the sacral nerve roots move laterally from the cauda equina as they near their exiting foramen. The diameter of the sacral roots exiting the sacral foramina decrease precipitously with each successive root. In contrast, the diameter of each neural foramen does not decrease as rapidly. Thus, the upper sacral roots have less free space around them at their exit through the respective foramen, where S1 occupies approximately one third of its foramen, while S4 approximately one sixth. The clinical significance of this is that the upper sacral roots can be more predisposed to injury than the lower roots.[8]

The dorsal roots supply sensory fibers to the skin and motor fibers to the paraspinous musculature. The cutaneous area supplied by one spinal nerve is a dermatome, and similarly, each nerve root innervates a group of muscles called a myotome. While a dermatome is usually a discrete and contiguous skin area, which may overlap markedly, most roots innervate more than one muscle, and most muscles are innervated by more than one nerve root.[17,22] The evaluation of nerve root damage can be done by testing the corresponding dermatomes and myotomes at specific key points/ movements.[22]

Ventrally, the L5 nerve passes through the lumbosacral canal, which is formed by the L5 transverse process superiorly, L5 vertebral body medially, sacral lateral mass inferiorly, and the lumbosacral ligament antero-laterally.[23] This path is usually the main fracture area in a vertically unstable sacral fracture, and the L5 nerve may thus be avulsed or stretched by bony fragments in cases of severe fracture displacements.[24,25] Further, it crosses the lateral mass descending distally and laterally into the pelvis, where a branch from the L4 nerve joins it to form the lumbosacral trunk (Figure 1). The lumbosacral trunk unites with the S1 root anterior to the SI-joint, and they in turn unite with the S2, S3 and S4 roots anterior to the piriformis muscle, thus forming the sacral plexus.

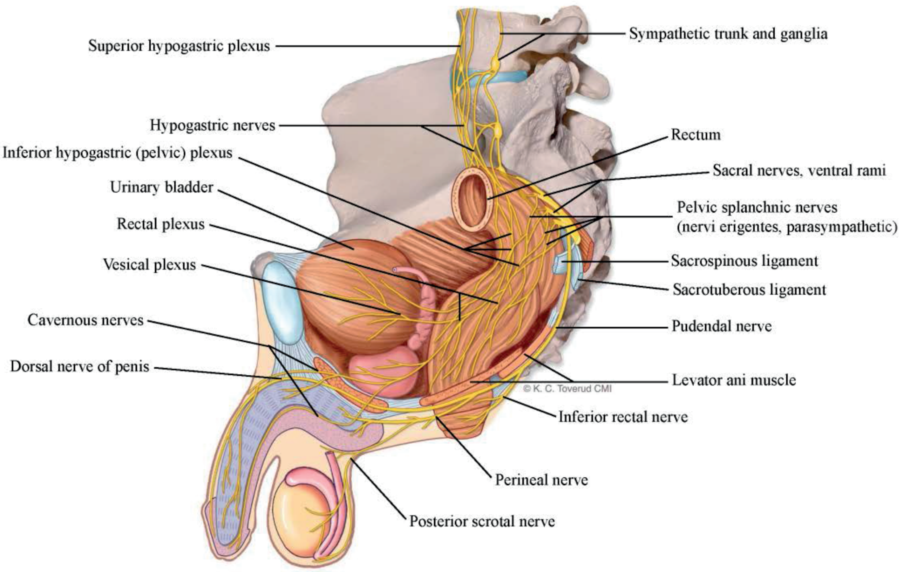

Figure 4. The innervation of the pelvic cavity, and the path of the pudendal nerve.

The sacral plexus then gives off branches to form the sciatic, superior gluteal, and inferior gluteal nerves, supplying sensory and motor fibers to the lower extremities and the gluteal muscles. It also gives rise to the pudendal nerves, the main nerves supplying the pelvic floor musculature, the perineum and sensory function of the external genitals.[10,26,27]

The pudendal nerve runs in anterior direction passing below the sacrospinous ligament and the ischial spine, along the lateral wall of the pelvic cavity, formed by the medial aspect of the ischial ramus, through the pudendal canal. It gives off the inferior rectal nerve and motor branches to the pelvic floor musculature. Anteriorly, ascending along the medial surface of the inferior pubic ramus, it gives rise to perineal nerves and the dorsal nerve of the penis or clitoris[10,28] (Figure 4). The ventral sacral roots also contribute to the autonomic functions, providing bowel, bladder, and sexual function.

The inferior hypogastric (pelvic) plexus is formed from the hypogastric nerves - which are mainly sympathetic - and long branches of the parasympathetic pelvic splanchnic nerves - also called nervi erigentes, originating from S2-S4 ventral rami. This pelvic plexus, which is a paired structure like the other spinal nerves, lies closely on both sides around the pelvic viscera, surrounding and innervating the rectum, bladder and the genital organs (Figure 4). The sympathetic fibers from the S1-S5 sympathetic ganglia are a part of the sympathetic chain that originates from the thoracic level.[10,29,30]

The coccygeal plexus is formed by anterior branches of S4-S5 and the coccygeal nerve, which supplies sensory fibers to the perianal area.[15]

Due to the paired innervation of the intrapelvic organs, unilateral injuries may cause less dysfunctions compared to bilateral injuries.[26,31,32]

The common iliac artery bifurcates into the external and internal iliac artery (IIA) at the lumbosacral intervertebral level, anterior to the sacroiliac joint. The main blood supply to the pelvic cavity, its organs and surrounding structures is provided by IIA, which bifurcates into an anterior, and a posterior trunk. Although some anatomical variations may occur,[33] the anterior trunk gives off branches supplying the visceral organs and the pelvic floor. From the posterior trunk arise the iliolumbar, superior gluteal and the lateral sacral arteries. The median sacral artery arises directly from the posterior aspect of the abdominal aorta, a little above its bifurcation and descends in the midline, anterior to L4, L5 vertebral bodies, the sacrum and the coccyx. It anastomoses with the lateral sacral arteries giving off branches into the anterior and posterior sacral foramina.[15] Vascular injury may occur by laceration or shearing of the vessels by boney fragments in cases of fracture displacement of the pelvic bones, with the internal iliac artery and its branches being most frequently injured.[34-37]

The major veins of the pelvis usually follow their named arterial counterparts, but the smaller branches may exhibit a considerable variation between individuals.[15] The presacral venous plexus is formed by the anastomosis of the median sacral vein with the lateral sacral veins from each side and communicating veins between them, covering the anterior aspect of the body of the sacrum.[38,39] The internal iliac vein is formed by the convergence of several veins, including the gluteal, internal pudendal, and obturator veins and the venous plexus of the pelvic viscera, as well as the lateral sacral veins. The internal iliac vein converges with the external iliac vein forming the common iliac vein. This complex and interconnected pelvic and sacral venous system may result in significant hemorrhage following posterior pelvic ring and sacral injuries or perioperative iatrogenic trauma.[38]

Functional anatomy and physiology

The structures involved in **urinary function** include the bladder, the urethra, the pelvic floor and the external urethral sphincter muscle. The process of micturition involves two steps; first, the bladder filling continuously until a threshold level of tension is reached in its walls, resulting in stretch signals from the bladder wall that are mediated by pelvic splanchnic nerves (S2-S3). This induces the next step, the micturition reflex, which is a parasympathetic nervous reflex that eventually empties the bladder by contraction of the smooth muscle of the bladder wall, called the detrusor muscle and inhibition of the internal sphincter contraction. The sympathetic nerves are responsible for contraction of the internal sphincter muscle, maintaining a resting tone, and are inhibited at micturition. Although the sympathetic nerves to the bladder play no active part in micturition, a disruption of sympathetic supply to the bladder results in decrease in bladder storage volumes and competency of the bladder neck and proximal urethra.[40,41] The micturition reflex is an autonomous spinal reflex, with an important regulatory influence from the cerebral cortex centers and the brain stem, to voluntarily initiate or inhibit micturition.[42] At the end stage of urination, the female urethra empties by gravity, while the remaining urine in the male urethra is expelled by sequential contractions of the ischiocavernosus and the bulbospongiousus muscles, mediated by the pudendal nerves (S2-S4).[41] The pudendal nerves mediate the voluntary control of the urinary function by contraction of external urethral sphincter, which is required particularly when intra-abdominal pressure increases (e.g. coughing, sneezing). In case of complete bilateral injury of the sacral roots S2-S4, the desire of voiding and detrusor activity is absent, and relaxation of the sphincter results in urinary incontinence.[31,43]

Distension of the **rectum** with feces initiates reflex contractions of its musculature and relaxation of the internal anal sphincter, resulting in the desire to defecate. The inferiormost portion of the levator ani muscle, called the puborectalis muscle loops posteriorly around the rectum at the anorectal junction, and as a unit, in close association with the external and the internal anal sphincters, they maintain fecal continence.[44] The external sphincter is innervated by the pudendal nerves and the puborectalis muscle receives its innervation directly from the sacral roots S2-S4. Both are under voluntary control via cortico-spinal descending motor pathways, as well as under reflex control via spinal and sacral reflex pathways.[45] The internal anal sphincter is a smooth muscle, innervated by sympathetic and parasympathetic systems. Sympathetic fibers originate in the L4-L5 level and cause contraction of the sphincter. Parasympathetic fibers originate in the S2-S4 segments causing its relaxation.[15] The internal anal sphincter is considered to contribute 80% of the resting tone in the anal canal. It has an autonomic innervation and is thus unaffected by pudendal nerve injuries.[46]

Sexual arousal is largely the product of the coordination of the autonomic and somatic nervous system within the lower spinal cord. These spinal reflexes are under excitatory and inhibitory control from the brainstem and hypothalamic sites.[47] The general pattern of innervation of the genitals is comparable between males and females, with the pelvic nerves (parasympathetic), together with the hypogastric, and the paravertebral sympathetic chains constitute the autonomic innervation to the sexual organs.[48,49] Sensory impulses from the penis/vulva are mediated by the pudendal nerve, involving sacral nerves above the level of S3.[31] In females, the pudendal nerve together with the parasympathetic nerves participates in pelvic venous congestion and vaginal lubrication. Orgasm is associated with contractions of the pelvic floor muscles, innervated primarily by the pudendal nerves[50,51]. Penile erection is effected by mental stimulation and/or by a sacral reflex arc involving the S2-S4, through the pelvic and pudendal nerves, resulting in dilation of the arteries to the cavernous bodies and contraction of the bulbocavernosus and ischiocavernosus muscles.[31] The sympathetic system also plays an important role in producing erection, by outflow from the upper lumbar segments.[49] Ejaculation is mediated by the sympathetic nerves and the pudendal nerve that cause contractions of the pelvic floor and perineal muscles and expulsion of semen.[31,52]

Epidemiology of sacral fractures

A sacral fracture is in the majority of the cases a part of a pelvic ring disruption. In a clinical series described by Park et al, an isolated sacral fracture was present in 10% of pelvic injuries.[53] There are no epidemiological data on the true incidence of sacral fractures or pelvic ring injuries. Historical reviews from 1930 and onwards report a wide range of incidence of sacral fractures in different pelvic fracture materials, ranging from 4%-74%.[18,54] Bydon et al.[55] presented a 10-year incidence of sacral fractures in the USA based on the International Classification of Disease (ICD-9) extracted from the Nationwide Inpatient Sample (NIS) database. They observed an increase in incidence from 0.67 cases per 100.000 persons in year 2002 to 2.09 cases per 100.000 persons in year 2011.

The incidence of all pelvic fractures are reported in a few epidemiological studies to be 20 to 43 cases per 100.000 persons per year,[56-58] and high-energy pelvic fractures 10 cases per 100.000 persons per year.[59] Other reviews from selected trauma and hospital registers have reported incidence rates of pelvic fractures ranging from 8%-28% in trauma patients.[60-62] These studies, however, do not report the incidence of sacral fractures specifically. High-energy pelvic ring injuries are common in young adults, with a slightly higher incidence in males.[63-65]

Fracture types and classifications

In 1961, George Pennal proposed three X-ray views; anteroposterior, inlet, and outlet views to define the patterns of displacement of **pelvic ring disruption**, based on the forces causing the pelvic ring injury.[66,67] Based on this, Tile and Pennal developed and presented a classification system of pelvic ring injuries.[68] Müller et al. presented "The Comprehensive Classification of Fractures of the Long Bones" in 1990, using the AO/ ASIF Documentation Center in Bern.[69] The Orthopaedic Trauma Association (OTA) fracture classification was published in a compendium of the Journal of Orthopaedic Trauma (JOT) in 1996.[70] It adopted Müller's classification of long bones and classified bones that had not been previously classified, including pelvic ring injuries influenced by the principles of Tile's classification.[70,71] The OTA classification, together with the Young-Burgess classification[72], is the most widely used system for classification of pelvic ring injuries. The OTA system divides the pelvic ring injuries in three categories; A, B, and C (Figure 5). Each category is further subdivided into three subtypes 1, 2 and 3. In type A injuries, the pelvic ring, including the posterior complex is stable. These injuries may be caused by direct trauma, resulting in avulsions of the iliac wings or transverse fractures of the sacrum distal to the SI-joints, or indirect trauma with fractures trough the pubic bones. In type B injures, there is a partial rotational instability of the posterior pelvic ring. The mechanism of injury is either antero-posterior (B1), resulting in external rotational instability, or lateral compression (B2) resulting in internal rotational instability. Type C pelvic ring disruptions are completely unstable posterior pelvic ring injuries with both vertical and rotational instability. The mechanism of injury is axial trauma in the cephalad direction, i.e. motor vehicle collision or fall from a great height. The posterior injury may be a dissociation of the SI joint, or a fracture through the postero-medial ileum or through the sacrum, accompanied with disruption of the pubic symphysis or fracture through the pubic bones anteriorly (Figure 5).[18,70]

Open pelvic fractures, defined as fractures that communicate with a laceration or puncture wound of the skin, rectum or vagina, are associated with higher rates of mortality and morbidity.[73,74]

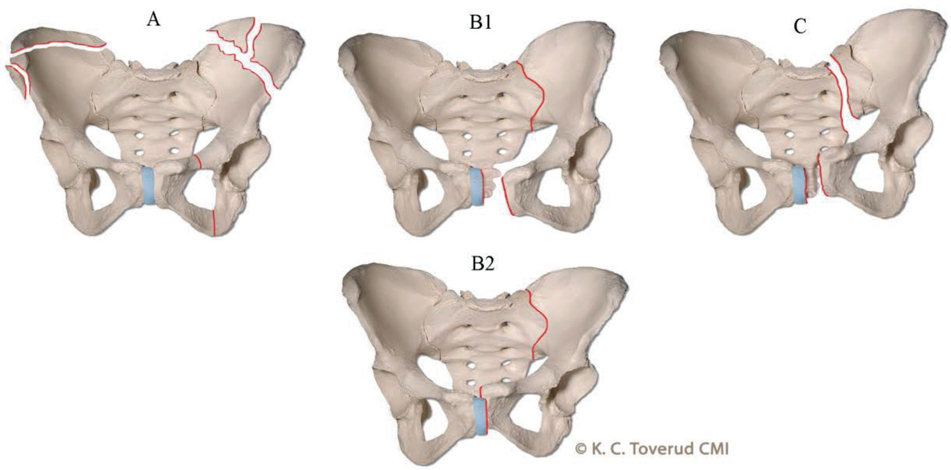

Figure 5. The AO/OTA classification of pelvic ring fractures, showing the main categories according to injury mechanism and direction of instability.

The sacrum has no fracture classification of its own in the OTA system, as sacral fractures generally occur as part of pelvic ring fractures. In 1945, Bonnin proposed the first classification of sacral fractures, dividing them into two categories; the ones caused by direct impact to the sacrum, and the other caused by indirect trauma, as a part of a pelvic ring disruption.[75] Several other classifications were proposed during the following years[76,77], but none was widely adopted until 1988 when Denis et al. [8] presented a simplified anatomic classification that correlates the fracture location with the incidence of neurologic lesion. Denis divided the sacrum into three zone; I, II, and III (Figure 6), with zone I fractures (transalar) being lateral to the foramina, zone II fractures (transforaminal) involving the foramina and zone III fractures (central) being medial to the foramina and involving the spinal canal. In an analysis of 236 patients, the authors found a close correlation between the zone of fracture and the rate of neurologic deficits; 5.9% in zone I, 28.4% in zone II and 56.7% in zone III fractures.[8] In a review of 377 patients with sacral fractures, Pohlemann et al.[9] found similar results, confirming that the highest incidence of neurologic injuries occur in zone III fractures.

Although most sacral fractures occur in the sagittal plane, transverse fractures may also occur, either as a solitary fracture in the lower segments below S3, caused by a direct blow to the coccyx or in the upper sacral segments, S1-S2, in combination with sagittal fracture lines.[78,79] In 1969, Purser [80] presented a case report with a fracture in the transverse plane through the upper sacrum and into both SI-joints. In the following years, numerous case reports were presented, most of them with associated neurologic injury.[78,79,81-84]

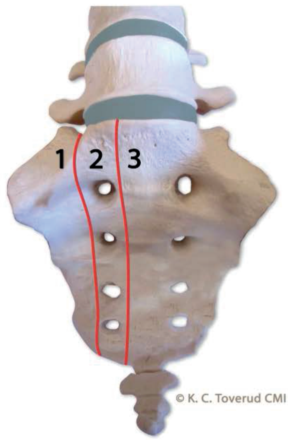

Figure 6. The classification of sacral fractures, by Denis et al., divided into 3 anatomical zones.

In a clinical series and a biomechanical study, Roy-Camille et al.[85] described and classified transverse upper sacral fractures, which they called the "suicidal jumper's fracture", due to a common injury mechanism in their series. The suggested mechanism of injury was kyphosis (flexion) or lordosis (extension) in the lumbar spine and the hips and extended knees at the time of impact, i.e. landing after a fall or jump from a great height (axial load from the lower extremities). They divided the fractures into three types based on the displacement characteristics in the sagittal plane as: type 1 (flexion), a simple anterior bending (kyphosis) of the proximal sacral segment, type 2, flexion combined with subsequent posterior translation of the proximal segment on the distal segment, and type 3, (extension), the proximal segment is translated anteriorly on the distal segment (Figure 7A). A fourth type was added later by Strange-Vognsen et al [86] describing a comminution of the upper segment, without flexion or extension displacement.

A.

B.

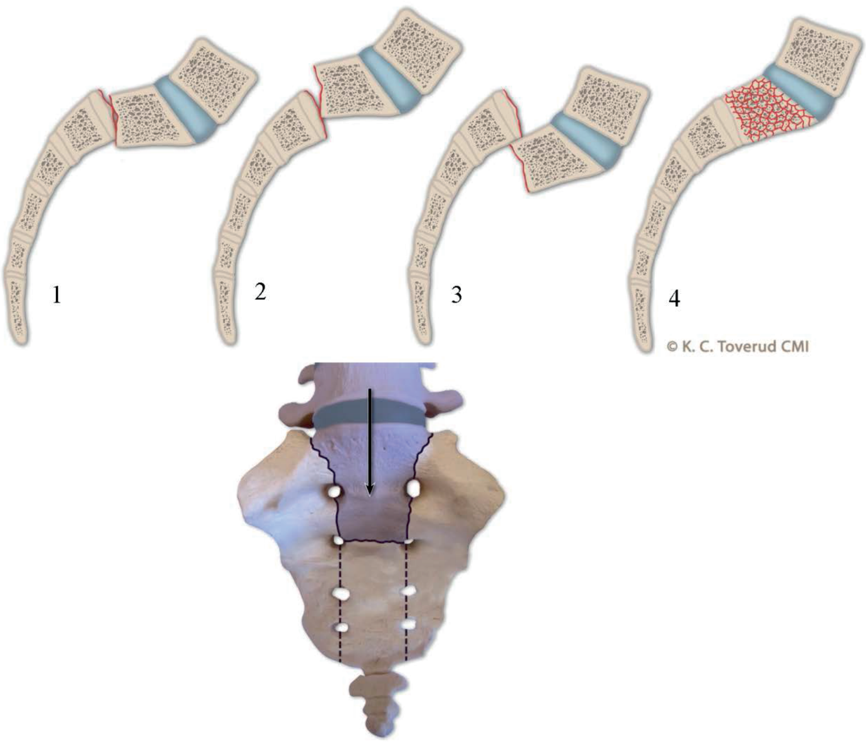

Figure 7. A. The classification of transverse sacral fractures by Roy-Camille et al, sagittal view. **B.** A frontal view of a lumbosacral dissociation fracture pattern, with the fracture lines having a U- or H-shape.

The combination of bilateral transforaminal vertical fracture lines with a transverse fracture line, usually between S1 and S2, forms a U or H shaped fracture in the upper sacrum, seen from the anterior aspect (Figure 7B). The upper fractured segment of the sacrum, is attached to the lumbar column, and when displaced, it dissociates the spine from the pelvis, while the posterior pelvic ring itself stays intact.[85,87]

There is no agreement on terminology of these injuries and terms that have been used in the literature include lumbosacral dissociation or dislocation, lumbopelvic dissociation, spondylopelvic dissociation, spinopelvic dissociation, and lumbosacral fracture dislocation, all describing the same distinct fracture pattern.[88-97] The majority of these studies report high rate of neurologic injuries associated with these fractures.

Radiologic assessment

An anteroposterior plain radiograph of the pelvis is usually sufficient to discover severely displaced fractures and gives an overview of the pelvic ring. However, it is insufficient for disclosing more subtle posterior pelvic ring injuries and displacements. With an inlet view of the true pelvis, the pelvic ring is better visualized revealing rotational instability or posterior displacements through the sacroiliac complex.[18] With the patient supine, this view is obtained by directing the x-ray beam from the head to the midpelvis at an angle of 60° to the x-ray table.[98]

In an outlet view, any vertical, cephalad displacement of the posterior complex can be visualized. [18] With the patient supine, the x-ray beam is directed from the foot to the symphysis at an angle of 45° to the radiographic plate.[98] Although most displacements of the pelvis can be visualized by examining anteroposterior, inlet, and outlet views, posterior injuries, including sacral fractures may be missed or underdiagnosed in many cases.[8,99,100] CT is a valuable tool that permits direct visualization of the bones without overprojecting structures, as seen in plain films. In addition to revealing occult fractures not seen on plain films, especially sacral fractures, it also allows evaluation of fracture displacement, stability, and soft tissue injuries.[101-104] This information is essential in formulating a treatment plan for these patients.

Indications for operative treatment

The aims of treatment of pelvic ring injuries are posterior pelvic stability, avoidance of nerve injuries, and restoration of pelvic alignment.[105] Type A injuries are usually stable and require no operative management, and should be treated symptomatically with early mobilization.[18] In displaced transverse sacral fractures below S2 level (A3.3), sacral plexus lesions are often present, and a sacral laminectomy with nerve root decompression and internal fixation is recommended.[18]

Partially stable type B pelvic ring injuries may require operative treatment in terms of reduction and stabilization depending on the extent of displacement of the hemipelvis or involvement of the sacrum or the SI joint. Open book injuries (B1), caused by antero-posterior forces, are characterized by a disruption of the pubic symphysis, anterior sacroiliac, sacrotuberous, and sacrospinous ligaments resulting in an external rotational instability of the hemipelvis. These injuries usually require open reduction and internal fixation. In B2 injuries, with lateral compression as injury mechanism, usually a fracture of the pubic bones is present, accompanied by an impaction of cancellous bone in the anterior border of the SI-joint and retention of the ligaments. In these injuries, the ligamentous integrity of the posterior pelvic ring is most often intact, thus the posterior pelvic ring remains stable, requiring no surgical intervention. [18,19,105,106]

In type C injures, the shearing forces cause marked displacement of the pelvic bone and gross disruption of the soft tissue structures. Rupture of the ligaments in the posterior pelvic ring and the pelvic floor produces a highly unstable pelvic ring in all directions, typically displaced in cephalad and posterior direction.[18] With regards to pelvic ring and fracture stability, most authors agree that injuries with greater than 1 cm of displacement should be considered unstable.[19,107-109] Other soft tissue injuries are also commonly caused by the shearing forces, such as nerve injuries, blood vessels, and other intrapelvic organs. Nerve lesions are frequently encountered in cases when the posterior injury involves the sacrum.[8,9] These highly unstable pelvic ring fractures require operative reconstruction with open or closed reduction and internal fixation.[18,19,110] External fixation alone of type C injuries results in insufficient stability of the posterior pelvic ring, and is therefore not recommended as the final treatment method of these injuries.[110,111] With complete posterior instability and vertical instability, it is recommended that the posterior fixation be supplemented with anterior stabilization.[112]

In U or H shaped sacral fractures, the integrity of the pelvic ring is most often unaffected with intact ligamentous complex in the posterior pelvic ring.[87] The instability is produced by a fracture through the upper bony portion of the sacrum, which, when displaced, causes a dissociation of the pelvis from the spine. These are rare and heterogeneous injuries that are frequently accompanied by high rate of lumbosacral plexus lesions.[113] The operative treatment goals are restoration of lumbosacral stability, spinal alignment, and decompression of the neural elements in the sacral canal. Roy-Camille recommended sacral laminectomy, reduction and internal fixation,[85] but there is no consensus on treatment guidelines for these injuries. Several authors report satisfactory results with operative treatment of severely displaced fractures with neurologic lesions.[94,97,114,115]

Several **surgical treatment methods** exist for internal fixation of posterior pelvic ring and sacral fractures, including open and closed/percutaneous procedures (Figure 8). A variety of different modes of internal fixation have been proposed, all based on three basic principles; posterior bridging fixation with plates or bars, iliolumbar fixation, and percutaneous iliosacral screw fixation, or combination of those.[114,116-119]

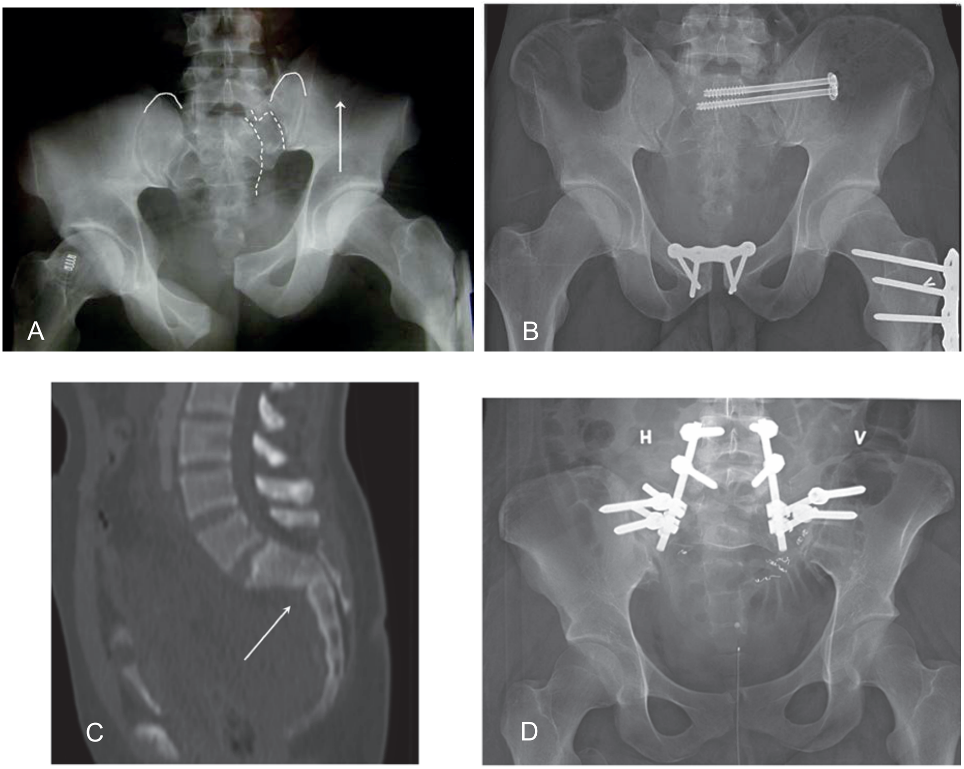

Figure 8: Two common operative techniques of unstable sacral fractures. **A.** Preoperative image of a type C vertically unstable pelvic ring disruption with a sacral fracture. The fracture lines demarcated with dotted lines. **B.** Postoperative image after closed reduction and IS screw fixation posteriorly and open reduction with plate fixation of the pubic symphysis. **C.** A preoperative sagittal CT image of a U-shaped sacral fracture, which was stabilized with iliolumbar fixation after open reduction **(D)**.

Open techniques are often indicated in highly unstable sacral fractures, which facilitate reduction and the possibility to remove bone debris impinging on neural tissue or perform decompressive laminectomy in cases where it may be indicated.[115,120] Iliolumbar fixation is the only method that may allow immediate full weight bearing.[121] However, soft tissue injures in the lumbar or pelvic area, and open pelvic fractures should be taken into consideration in decision making and choice of operative treatment method.[122]
Complications associated with open procedures include excessive hemorrhage, iatrogenic damage to the neural elements during dissection, infection, and tissue breakdown due to prominent implants.[112,123,124]

Percutaneous iliosacral screw fixation has been increasingly popular in treatment of unstable posterior pelvic ring and sacral fractures, with the advantage of minimizing complications such as blood loss and infection.[125,126] However, the main disadvantage of this technique is the risk of iatrogenic nerve injuries by misdirected screws, and occasional fixation failure[127,128] (Figure 9). The surgeons experience, optimal fluoroscopic quality and imaging during the procedure, and knowledge about anatomic variations are essential in achieving successful screw placement and fixation.[73,129,130]

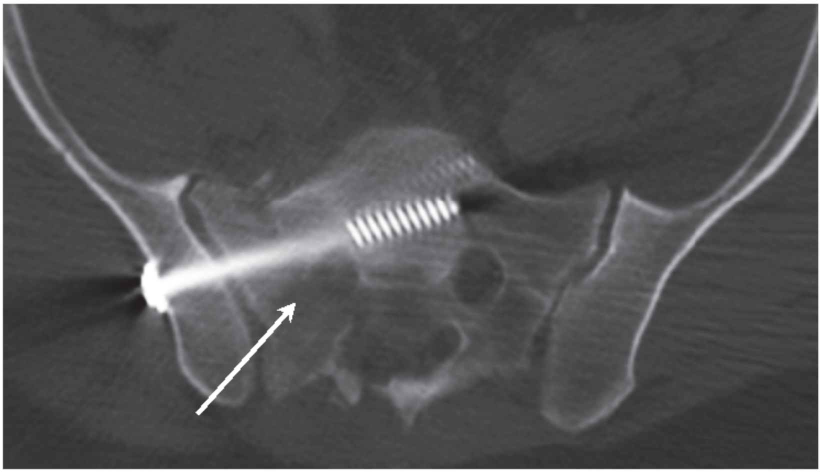

Figure 9: A postoperative CT scan showing a misdirected iliosacral screw violating the sacral nerve foramen.

In transforaminal zone II sacral fractures, comminuted bony fragments may be displaced into the neural pathway, which can be visualized preoperatively by CT (Figure 10). In these cases, in order to avoid neural damage, the fractures may be stabilized by open technique, which also allows for removal of the bony fragments around the nerves. Closed reduction and fixation with iliosacral screws can also be used, but overcompression of the screws should be avoided in cases with transforaminal sacral fractures to prevent further nerve root damage. This can also be achieved by using fully threaded screws instead of partially threaded screws.[131,132]

The surgical technique should be selected based on the patients' medical condition, soft tissues and fracture pattern.

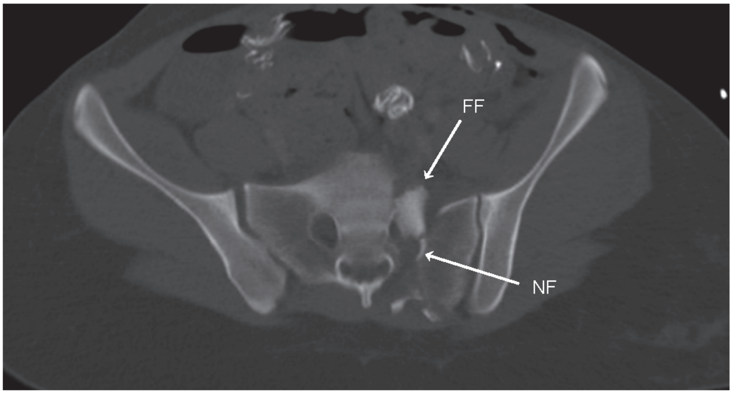

Figure 10. An axial CT slice of a displaced sacral fracture showing the fracture line going through and disrupting the neural foramen (NF). A fractured bony fragment (FF) is displaced into the fracture gap and the neural foramen.

Associated injuries

Pelvic fractures are caused by considerable amount of force, such as in high-speed motor vehicle accidents, fall from heights or crush injuries, and associated injuries to multiple anatomic sites are common,[5,7,61] including cerebral, thoracic, vertebral, abdominal, limb, and extra-pelvic vascular injuries.[1,61,62,133-136] The energy causing the pelvic fracture has also been shown to result in damage in surrounding soft tissues, such as the abdominal organs, vascular structures, genitourinary organs and nerve injuries.[6,122,137,138]

Nerve injuries are common in pelvic fractures, especially in the presence of a displaced sacral fracture.[8,24,139,140] The reported incidence of neurologic lesions in posterior pelvic injuries and sacral fractures are between 24%-60%, with bilateral sacral fractures having the highest rate of nerve damage.[6,140,141] In fracture displacements, the sacral nerves injuries may be due to rupture, crush, or traction, which may result in avulsion of the spinal roots from the spinal cord. Due to the close relationship of the neural elements with bony structures in their course through the sacral foramina (Figure 8), the sacral nerves are particularly prone to injury in fractures involving the sacral foramina and the spinal canal (zone II and zone III).[8,24] Also the L5 nerve and the lumbosacral trunk are predisposed to injuries in case of a fracture displacement due to their anatomical path through the lumbosacral canal and across the SI-joint.[25,142]

Intra-pelvic **bleeding** may originate from exposed cancellous bone and injured soft tissue at the fracture sites, or from the veins, especially the presacral venous plexus, or arteries and their branches that traverse the pelvis.[63] Patients with B-type injuries have more commonly injuries to the anterior division vessels, which can be anticipated in a group of injuries with anterior pelvic disruption and partially stable posterior pelvic ring.[143] Conversely, in C-type pelvic disruptions the hemorrhage is usually identified within the posterior sources due to the disruption of the posterior elements.[37,143]

The reported incidence of **urogenital injuries** in conjunction with pelvic injuries varies from 1.6% to 40%. This great variance is mainly influenced by differences in age groups, types of pelvic fractures in different series, and missed diagnosis of urogenital injuries in the initial management of the patients.[144-147] Male urethral injuries commonly occur at the bulbomembranous junction distal to the external urinary sphincter, where the urethra is vulnerable to direct avulsion when fractured pubic rami are displaced, or indirectly as a result of shearing forces.[148,149] The incidence of urethral injuries is considerably lower in females, due to the shorter urethral length and more mobile, non-rigidly fixed urethra.[147,150] In small series, the pelvic fracture urethral injury rates vary from 6% to 19%, and bladder rupture from 0.7% to 28%.[145,146,150-152] However, a recent review of the National Trauma Data Bank (NTDB) reported a lower incidence of urethral injuries of 1.54% for men and 0.15% for women, and bladder injury rate of 3.4%, which was equal for both sexes.[64]

Rectal injuries are uncommon, occurring in approximately 2% of patients with high-energy pelvic injuries, and if unrecognized they are associated with significant morbidity and mortality.[153,154]

Outcome

Functional outcome has been investigated by numerous authors in patients with displaced sacral fractures and posterior pelvic ring injuries. The majority of these studies report considerable impairments, including neurologic deficits, bladder, bowel, and sexual dysfunctions, as well as pain and poor patient-reported health and quality of life. Outcome after lumbosacral dissociation injuries are mostly reported as case reports or small case series, commonly with high rates of neurologic injuries and residual pain.[88,92,113,155-157] A summary of some of studies reporting outcome after displaced sacral fractures and pelvic ring injuries is listed in Table 1.

Table 1. Summary of studies on outcome following pelvic ring disruptions and sacral fractures.

Outcome measure	*Author*	*N*	*FU time*	*Fracture type*	*Treatment*	*Results*
Neurologic deficits	Templemann et al.[108] (1996)	30	28 months (12-57)	Displaced sacral fractures	Int. fix.	47% 2 (7%) iatrogenic.
	Lindahl et al.[141] (2005)	101	23 months (12-85)	Type C	Int. fix.	40/101 (40%) motor recovery in 22/40 (55%)
	Pohlemann et al.[158] (1996)	58	28 months (12-58)	Type B and C	Ext. and int. fix.	B: 32% C: 40% sensory, 33% motor.
	Tornetta et al.[159] (1996)	46	44 months (12-101)	Unstable posterior pelvic ring injuries	Int. fix.	35%
	Ayoub et al.[160] (2009)	32	24 months (19-47)	Sacral fractures OTA type C	Int. fix.	34%
	Suzuki et al.[161] (2007)	57	47 months (24-107)	Type B and C	Mixed	28%
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	7/11 sensory (67%) 2/11 motor (18%)
	Majeed[163] (1990)	42	40 months (12-72)	Unstable pelvic fractures	Ext. fix.	38%
	Rommens et al.[106] (2002)	122	22 months (12-73)	Type B and C	Ext. and int. fix.	B:27% , C: 42% Recovery 72% (B), 29% (C)
	Henderson et al.[164] (1989)	26	8 years (5-14)	Type B and C	Non-op.	46% sensory 38% motor and reflex deficits.
	Ayoub et al.[115] (2012)	28	26 months (20-37)	Displaced spinopelvic dissociations	Int. fix.	19/28 (68%) complete recovery. 8/28 (29%) partial recovery. 1/28 (3%) no recovery.
	Gribnau et al.[113] (2009)	8	36 months (5-56)	U-shaped sacral fractures	Int. fix.	No complete recovery. 4 (50%) improved. 4 (50%) unchanged.
	Nork et al.[114] (2001)	13	14 months (7-48)	U-shaped sacral fractures	Int. fix.	11/13 complete recovery.
	Schildhauer et al.[97] (2006)	18	31 months (12-57)	Spinopelvic dissociations with cauda equina	Int. fix.	3/18 complete recovery. 15/18 improved.

Outcome measure	*Author*	*N*	*FU time*	*Fracture type*	*Treatment*	*Results*
Pain	Tornetta et al.[159] (1996)	46	44 months (12-101)	Unstable posterior pelvic ring injuries	Int. fix.	48%
	Lindahl et al.[141] (2005)	101	23 months (12-85)	Type C	Int. fix.	34/101 (34%)
	Pohlemann et al.[158] (1996)	58	28 months (12-58)	Type B and C	Ext. and int. fix.	B: 11% C: 67%
	Kabak et al.[145] (2003)	36	45 months (21-116)	Type C	Int. fix.	11/36 (31%)
	Sen et al.[165] (2010)	24	31 months (24-49)	Pelvic ring injuries	Mixed	13/24 (54%)
	Rommens et al.[106] (2002)	122	22 months (12-73)	Type B and C	Ext. and int. fix.	B1: 29%, B2-3: 16.5% C: 54%
	Helgeson et al.[89] (2011)	15	1.7 years (1-4.5)	Lumbosacral dissociations, blast injuries	Mixed	6/15 (40%)
	Gribnau et al.[113] (2009)	8	36 months (5-56)	U-shaped sacral fractures	Int. fix.	7/8 (88%)
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	11/11 (100%)
	Henderson et al.[164] (1989)	26	8 years (5-14)	Type B and C	Non-op.	85%
	Keating et al.[166] (1999)	26	19 months (13-48)	Type C	int. fix.	85%
Urinary dysfunction	Odutola et al.[167] (2012)	151	min. 1 year	Unstable pelvic fractures	Ext. and int. fix.	41%
	Kabak et al.[145] (2003)	36	45 months (21-116)	Type C	Int. fix.	11/36 (31%)
	Cole et al.[168] (1996)	52	36 months (5-74)	Type C	Int. fix.	19/52 (37%)
	Pohlemann et al.[158] (1996)	58	28 months (12-58)	Type B and C	Ext. and int. fix.	B: 6/58 (10%) C: 9/58 (16%)
	Lindahl et al.[141] (2005)	101	23 months (12-85)	Type C	Int. fix.	5/101 (5%)

Outcome measure	*Author*	*N*	*FU time*	*Fracture type*	*Treatment*	*Results*
Urinary dysfunction	Ayoub et al.[160] (2009)	32	24 months (19-47	Sacral fractures OTA type C	Int. fix.	4/32 (13%)
	Suzuki et al.[161] (2007)	57	47 months (24-107)	Type B and C	Mixed	16/57 (28%)
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	5/11 (45%)
Bowel dysfunction	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	6/11 (54%)
	Brenneman et al.[169] (1997)	27	4 years (average)	Open pelvic fractures	Mixed	3/27 (11%) fecal incontinence.
Sexual dysfunction	Kabak et al.[145] (2003)	36	45 months (21-116)	Type C	Int. fix.	14/32 (44%)
	Cole et al.[168] (1996)	52	36 months (5-74)	Type C	Int. fix.	15/52 (29%)
	Pohlemann et al.[158] (1996)	58	28 months (12-58)	Type B and C	Ext. and int. fix.	Sexual dysf. seen only in type C. 5/40 males (13%) erectile dysf. 1/18 females dyspareunia.
	Tornetta et al.[159] (1996)	46	44 months (12-101)	Unstable posterior pelvic ring injuries	Int. fix.	13%
	Odutola et al.[167] (2012)	151	min. 1 year	Unstable pelvic fractures	Ext. and int. fix.	43%
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	4/11 (36%)
	Harvey-Kelly et al.[170] (2014)	80	36 months (12-96)	Pelvic ring fractures	Mixed	14/32 females (44%) 25/48 males (52%)
	Vallier et al.[171] (2012)	92	46 months (12-129)	Type B and C	Mixed	Women only. 48/92 (56%) Dyspareunia.
	Wright et al.[172] (2006)	34	1 year (10-14 months)	Posterior pelvic ring injuries	NS	10/21 men (48%) 2/13 women (15%)
	Malavaud et al.[173] (2000)	46	27 months (± 13)	Pelvic ring fractures	NS	Men only. 30% with erectile dysfunction.

Outcome measure	*Author*	*N*	*FU time*	*Fracture type*	*Treatment*	*Results*
Return to work	Kabak et al.[145] (2003, Turkey)	36	45 months (21-116)	Type C	Int. fix.	26/36 (72%)
	Cole et al.[168] (1996, USA)	52	36 months (5-74)	Type C	Int. fix.	Work status affected in 35%
	Tornetta et al.[159] (1996, USA)	46	44 months (12-101)	Unstable posterior pelvic ring injuries	Int. fix.	41/46 (89%)
	Templemann et al.[108] (1996, USA)	30	28 months (12-57)	Displaced sacral fractures	Int. fix.	16/30 (53%)
	Suzuki et al.[161] (2007, Japan)	57	47 months (24-107)	Type B and C	Mixed	48/57 (84%)
	Sen et al.[165](2010, India)	24	31 months (24-49)	Pelvic ring injuries	Mixed	16/24 (67%)
	Gruen et al.[174] (1995, USA)	48	min 1 year (mean 17.5 months)	Type B and C	Mixed	76% of those in full time job pre-injury.
	Brenneman et al.[169] (1997, Canada)	27	4 years (average)	Open pelvic fractures	Mixed	14/22 (64%)
	Miranda et al.[175] (1996, USA)	80	7.5 years average	All pelvic fractures	Ext. fix. and non-op.	Return to previous job: Type A: 77%, B: 75%, C: 81%
	Van den Bosch et al.[176] (1999, Netherland)	38	36 months (4-84)	Type B and C	Ext. and int. fix.	19 back to full time jobs, 6 changed job, 2 unable to work and 11 not specified.
	Keating et al.[166] (1999, Scotland)	26	19 months (13-48)	Type C	Int. fix.	65%
	Gabbe et al.[177] (2014, Australia)	111	24 months	Type B and C	Mixed	Type B: 63% Type C: 50%
Patient-reported health	Suzuki et al.[161] (2007)	57	47 months (24-107)	Type B and C	Mixed	SF-36: lower than the norm.
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	SF-36: lower than the norm.
	Borg et al.[178] (2010)	45	2 years	Type B and C	Int. fix.	SF-36 and LiSat-11; both lower than the reference population.
	Van den Bosch et al.[176] (1999)	38	36 months (4-84)	Type B and C	Ext. and int. fix.	SF-36: lower than the norm.
	Oliver et al.[179] (1996)	35	24 months (16-28)	Type B and C	Int. fix.	Physical activities more affected than mental activities, compared to the norms.

Outcome measure	*Author*	*N*	*FU time*	*Fracture type*	*Treatment*	*Results*
Radiological outcome	Pohlemann et al.[158] (1996)	58	28 months (12-58)	Type B and C	Ext. and int. fix.	Type C: RD = 0: 15/30 (50%) RD = 1-10 mm: 13/30 (43%) RD > 10 mm: 2/30 (7%)
	Cole et al.[168] (1996)	52	36 months (5-74)	Type C	Int. fix.	Non-union 1/52 RD > 5 mm: 7/52 (13%)
	Kabak et al.[145] (2003)	36	45 months (21-116)	Type C	Int. fix.	RD < 10 mm: 34/36 (94%) RD > 10 mm: 2/36 (6%)
	Lindahl et al.[141] (2005)	101	23 months (12-85)	Type C	Int. fix.	RD > 10 mm: 10/101 (10%)
	Ayoub et al.[160] (2009)	32	24 months (19-47)	Sacral fractures OTA type C	Int. fix.	RD > 10 mm: 5/32 (16%)
	Griffin et al.[180] (2003)	62	Min. 12 months	Type C	Int. fix.	RD > 10 mm: 10/62 (16%)
	Suzuki et al.[161] (2007)	57	47 months (24-107)	Type B and C	Mixed	RD average 5 mm (0-40 mm)
	Nepola et al.[181] (1999)	33	7.2 years	Type C	Ext. fix. or non-op.	RD average 18 mm (range 2-52) No correlation to SF-36, genitourinary dysfunction, or pain.
	Ayoub et al.[115] (2012)	28	26 months (20-37)	Displaced spinopelvic dissociations	Int. fix.	No loss of reduction or increase in kyphosis.
	Siebler et al.[162] (2010)	11	43 months (25-67)	Sacral fractures zone-III	Non-op.	All healed. Increased kyphosis: 6/11 (55%)
	Helgeson et al.[89] (2011)	15	1.7 years (1-4.5)	Lumbosacral dissociations, blast injuries	Mixed	Initial kyphosis in 11/15; increase of kyphosis in 2/11, both were treated non-op.
	Nork et al.[114] (2001)	13	14 months (7-48)	U-shaped sacral fractures	Int. fix.	No significant changes in kyphosis. All healed.
	Schildhauer et al.[97] (2006)	18	31 months (12-57)	Spinopelvic dissociations with cauda equina	Int. fix.	Kyphosis unchanged post-op. to follow-up.

Ext. fix.: External fixation, Int. Fix.: Internal fixation, Non-op.: non-operative treatment, Mixed: mixture of operative and- non-operative treatment, NS: Not specified, RD: residual displacement.

Mortality rates in patients with pelvic fractures vary considerably, 4% to 31%, depending on the populations or series studied.[63,65,182,183] Death directly attributable to pelvic fracture is uncommon; however, the presence of a pelvic fracture is significantly associated with increased mortality for the majority of trauma patients.[184-187] Although, pelvic fracture is one variable among many that contribute to mortality risk,[1,188,189] other important factors include additional injuries and injury severity, [63,190-192] head injuries,[65,193] hemodynamic instability and amount of blood transfusion,[65,183] and higher age.[191,194,195]

Before the 1980s, pelvic fractures were largely treated with non-operative modalities.[196-198] Non-operative forms of treatment have been employed in earlier reports with acceptable results, but with the unstable posterior pelvic injuries having poorer outcome compared to stable types.[107,164] In a review of 42 patients, Pennal and Messiah[199] reported the final disability of 42 patients, 18 of whom were treated operatively and 24 non-operatively. High rates of disability were reported in the non-operative group versus the operative group. Malunions and nonunions are reported by several authors, mainly occurring as a result of non-operative treatment or delayed treatment of unstable pelvic ring fractures.[199-204] Common problems reported in these series were low back and posterior pelvic pain, sitting imbalance, posterior iliac prominence, limp, and vaginal wall impingement. Later, operative treatment with open or closed reduction and internal fixation has become the widely accepted treatment method for unstable posterior pelvic ring and sacral fractures.[73,145,158,205] With increasing surgical treatment of these injuries, early surgical stabilization of unstable pelvic fractures was reported to reduce the rate of complications.[206,207] These include thromboembolism, acute respiratory distress syndrome (ARDS), infections, multi organ failure, and decubital ulcers, as well as reducing hospital stay. However, as the majority of patients with pelvic fracture are polytraumatized, they are most often respiratory and hemodynamically unstable, requiring resuscitation in the early, acute phase. Timing of the definitive surgical fixation has been shown to be of great importance, with the “damage control orthopaedics” principles, in terms of reducing the complications.[208-212]

Patients surviving severe pelvic and polytrauma may suffer considerable morbidity and functional disability, influenced by the additional injuries to other body regions,[7,63,64] limiting complete recovery and increasing the risk of subsequent disability.[145,213,214] The reported outcome for type C pelvic ring injuries is generally worse than type B injuries.[6,106,158,174]

2. AIMS OF THE STUDY

The overall aim of this study was to assess long-term problems and functional outcome after high-energy sacral fractures. We aimed to describe clinical, functional and radiological outcome in a 10-year perspective. A better understanding of the sequelae and outcome after displaced sacral fractures is important in improving treatment and rehabilitation of future patients sustaining these injuries.

The specific aims were:

- To describe functional outcome after operatively treated displaced sacral fractures, 10 years post-injury. Also to record changes of the outcome measures over time by comparing the 10-year results with results from the 1-year follow-up of the same patient cohort (Paper 1).

- To assess radiographic findings more than 10 years after surgically treated displaced sacral fractures. To investigate the correlation between long-term radiographic findings and neurologic deficits and pelvis related pain at follow-up (Paper 2).

- To assess long-term patient-reported health (PRH) in patients with surgically treated displaced sacral fractures, and its changes over time by comparing the 10-year results with results from the 1-year follow up (Paper 3).

- To describe long-term functional outcome and radiographic findings in patients with traumatic lumbosacral dissociation (Paper 4).

3. MATERIALS AND METHODS

Patients

<u>*Paper 1-3*</u>

From July 1996 – October 2001, in a prospective registration of pelvic fractures at Ullevaal university hospital, 39 consecutive patients with displaced sacral fractures, as part of vertically unstable pelvic ring disruptions were registered. All were treated operatively. A one-year follow-up study of these patients, with functional outcome assessment was conducted, where 32 of the 39 patients were available for the 1-year follow-up study, the results of which are published previously[214,215]. In the present study, these patients were followed up at a convenient long-term time point with a mean of 10.7 (range 8.1-13.4) years after the injury. Same outcome measures were assessed with the same methods in both follow-ups with collection of comparative data. In this way, we were able to determine changes in clinical parameters over time.

The 7/39 patients who were lost to follow-up at the 1-year study, were not contacted to participate in the present long-term study, as no data were available on these patients from the 1-year follow-up.

Of the 32 patients, one was excluded due to a complete spinal cord injury with subsequent paraplegia, and one was deceased. Two patients were lost to follow-up, as they declined to participate. Thus, out of 30 eligible patients, 28 were available for the current 10-year outcome study.

<u>*Paper 4*</u>

In a retrospective review of the Pelvic Fracture Register and hospital charts at the Orthopaedic department, Ullevaal university hospital, patients with high-energy lumbosacral dissociation fractures were identified during the period of March 1997 to September 2006. Exclusion criteria were low-energy osteoporotic fractures, sacral insufficiency fractures, associated unstable pelvic ring injuries, and displaced acetabular fractures. Of the 21 patients who met the inclusion criteria, three were foreign residents and two were deceased. Of the remaining 16 eligible patients, one was not traceable and lost to follow-up. The remaining 15 patients were included in this long-term follow-up.

Methods

Data collection and clinical examination

All patients (paper 1-4) were contacted by mail and telephone. Written information was sent to the patients prior to inclusion, and they were asked to respond in a written form, which was attached to the information letter.
The examinations and interviews of the patients were conducted uniformly according to the study protocol at the outpatient clinic at Oslo University Hospital, by two physicians not involved in the initial treatment of the patients.
All patients signed an informed consent form at the day of examination.

Neurologic function

Sensorimotor function in the lower extremities and the perineum (lumbosacral dermatomes) was classified according to the International Standards for Neurological Classification of Spinal Cord Injury (ISCOS), developed by the American Spinal Injury Association (ASIA)[22] *(Appendix I)*. Sensory function in the lumbosacral dermatomes was assessed by pinprick at key points, and graded as normal, partial or lacking. Motor function was assessed by manual testing of muscle strength in five key movements corresponding to lumbosacral segments, and graded as normal (ASIA 5), slightly changed (ASIA 4-3), significantly changed (ASIA 2-1) and total paralysis (ASIA 0).
The grading system of neurological injuries associated with sacral fractures, developed by Gibbons et al.[139] is widely used, where the neurologic injuries are classified as: 1. none, 2. paresthesias only, 3. motor loss (with or without sensory loss), and 4. bowel and/ or bladder function impaired (with or without motor or sensory loss). We modified the Gibbons system by removing the bowel/bladder dysfunction component from grade 4. and assessed the bladder and bowel functions separately. Thus, the overall neurologic function according to the modified Gibbons system was: 1. normal; 2. sensory changes only; 3. partial, combined sensory and motor deficits; and 4. complete loss of neurological function.

Urinary function

Urinary function was assessed with a questionnaire[216] concerning frequency, urgency, hesitation, or incontinence *(Appendix II and III)*. In patients with volitional voiding, flowmetry was used to determine maximum flow. Postmicturition volume was assessed by ultrasound within 10 minutes after emptying of the bladder. Measurements of maximum flow were classified and graded into percentiles according to the Liverpool nomograms, developed by Haylen et al.[217] offering reference ranges for both maximum and average urinary flow rates in both sexes. Overall bladder function was graded based on results from questionnaires, flowmetry/nomograms, and ultrasonography as: 1. normal voiding pattern (same as before injury); 2. slightly changed voiding pattern but normal flow and residual urine less than 50 mL and no incontinence; 3. significantly changed voiding pattern with reduced flow below 5th percentiles, or more than 50 mL residual urine or incontinence; and 4. no volitional voiding and regular intermittent catheterization or urinary deviation.

Bowel function

Bowel function was assessed with an interview-based questionnaire [216] addressing frequency and problems with urgency, diarrhea, constipation, or incontinence *(Appendix II)*. Bowel function was graded according to the questionnaire as: 1. normal bowel patterns (same as before injury); 2. slightly changed (changes in frequency or need of medication such as laxatives); and 3. completely changed with incontinence and/or need of enemas or colostomy.

Sexual function

Problems associated with sexual function were assessed in an interview with open questions *(Appendix II)*. In female patients, problems related to sexual function, in particular, pain during sexual intercourse or reduced arousal was noted. In male patients, erectile dysfunction was assessed using questions from the Norwegian version of the International Index of Erectile Function (IIEF) [218] questionnaire, pertaining to sexual activity during the past 4 weeks *(Appendix IV)*. This questionnaire addresses the different domains of male sexual function, including sexual desire, erectile, and orgasmic function, intercourse, and overall satisfaction.

Patient-reported outcome

Patient-reported health was assessed with the Norwegian version of the SF-36, version 2. The questionnaires were mailed to the patients, to be filled out prior to the clinical examination, and were collected at the time of examination *(Appendix V).*

The SF-36 is a generic, self-assessed health outcome measure containing scales for physical functioning, role-physical function, bodily pain, general health, vitality, social functioning, role-emotional function, and mental health. The scale range is 0 to 100, worst to best.[219] There are two versions of SF-36, version 1 (V1) and version 2 (V2), both translated into Norwegian. The SF-36-scores from the 1-year follow-up and the validated scores for the Norwegian population are based on V1.[215,220,221] The V2 is a slightly modified version of V1, with improved accuracy and sensitivity.[222] The SF-36 V2 scores from the present study were converted to SF-36 V1 scores prior to comparison with the 1-year scores and the norm based scores. Conversion across the versions was made using the QualityMetric Health Outcomes™ Scoring Software 4.0, provided by QualityMetric Inc. Lincoln, RI, USA.

Ten-year SF-36 scores were adjusted for sex and age, and then compared with sex- and age-adjusted norm-based scores.[221] Ten-year SF-36 scores were also compared with 1-year SF-36 scores to observe any changes over time.

Pain

Pain was self-assessed by the patients, using a visual analogue scale (VAS) ranging from 0-10, with 0 representing no pain and 10 the most severe pain experienced within the last 24 hours. The patients were asked to rate their average pain level, particularly in the lower back and posterior pelvic area. When present, radicular pain to the lower extremities was recorded. Patients were also asked to demarcate painful areas on a drawing of a human body. These drawings were scanned and the marked areas superimposed and compiled (Figure 11). Peripheral pain in the lower limbs was not considered in cases where there were sequelae after lower extremity injuries.

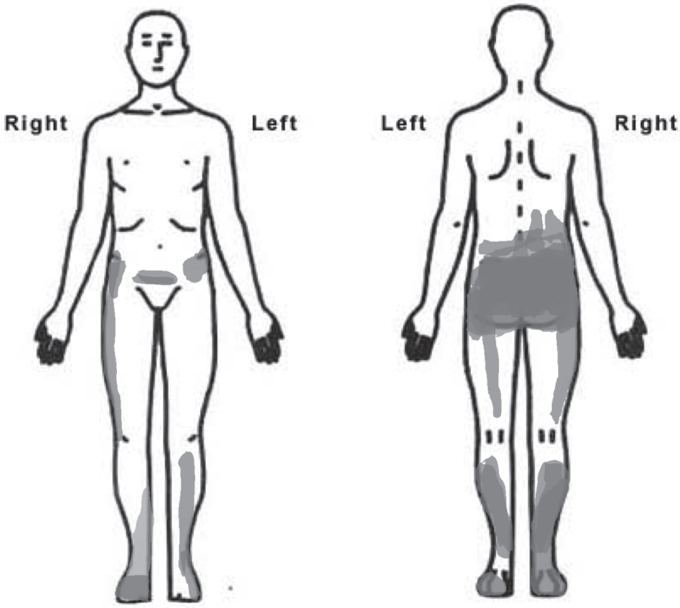

Figure 11. Superimposed areas of pain, reported and drawn by the patients. The darker the shade, the more patients have demarcated the area, notably in the lower back and the posterior pelvic area. Demarcated areas in the lower extremities illustrate radiating pain.

Ambulation

The assessment of ambulation was based on clinical examination/ inspection and patient-reported function, and was graded as normal (same as before injury); slightly impaired (reduced endurance or a limp, but able to walk unaided); significantly impaired (dependent on walking aid or wheel chair for long distances); and severely impaired (permanent use of manual or electric wheel chair).

ADL and employment status

Information regarding ADL and employment status was obtained by structured interview. ADL was defined as dependence or independence of another person or healthcare services in the daily activities.

Radiographic assessment

Plain radiographs

At follow-up, all patients **(paper 2)** underwent a standardized x-ray examination of the pelvis and the lumbar spine. This included pelvic antero-posterior, inlet and outlet views according to standard radiographic protocol. [223]

Residual displacement (RD) was defined as a cephalad or posterior displacement of the hemipelvis and sacrum, and graded as less than 10mm or $\geq$ 10 mm. In the outlet views, cephalad residual displacement (CRD) was recorded by measuring the height difference between the top lateral prominences of the two sacral transverse process elements.[10] In the inlet views, posterior residual displacement (PRD) was recorded by measuring the height difference between the posterior superior iliac spines.[203]

Computer tomography (CT)

All patients were also examined with a 64 channel Multi Detector Computer Tomography (MDCT) **(paper 2 and 4)**. The CT images were scrutinized for nonunion, ankylosis, osteoarthritis (OA) and heterotopic ossification. Fracture healing was confirmed by the presence of bridging trabecular bone across the fracture lines on CT.

To identify any bony entrapment of the nerves, all three sets of 2D CT images were used, following each nerve from the spinal canal to the point where the nerve was peripheral to the sacrum. Narrowing of the neural foramina were recorded and then divided into four categories: 1- no narrowing, 2- less than 50% narrowing, 3- more than 50% narrowing, and 4- total occlusion of the foramen.

L5 and S1 nerves were then followed in their post-foraminal course and any changes of their path, i.e. displacement of the nerves by pathologic bony structures and thus diversions from the assumed anatomical course or entrapment/overgrowth of the nerves by bony structures were recorded. The S2-S4 nerves were not as readily identifiable post-foraminally as L5 and S1, and therefore not included in the post-foraminal assessment. Finally, any narrowing of the spinal canal was recorded, using the midline sagittal images evaluating the inner tapering AP-diameter.

An experienced radiologist in pelvic traumatology reviewed all the radiographs and CT scans at least twice. He was blinded to the clinical information.

Statistics

In papers 1, 2 and 4, we used nonparametric methods for statistical analyses due to skewed distribution of the variables. Wilcoxon signed rank test for paired samples was used to compare medium- and long-term results and for the correlation analyses, Spearman correlation coefficients were used.

In paper 3, the data were tested for normality with Q-Q plots, and were found to have an acceptable normal distribution. Z-scores were calculated, using sex- and age-adjusted norm-based scores for the general Norwegian population [221]. The one-sample t-test was used to compare 10-year SF-36 scores with norm-based scores and the paired-sample t-test was used for comparison with 1-year SF-36 scores. For the correlation analyses, Pearson correlation coefficients were used. A p-value of ≤ 0.05 was considered statistically significant.

All statistical analyses in papers 1 and 2 were performed with PASW Statistics 18 software and in paper 3 and 4 with SPSS Statistics 21 software, both provided by IBM SPSS Inc.

Ethics

The study was reviewed and approved by the Regional Committee for Medical and Health Research Ethics, Region South- East Norway. All patients signed an informed consent document at follow-up.

4. SUMMARY OF PAPERS

Paper 1

A cohort of 28 consecutive patients with operatively treated displaced sacral fractures was followed in a 10-year follow-up study. The aim was to assess functional outcome pertaining to neurologic function in the lower extremities and perineum, urinary bladder function, bowel and sexual function. Comparative data were available from a 1-year follow-up study of this cohort, conducted by Tötterman et al[214]. The 10-year results were compared with 1-year results to record any changes in these functions over time. This investigation revealed a high rate of impairments among the patients, especially concerning neurologic deficits and urinary dysfunctions. Neurologic deficits were found in 26, and 19 patients had urinary dysfunctions. Eight patients reported bowel dysfunctions and 12 reported problems associated with sexual function. When comparing the 10-year with the 1-year results, we observed a significant deterioration of urinary function in 11 patients (p=0.005) and only 1 patient had improved bladder function. A slightly higher number of patients reported problems associated with sexual function, 44% at 10 years vs. 38% at 1 year, and no significant changes were found in neurologic or bowel functions.

Paper 2

In this paper we aimed to assess radiological outcome in a 10-year follow-up of 28 patients with operatively treated displaced sacral fractures. We also aimed to investigate any correlations between pathologic radiographic findings and neurologic deficits and pain. In 16 patients we found residual displacement (RD) more than 10 mm of the sacrum and hemipelvis, either in cephalad direction, posterior direction or in combination of both. No sacral non-unions were observed, but the CT scans revealed bony changes around the fracture area, including narrowing of the sacral neural foramina. A further frequent finding was topographical changes of the sacral bone and bony impingement/ encroachment of the L5 and S1 nerves. These pathologic findings correlated significantly with neurologic deficits in the lower extremities. No correlations were found between any of the pathologic findings, including RD, and posterior pelvic pain.

Paper 3

The main outcome measure of this paper was patient-reported health (PRH), measured by a generic health outcome instrument, namely the SF-36. The study population was the same cohort as in paper I and II. The aim of study was to assess PRH among these patients in a long-term perspective, and compare the 10-year results with the 1-year results to detect any changes in self perceived health among these patients over time. A further question was if there were any correlations between PRH and clinical outcome data, such as neurologic deficits, urinary, bowel and sexual dysfunctions and pain. Finally, we recorded the patients' employment status and return to work. The overall 10-year SF-36 scores were significantly lower than norm-based scores for the Norwegian population. This applied for all domains, except for mental health. No significant changes were observed in scores when comparing 10-year results with the 1-year results. Significant correlations were found between pain and several SF-36 domains (physical functioning, role physical, bodily pain, general health and role emotional). Significant correlations were also found between SF-36 and bowel dysfunction (bodily pain, role emotional) and sexual dysfunction (social functioning, role emotional). Six patients were on permanent disability pension before injury. Of the 22 patients who were in full-time employment (including 3 students) before injury, 12 returned to full-time employment and 10 went on to permanent disability pension.

Paper 4

In this retrospective study, 13 patients with traumatic lumbosacral dissociation fractures (TLSD) were included. The aim of this study was to asses the functional and radiological outcome in patients with this rare type of sacral fracture. Five patients were treated operatively and 8 were treated non-operatively. The mean follow-up time was 7.7 years (range 3-12).The assessment of functional outcome included neurologic function in the lower extremities, urinary, bowel and sexual function, self-reported pain on a visual analog scale (VAS) and patient-reported health (PRH) measured by SF-36. CT scans were obtained from the lumbar spine and the pelvis. Eleven had neurologic deficits in the lower extremities, 9 had urinary bladder dysfunction, including 2 who had no volitional urinary voiding, and 3 reported altered bowel function. Eight patients reported problems associated with sexual function. Among the male patients, erectile dysfunction was most frequently reported and female patients complained mostly about pain during intercourse. The SF-36 scores were significantly lower than the norm based scores, except for vitality, role emotional, and mental health, which were also lower than the norm, but without statistical significance. All fractures went to union, although with residual displacement in terms of kyphotic angulation across the fracture site with a mean of 33 degrees (range 15-63), antero-posterior translation of the proximal fragment and narrowing of the central sacral canal. An increase of sacral kyphotic angulation was observed in four patients, two of whom were treated operatively. The other two patients were treated non-operatively, one of whom had a minimally displaced sacral fracture and no neurological deficits initially. In addition to the increase of kyphosis, this patient also developed secondary neurologic deficits, both sensory and motor, in L5-S4 dermatomes.

5. DISCUSSION

Among the strengths of this study is the long observation period of mean 10.7 years **(paper 1-3)** and mean 7 years **(paper 4)** post injury. Another strength lies in the detailed assessment of outcome measures such as neurologic, and bladder function, radiologic outcome and patient-reported health. We had also a high response rate, 28/30 (93%) of the eligible patients in paper1-3, and 15/16 (94%) in paper 4.

The designs of **papers 1 and 3** are longitudinal prospective cohort studies, with all the patients enrolled at the time of injury, with follow-up and similar data collection at two time points for comparison. The design in **paper 2** is a cross sectional study, with a “snap-shot” of patients’ radiological findings at present follow-up. This is due to the obvious limitations represented by the poor availability of previous radiographs of a considerable number of patients. A large number of postoperative radiographs, and radiographs from the 1-year follow-up were untraceable. Therefore, in spite of having complete sets of plain x-ray films and CT scans from this long-term follow-up, we were not able to make comparisons or evaluation of the radiological changes over time in **paper 2**.

Being a retrospective case series, **paper 4** has its inherent limitations. The initial data were collected retrospectively, and were dependent on the availability and accuracy of the medical records. Selection bias was minimized by thorough review of the Pelvic Fracture Register and hospital records, in addition to a detailed review of the initial radiographs, to capture the specific fracture types.

Another limitation in this study (all papers) was the heterogeneity and the low number of study patients, due to the rarity of displaced sacral fractures, despite relatively long inclusion period. Therefore, the results of the statistical analyses should be interpreted with caution.

Methodological considerations

Assessment of neurologic function in the lower extremities and the perineum was carried out using ASIA chart and Gibbons’ score. The ASIA system is based on neurological responses; touch and pin prick sensations tested at key points in each dermatome, and strength in the muscles that control key motions in the four extremities.[22] It is not validated for patients with sacral fractures, but for patients with spinal cord and other neurological injuries, sharing the same symptoms with neurological deficiencies. A sum score can be yielded in the chart after examination and scoring of each dermatome from C2-S4 bilaterally, indicating a “total” neurological status of the patient. In this study, we were interested in neurological injuries and dysfunction related to the sacral and pelvic fractures. Therefore, only the part of the ASIA chart that concerns the lumbar and sacral roots and dermatomes were used, to assess neurologic function in the lower extremities and the perineum. Thus, we did not use the sum scores of the ASIA chart, but scores in each dermatome.

In order to evaluate the extent of neurologic deficits, these scores were then graded according to the scoring system developed by Gibbons et al.,[139] in which bladder and bowel dysfunction is included in the evaluation of the neurologic deficits. Previous studies have shown that determining bladder dysfunction solely by neurological examination may be insufficient.[224] Furthermore, bladder and bowel dysfunction may be caused not only by neurologic injuries, but also by direct injuries to these organs.[61,225] Therefore, we modified the Gibbons' score by removing bladder and bowel components from its grade 4, and replace it with "total loss of neurologic function". Also, in this way the neurologic deficits could be graded, ranging from grad 1 being normal to grade 4 complete loss of neurologic function. The assessment of bladder and bowel function was performed separately, as described in the methods section.

Urinary bladder, bowel and sexual functions were assessed by structured interview based on questionnaires *(Appendices II and III)* in order to gather patient-reported information concerning problems with these functions. The questionnaires used as the basis for the interview are not validated assessment tools, but rather a "check-list" in order to standardize the questions uniformly for all patients. In one questionnaire, only bladder function is in focus *(Appendix III)* and the questions concern incontinence, urge and frequency, in addition to the patient's subjective experience of having urinary problems. This questionnaire is not a disease specific assessment tool , but it is developed for assessment of bladder function in patients with neurogenic bladder dysfunction such as myelomeningocele and sequelae after spinal cord injuries.[216,226] In addition, in patients with volitional voiding, uroflowmetry followed by residual urine measurement by ultrasound allowed an objective evaluation of bladder function, and its ability to expel urine. The Liverpool Nomograms [217] were developed to establish normal reference ranges for maximum and average urinary flow in both sexes were used as normative references to evaluate the flowmetry results in our patients. These results, together with residual urine measurements and the patient-reported information of urinary symptoms allowed a comprehensive assessment of bladder function. In this way, not only we were able to report that these patients had bladder dysfunctions, but also to characterize and evaluate the extent of the pathologic function.

Sexual function assessment is complex, as it is influenced by physical and psychosocial factors.[227] In the interest of brevity and simplicity, we chose to not use any questionnaires or other scoring tools to evaluate sexual dysfunction, as an in-depth analysis of this outcome measure was beyond the scope of the current study. Instead, as a part of the structured interview, we asked the patients directly about any sexual problems and in that case what kind of disturbance they experienced *(Appendix II).* The International Index of Erectile Function (IIEF) was not used in this study for scoring of the erectile function in men. However, we used selected questions from the IIEF questionnaire in the interview for the purpose of standardization of the interview questions.

As all these questionnaires and methods for assessment of urinary, bowel and sexual functions also were used in the 1-year follow-up, the data were comparable which allowed assessment of changes in these functions over time.

Patient-reported health. Health can be measured either by disease-specific or generic instruments. There are no validated disease-specific instruments for pelvic or sacral fractures available in the Norwegian language. Also, no other self-assessed or patient-reported health measurement tools exist for pelvic fractures. Therefore, generic instruments can be used to assess general health, seen from the patients' perspective. Our choice of the SF-36 for this purpose was based on the fact that it is a widely used and validated generic health outcome measure, with translated versions in several languages including Norwegian, as well as norm-based population data in several countries.[161,228] Another argument for choosing SF-36 rather than other patient-reported health surveys was the possibility to compare our results with other similar studies that have used SF-36 (Table 1) and with the SF-36 results of our cohort from the 1-year follow-up to record changes over time.
The SF-36 V2 (version 2) is a revised version and contains some minor differences from V1 (version 1). We used the V2, as it is improved with simpler instructions and questionnaire items, an improved layout for questions and answers in the self-administered version. It also has greater comparability with widely used translations and cultural adaptations, and five-level response choices in place of dichotomous response choices for items in the two role functioning scales.[222] The new changes have improved the precision and responsiveness of the SF-36 without jeopardizing its underlying structure.[222,229] With the conversion software, the QualityMetric Health Outcomes™ Scoring Software 4.0, provided by QualityMetric Inc. Lincoln, RI, USA, converting the version 2 scores into version 1 scores, a comparison of data across the two versions is uncomplicated.

Pain assessment in patients after polytrauma can be challenging, as it may have multiple sources. Pain is evaluated based on the patients' subjective reporting, as it cannot be measured in any objective means. No validated pain assessment instruments or questionnaires are available for pelvis related pain following pelvic trauma. A few pelvic outcome scores have been proposed previously, where pain is one of several outcome measures incorporated in the scoring systems, often divided into categories rather than a scale.[158,181,230] In order to assess pain as a separate entity, we chose to use a visual analog scale (VAS), which is simple to administer and is a widely used instrument for pain assessment in several conditions, as it is not specific for any disease or body region. We asked our patients to demarcate their painful body regions on a drawing to visualize these areas, both for us and the patients themselves. Then, they were asked to grade their pain specifically in the pelvic area and radiating pain to the lower extremities on the VAS scale. Being continuous data, the VAS scores can also be used in statistical analyses.

Ambulation, ADL and return to work are not as readily quantifiable outcome measures as the other measures evaluated in this study, and were assessed by direct questions as part of the structured interview.

Radiologic assessment. There are no validated radiographic measurement methods evaluating the sacrum or the pelvic ring.[231] Although several authors have suggested different methods,[118,203,205,232] all measure deformities or overall displacements of the hemipelvis or the pelvic ring on plain radiographic films. Kuklo et al.[102] described methods for diagnosis and measurements of sacral fracture displacements on CT in the acute phase. In their methods, 2D images were used to measure fracture gaps and translations of fragments using the cortices of each side of the fracture as reference points. However, these methods are not applicable in healed fractures, as fracture lines are not as readily identifiable as in the acute fracture. No methods are available for measurement of residual displacement (RD), after fracture healing, in the sacral bone using CT. Therefore, we chose to use plain radiographs for measurement of (RD) of sacral fractures, as different methods already existed using plain films to evaluate the pelvic ring, although not validated. Plain film radiographs are readily available, and most commonly used by most orthopedic surgeons in the outpatient clinical setting. We chose the method suggested by Mears and Velyvis;[203] they used the height difference between the top of the two iliac wings to determine cephalad RD on outlet films. However, since the sacrum and any RD in the sacral bone was our main focus, we modified the measurement landmarks on the outlet films, using the top of the sacral lateral process elements (Figures in paper 2). Landmarks on the inlet view for measurement of posterior RD (posterior superior iliac spines) were not modified.

General discussion

Neurologic injuries and sequelae are commonly associated with sacral fractures and posterior pelvic injuries (Table 1), also shown in large clinical series by Denis et al.[8] and Pohlemann et al.[9] In our series, we found a high rate of neurological deficits (93% in **paper 1**), which is unfavorable compared with other studies listed in Table 1. This may be due to differences in terms of fracture types included. In the majority of the previous reports, several types of fractures are included, while our series consisted only of displaced sacral fractures as part of vertical shear pelvic disruptions. Differences in treatment methods, the range of additional injuries including peripheral nerve injuries, as well as the methods used for neurological assessment may also affect the reported results. These methodological differences may also apply for other outcome measures discussed here. Our results in **paper 4** with 87% of the patients having neurological deficits are in accordance with other studies on TLSD injuries reporting neurotrauma.

The reported rate of neurological recovery in the literature varies, partly depending on whether recovery is defined as total or partial. Most authors report some limited recovery, especially in type C pelvic injuries.[106,107,159] In an autopsy study, Huittinen[24] found a 47% incidence of neural injuries, and based on macroscopic and histopathologic findings, the neural lesions were divided into three categories; traction injuries (53%), compression injuries (10%), and ruptures (37%). Traction and compression injuries may have a potential for recovery, whereas this is unlikely in cases where the nerve or nerve roots are ruptured.[109] The role of surgical decompression in improving neurological recovery after displaced sacral fractures is controversial. Some authors recommend routine decompressive laminectomy for all sacral fractures with neurological deficits.[85,233] However, the procedure may have potential risks of complications with hemorrhage from cancellous bone, cerebrospinal fluid leakage, tissue breakdown and infection.[109] Similar rates of neurological recovery are reported both in studies where surgical decompression is performed,[97,114,115] and in studies where non-operative treatment has been applied.[234-236] Considering Huittinen's study, with 2/3 of the neural injuries being partial, some of the recovery demonstrated in clinical studies may not only be due to successful treatment, but may be explained by the spontaneous recovery potential of partial injuries. Likewise, as up to 1/3 of the nerve injuries may be complete (Huittinen), surgical decompression would be less useful in these cases. This is probably confirmed in the clinics, when no recovery occur in some patients following decompression. In our series (**paper 1**), decompressive laminectomy was performed in 12/28 patients. Recovery was seen in 3/28 patients, all treated without decompression; one had full recovery and two showed improvement (11%) from 1 to 10 years. In **paper 4**, only 1/13 patients recovered fully after non-operative treatment. Although there is insufficient evidence for treatment algorithms for sacral fractures with neurologic injury, early decompressive laminectomy may be beneficial for zone-III fractures with cauda equina syndrome.[237]

In our cohort study (**paper 1**), we could not detect significant improvement in neurologic function between the medium-term and the long-term follow-ups. This finding implies that neurologic deficits can be considered permanent, if still present at 1-year after injury. Prognostication of neurological impairments at an earlier stage may have several benefits for the affected patient, in terms of insurance, the ability to return to work, disability grading, and psychosocial problems.

In **paper 2** we found a correlation between radiological findings (CT) of bony changes around the neural tissues and neurologic deficits in the L5 and sacral dermatomes. The clinical value of these findings is uncertain, as we did not have CT images from earlier follow-ups to evaluate the progression of the bony changes in relation to the neurological deficits. Therefore, we could not tell if the observed correlations were causal or only associated findings. Consequently, no cause and effect conclusions could be drawn from these results to determine the role of the bony changes on neurologic deficits or their recovery. Future studies are needed to explore this relationship.

In contrast to the neurologic deficits that did not change significantly over time, we observed a significant deterioration in **bladder function** several years post injury (**paper 1**). As demonstrated in Table 1, several studies have reported bladder/urinary dysfunction in association with unstable sacral and pelvic ring fractures. However, changes/deterioration in bladder function many years after injury has not been reported previously. In addition to objective methods for evaluation of bladder function by urodynamic tests, we also assessed the subjective aspects of bladder function by a structured interview *(Appendix III).* We observed a clear discrepancy between the patient-reported, subjective perception of urinary dysfunction and the urodynamic test results. This implies that a considerable number of the patients have subclinical bladder dysfunction, despite the deterioration in a significant number, with reduced voiding volume and flow, and increased residual urine. This may also partly explain the unfavorably high rates of bladder dysfunction in our series (68%) compared to other studies (Table 1). The bladder dysfunctions encountered in our material was considered neurogenic, as only one patient presented with a urethral injury initially. The most common finding in these patients was bladder inertia, characterized by poor flow, low micturition volume and residual

urine, suggesting injuries to the parasympathetic innervation. A considerable number of these patients reported that they had to “assist” their urinary voiding. This was done by Valsalva maneuver (straining of abdominal muscles) or Crédé (manual compression of the lower abdomen) to increase the intravesical pressure and enhance voiding.
However, over time, using Valsalva and Crédé techniques may lead to reflux into the upper urinary tract (vesicoureteric reflux) eventually resulting in reflux nephropathy.[238,239]
In the present study, we did not evaluate the function and condition of the upper urinary tract, so whether the deteriorating bladder function observed may lead to further damage to the ureters and the kidneys remains to be assessed. This may suggest a longer follow-up with monitoring the urinary tract.

Bowel dysfunction associated with sacral fractures is scarcely described in the literature, where most authors describe it as present or absent in association with neurologic injury.[115,139,162,240] In our study (**paper 1**), we chose to characterize the bowel problems by a structured interview to address the patient-reported aspect of these debilitating symptoms *(Appendix II)*. The problems reported, including urge, incontinence, and constipation may be explained based on possible injuries to the nerves responsible for bowel function, as described in the introduction section. By characterizing the bowel problems, we were also able to grade the dysfunctions and evaluate possible changes in function over time. We did not observe any significant changes in bowel function over time (**paper 1**), but significant correlations with the bodily pain and role emotional domains of the SF-36 (**paper 3**). The relevance of the correlation with bodily pain is uncertain, since the questions in SF-36 pertaining to bodily pain are not meant to address specific pain localization, and therefore may be biased by other musculoskeletal pain. However, the correlation with role emotional domain may imply a possible emotional impact of bowel disorders.

There is a great variation (13%-52%) in reported rates of **sexual dysfunction** in patients with unstable pelvic and sacral fractures (Table 1). In our study, 44% (**paper 1**) expressed complaints about their sexual function, which is in accordance with previous reports, although using different assessment methods. However, 67% of TLSD patients (**paper 4**) reported sexual difficulties, including 5/13 (38%) with lumbosacral pain during intercourse, compared to 2/28 (7%) with the same problem in the type C group. Several factors may affect sexual function following polytrauma and severe sacral fractures.[241] As explained in the introduction, intact neurologic function is essential for normal sexual function, with a close interaction between the autonomous and the somatic nervous system.[26,48] It plays a central role in the normal physiology of the sexual arousal and performance, and any damage to these neural tissues may result in disturbances in sexual function. Furthermore, perineal and urogenital injuries, intrapelvic vascular injures, malunion, and extrapelvic polytrauma may also contribute to sexual dysfunctions.[49,171,242,243] However, as sexual behavior is also guided by the cerebral cortex, psychological, social and cultural problems may have a significant impact on sexual function, including depression and altered self image.[145,244,245] Consequently, considering the multifactorial nature of sexual behavior and function, in addition to reluctance to disclose sexual problems (reporting bias), assessment of sexual dysfunction may be complex and challenging. Nonetheless, it is important to address sexual problems in patients after sacral and

pelvic fractures, as it may be associated with decreased quality of life.[170] This was also reflected in our study, where we found significant correlations between sexual dysfunction and poor scores in social functioning and role emotional domains of the SF-36 (**paper 3**).
In the majority of the studies (Table 1), sexual function is assessed and considered as an associated injury to urogenital injuries. There is limited information on sexual function after displaced sacral and pelvic ring fractures in the absence of urogenital injuries.[170] Such information would illuminate factors other than urogenital injuries interfering with sexual function, and potentially improve treatment of sexual disorders in this patient group. In the present study, with a high number of patients having neurologic deficits, and only one with urethral injury in **paper 1 (**none in **paper 4)** diagnosed initially, the neurologic contribution may be evident. However, we did no in-depth analysis of the psychosocial aspects of sexual disturbances among our patients.

In addition to sexual disturbances, several other factors may affect the patients' perception of own health and well-being. Several authors have approached **patient-reported health** (PRH) among sacral and pelvic fracture patients (Table 1). The majority of these studies report poor results in (PRH) assessment, compared with normal data in respective countries. Our results (**papers 3 and 4**) support these studies, as our patients also had lower scores than the Norwegian normal population. Notably, we did not observe any significant changes in the (PRH) results (SF-36) form 1 to 10 years post injury. However, confounding factors may affect the assessment of quality of life/ (PRH) over a long time period from the initial injury. One of these confounders is response shift, which refers to a change in the meaning of one's self-evaluation over time. It is based on changes in the respondents' own standards, values, and reconceptualization of quality of life in the course of a disease trajectory.[246] These changes are considered inherent to the process of accommodating the illness. A patient may relate to an illness or impairment differently between two time points, depending on changes in these parameters and adaptation to the illness. Applied to our series, the lack of changes in SF-36 results over time may be confounded by response shift, in that the patients may have adapted to their impairments over the years. If so, the unchanged PRH between 1 and 10 years may actually veil a deterioration, since in spite of the patients' adaptation to their impairments, they score their own health low. In our study, we have not adjusted our data for this confounder, but methodological models have been suggested to correct this confounder in health assessment.[247,248]

An interview-administered health assessment may be biased with social desirability bias, where the respondent answers as they think it would satisfy the interviewer. In self-administered surveys this bias is reduced, but the respondents may still give "eager to please" answers or have problems with the semantics of the questionnaire. We dealt with this bias by sending the SF-36 questionnaires to the patients, so that they could fill them out at home, without the influence of any health personnel.

The results from the SF-36 surveys indicated a significant association between poor scores and pain (**paper 3**). However, in spite of high rates of neurologic deficits and bladder dysfunctions (with deteriorating trend), we found no correlations between these parameters and poor SF-36 results. Although approximately half of the patients (13/28) had VAS scores ≥ 2, this correlation was clear, suggesting pain as the important determinant of quality of life.

Residual **pain** following pelvic and sacral injures is reported by many authors, with great variation in reported rates (Table 1). This mainly due to wide variety in used methods for pain assessment, definition of pain, and the fracture types included. In our material in **paper 2**, 20/28 (71%), and in the TLSD group (**paper 4**), 14/15 (93%) reported pain. These figures are in accordance with other studies reporting similar injuries.
The reported pain in our material was localized to the lumbosacral area, and in 9/28 accompanied by radiating pain to the lower extremities (Figure 8), indicating neurogenic pain in L5 and upper sacral dermatomes.
The causality of pain following displaced sacral fractures may be multifactorial. Accurate and anatomic reduction has been advocated by several authors, as (RD) > 10 mm has been considered as poor prognostic factor.[141,159,249] This is not supported by other authors, Nepola et al.[181] found no correlation between RD> 10 mm and pain, and Pohlemann et al.[158] reported high rates of pain, despite few patients (2/30) with RD > 10 mm. In accordance with the latter studies, we found no correlation between RD and pain (**paper 2**). Notably, no other radiologic findings such as degenerative changes in the lumbosacral column were found to correlate with pain. This may suggest that no single radiologic finding, including RD may be causative of pain. Whether pain is caused by the cumulative effect of the radiologic findings, with or without a contribution of neurologic lesions, or bony encroachment of neural elements cannot be determined by this study, and should be subject for future studies.

Independence in activities of daily living (**ADL**), **ambulation**, and the ability to return to work after multitrauma is affected by several factors, including the range and severity of additional injuries and their sequelae.[250] ADL and ambulation may therefore be affected by lumbosacral nerve injuries or severe injuries to the lower extremities. At the1-year follow-up, 35% of our patients required help for their ADL,[215] all of whom reported independence in ADL at the current 10-year follow-up (**paper 3**). In the TLSD group, 3/15 patients were still dependent on assistance on a daily or non-daily basis (**paper 4**). ADL is sparsely reported in studies on outcome after sacral and pelvic fractures, and mobility is defined differently between the studies. In a 5-year follow-up of 35 patients with pelvic fractures, Mkandawire et al.[213] reported problems with ADL in 2/9 (22%) patients after unstable, and 2/26 (7%) after stable pelvic fractures. They also reported problems in mobility in 9/9 (100%) of the patients with unstable pelvic fractures, however, without defining the severity or range of walking disabilities. Nepola et al.[181] defined walking problems by leg length discrepancy and limp, and reported a 34% incidence, while Tornetta et al.[159] reported 12% limp and 25% walking impairments (not specified) due to neurological injury. We defined ambulation/ walking ability based on patient-reported function, and dependence or independence of walking aids or wheelchair. We reported that 26/28 (93%) in **paper 1** and 14/15 (93%) in **paper 4** could walk independently without walking aids, however with some restrictions in running or strenuous activities. These examples demonstrate the great heterogeneity in reported results across the studies, depending on different definitions and heterogeneity of patients and injury severity.

The number of our patients who **returned to work** was 12/22 (54%) in **paper 3** (6/28 were unemployed/ received disability pension before injury) which is slightly lower than other studies (Table 1). These studies are conducted in several different countries, the majority in the USA, indicating differences in public health systems as a possible explanation of the diverging results from ours. Five out of 8 patients with TLSD (**paper 4**) returned to fulltime job, however, no comparative data on return to work in this patient group were found from other studies. In our study, of the 10 patients in **paper 3** who did not return to work, 8 were manual workers. Conversely, none of the 3 patients in the TLSD group (**paper 4**) who did not return to work did manual work before injury.
In a 5-year follow-up of 75 patients after polytrauma, Søberg et al.[251] found that level of education, physical and psychosocial functioning, and coping strategies were all important predictive factors of return to work. However, similar analyses were not applied in the present studies; therefore, the association of these parameters and the rate of return to work in our study is uncertain.

In this study, we have investigated two types of sacral fractures by evaluating the long-term functional outcome in patients with these injuries; namely displaced sacral fractures as part of vertical shear pelvic ring injuries (type C), and traumatic lumbosacral dissociation injuries (TLSD). Both are serious injuries, caused by high energy forces, having several characteristics in common, including high incidence of neurologic injuries, and persistent pain. We observed also some differences; in the group with TLSD, also called "suicidal jumper's fractures", the mechanism of injury was suicidal jump in 3/13 (23%) patients versus 2/28 (7%) in the type C group. This indicates a higher incidence in patients with pre-existing psychiatric disorders sustaining TLSD injuries with its specific injury mechanism, proposed by Roy-Camille et al.[85,252] We did not observe any difference between the two groups in terms of percentage of patients who were unemployed/ received permanent disability pension prior to their injuries; 3/13 (23%) in the TLSD group and 6/28 (21%) in the type C group. We observed a higher frequency of residual lumbosacral pain (with or without radicular pain) in TLSD group than the type C group; 12/13 (92%) and 20/28 (71%) respectively, and more TLSD patients had VAS scores ≥ 3; 9/13 (69%) vs. 13/28 (46%) in the type C group. Also, more patients in the TLSD group had complaints of lumbosacral pain during intercourse, in both sexes, compared with the type C group, 5/13 (38%) and 2/28 (7%) respectively. This may possibly be explained by the kyphotic deformity of the sacrum observed in the majority of the TLSD patients, which was not present in the type C group. The influence of sacral kyphotic deformity on lumbosacral pain could not be evaluated by our study, and should be subject for future studies with larger cohorts.
These differences between the two fracture types are based on our observations only, with no further statistical analyses to support them, as these two groups were heterogeneous in several aspects, and the number of patients was too low to allow any meaningful analyses. However, principally they are two different entities, as in type C injuries also the pelvic ring is disrupted, which is not the case in the majority of TLSD injuries.
Being displaced sacral fractures, functional sequelae are common in both of these fractures types, and our findings suggest that these patients should be followed for many years post injury by a multidisciplinary approach, addressing the specific impairments and dysfunctions.

6. CONCLUSIONS

- Neurological deficits and pain following high energy, displaced sacral fractures are common, and persist even following open reduction and internal fixation.
- Neurologic recovery after displaced sacral fractures is poor, and can be considered permanent if still present one year post-injury.
- Bladder dysfunction is common, often subclinical, and in many cases also deteriorates over time.
- Disturbances in sexual function are frequent and their causality is multifactorial.
- All sacral fractures were healed.
- Pathologic radiographic findings are common, but no single type of pathologic finding can predict lumbosacral pain.
- Patient-reported health after displaced sacral fractures is poorer than the general population, with no significant changes after many years.
- There is a close association between pain and poor self-reported health, emphasizing the importance of pain management.
- A considerable number of patients cannot return to work after displaced sacral fractures.
- Despite high rates of impairments, the majority of patients are independent in their activities of daily living and ambulation.
- Lumbosacral dissociation fractures are rare and a district entity of sacral fractures. Apart from the fracture pattern, they share many of the characteristics of other sacral fractures, in terms of neurologic lesions, pain and poor outcome.

7. PERSPECTIVES

We found significant correlations between neurologic deficits and radiographic findings, i.e. bony encroachment of L5 and sacral nerves. Many of these patients presented with neurologic symptoms at the time of injury and at 1-year follow-up. The true meaning of these findings is uncertain. Our study was unable to determine whether or not the encroaching bony tissue inhibited the recovery of the affected neural elements, or contributed to deterioration of neurologic function, as seen in some patients. Further, this raises the question whether a surgical intervention with sacral foraminotomy and/or L5 release postforaminally would improve nerve recovery. As these issues have not been studied before, this question should be subject to further investigation by a detailed prospective, parallel monitoring of the neurologic function and radiologic findings/changes at several intervals.

One of our main findings was the deteriorating bladder function, but the causality and long-term consequences of these findings remain uncertain. These findings call for further studies to approach the worsening of the bladder function over time, and especially focus on any potential detrimental effects on renal function.

The assessment and interpretation of sexual dysfunction is complex, due to its multifactorial nature. Separate studies should be conducted focusing on sexual disturbances to explore the different physical and emotional/mental dimensions of dysfunction.

The number of patients in our studies was low due to the rarity of displaced sacral fractures, especially the TLSD injuries. A long inclusion period may be exhausting and limit the collection of sufficient amount of eligible patients, resulting in limited power in the statistical analyses. Future studies should therefore be conducted as multicenter studies to include more patients in shorter time.

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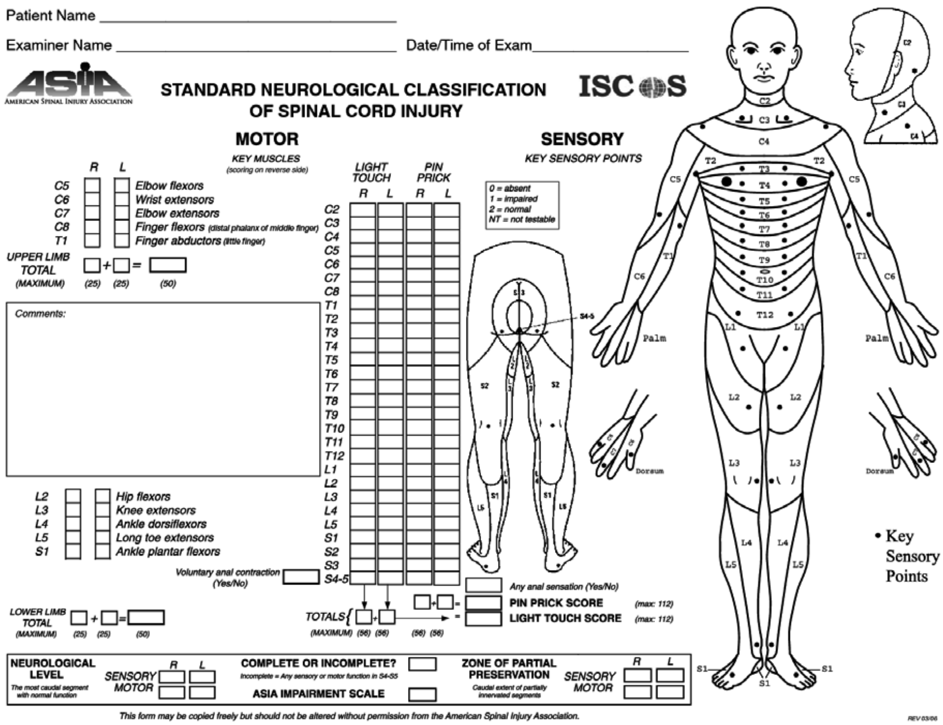
Errata

Paper 1: Page E1014 in the discussion section; in the sentence "*Our findings do not support this, as only 2 patients were identified with bladder or urethral ruptures...*"
2 patients should be 3 patients.

Appendices

Appendix I

Standard neurological classification chart developed by the American Spinal Injury Association (ASIA).[22]


Patient Name ______

Examiner Name ______ Date/Time of Exam ______

ASIA — American Spinal Injury Association

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

ISCoS

MOTOR

KEY MUSCLES (scoring on reverse side)

	R	L	
C5			Elbow flexors
C6			Wrist extensors
C7			Elbow extensors
C8			Finger flexors (distal phalanx of middle finger)
T1			Finger abductors (little finger)

UPPER LIMB TOTAL (MAXIMUM) ☐ + ☐ = ☐ (25) (25) (50)

Comments:

	R	L	
L2			Hip flexors
L3			Knee extensors
L4			Ankle dorsiflexors
L5			Long toe extensors
S1			Ankle plantar flexors

Voluntary anal contraction (Yes/No) ☐

LOWER LIMB TOTAL (MAXIMUM) ☐ + ☐ = ☐ (25) (25) (50)

SENSORY

KEY SENSORY POINTS

LIGHT TOUCH R L — PIN PRICK R L

C2, C3, C4, C5, C6, C7, C8, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1, L2, L3, L4, L5, S1, S2, S3, S4-5

0 = absent
1 = impaired
2 = normal
NT = not testable

Any anal sensation (Yes/No)

TOTALS (MAXIMUM) (56) (56) (56) (56)

PIN PRICK SCORE (max: 112)

LIGHT TOUCH SCORE (max: 112)

NEUROLOGICAL LEVEL — The most caudal segment with normal function — SENSORY R L, MOTOR R L

COMPLETE OR INCOMPLETE? — Incomplete = Any sensory or motor function in S4-S5

ASIA IMPAIRMENT SCALE

ZONE OF PARTIAL PRESERVATION — Caudal extent of partially innervated segments — SENSORY R L, MOTOR R L

• Key Sensory Points

Palm

Dorsum

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REV 03/06

Appendix II

Bakgrunns opplysninger

Initialer: ______________ Født: __________________

Fast lege:
____

Skadedato: ____

Resyme sykehistorie:
Årsak
Initial behandling
Rehabilitering

Kjønn
- ☐ Kvinne
- ☐ Mann

Hva er din sivilstand i dag?
- ☐ Enslig
- ☐ Gift / samboer
- ☐ Skilt / separert

Hva er din nåværende beskjeftigelse? Du kan krysse av ett eller flere alternativer.
- ☐ Inntektsgivende arbeid (minst 15 timer per uke i snitt)
- ☐ Student/elev
- ☐ Sykemeldt
- ☐ Attføring
- ☐ Uføretrygdet/pensjonist
- ☐ Hjemmeværende
- ☐ Annet, i så fall beskriv dette her: _____________________________

Bruk av medisiner fra apotek/lege:
____

Bruker du medisiner for tiden?
- ☐ Ja
- ☐ Nei

Hvis ja, hvilke medisiner?

Navn på medisin:	Dosering per dag:

Mage/tarm-funksjon

Hvordan foregår tarm tømming i dag? Du kan krysse av ett eller flere alternativer som du synes beskriver best.

☐ Omtrent normalt ved avføringstrang
☐ Avføringsmidler eller klyx
☐ Vannklyster/klyster
☐ Plukking
☐ Pressing med magemuskler eller trykk fra hendene over magen

Hvor ofte har du avføring i gjennomsnitt?
Antall ganger pr. uke: ___________________

Mottar du vanligvis personhjelp til tarm tømming?
☐ Selv uten hjelp av andre
☐ Foreldre/ samboer/ektefelle
☐ Hjemmesykepleie / personlig assistent
☐ Annen

Har du noen gang lekkasje for avføring?
☐ Alltid, det lekker hele tiden ukontrollert
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

Er lekkasje for avføring et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

Opplever du ofte å være forstoppet?
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

Er forstoppelse et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

Har du ofte diare?
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

Er diare et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

Har du ofte magesmerter?
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

Er magesmerter et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

Er du operert for problemer med tarm tømming?
☐ Ja
☐ Nei

Hvis ja, beskriv nærmere: ___________________________

Tidligere undersøkelser og behandling for urinblære- og nyre problemer

---

Har du de siste 2 årene gjort noen av disse undersøkelsene av nyrene dine? Kryss av én eller flere.
☐ Ultralyd
☐ Urografi
☐ Renografi
☐ Vet ikke

Har du brukt antibiotika mot urinveisinfeksjon siste året?
☐ Nei
☐ Én gang
☐ Et par ganger (2-4 ganger)
☐ Ofte (5 eller flere ganger)
☐ Bruker forebyggende hele tiden
☐ Vet ikke

Har du noen gang tidligere hatt nyrebekkenbetennelse (feber og urinveisinfeksjon?)
☐ Ja, én gang
☐ Ja, flere ganger
☐ Nei
☐ Vet ikke

Har du tidligere blitt operert i urinblæren eller nyrene?
☐ Ja
☐ Nei
☐ Vet ikke

Hvis ja, vet du hvilke (t) sykehus, hvilke (t) år du ble operert og hva slags operasjon som ble gjort?

Sykehus:	Årstall:	Hva slags operasjon:

Reduserer du drikkemengden for å nedsette vannlatingsplagene dine?
- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

Er dette et problem for deg?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Hvor ofte har du smerter i urinblæren?
- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

Er dette et problem for deg?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Hindrer vannlatingsproblemene ditt sosiale liv (gå ut, treffe venner, delta i foreninger, idrett og lignende)?
- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

Er dette et problem for deg?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Har du problem med at det kan lukte urin av deg?
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

Er dette et problem for deg?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort. problem
- ☐ Et alvorlig problem

Må du planlegge dagen på grunn av vannlatings problemer (for eksempel huske utstyr, undersøke tilgang på toalett og lignende)?
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri
Er dette et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort. problem
☐ Et alvorlig problem
Har du tidligere forsøkt å tømme urinblæren med engangs katetre?
☐ Ja
☐ Nei
☐ Vet ikke

I så fall for hvilken periode?
Startet: ____________ Sluttet: ____________

Hvis du sluttet, hva var grunnen(e)?
1. ____
2. ____
3. ____

Seksualliv

Er eller har du vært seksuelt aktiv etter ulykken?
☐ Ja
☐ Nei, hvis nei hopp over denne siden

Hvis ja, i hvilken grad føler du, at ditt seksualliv er blitt ødelagt p.g.a. denne ulykken?
☐ Nei, ikke i det hele tatt
☐ Litt
☐ Til en viss grad
☐ En del
☐ Mye
Er dette et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem
☐
Lekker det urin når du har samleie?
☐ Aldri
☐ Sjelden
☐ Av og til
☐ Som oftest
☐ Alltid
Er dette et problem for deg?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

Appendix III

Vannlatingsmetoder og problemer

Hensikten med disse spørsmålene er å få et inntrykk av hvordan du tømmer urinblæren og problemer som kan være knyttet til dette. På denne siden er det spørsmål om mulige måter å tømme urinblæren på, og ett om du har problemer med urinlekkasje.

2.1.1 Er du i stand til å kontrollere vannlatingen? Har du følelse av når du skal på toalettet og går så på toalettet for å late vannet viljemessig?

☐ Ja, hvis ja fyll ut gule ark (del 1)
☐ Nei

2.1.2 Bruker du magemusklene, hendene eller banke over nedre del av magen for å ut urin ?

☐ Ja, hvis ja fyll ut grønt ark (del 2)
☐ Nei

2.1.4 Bruker du å tømme du urinblæren med kateter daglig?

☐ Ja, hvis ja fyll ut blå ark (del 3)
☐ Nei

2.1.5 Lekker du noen gang urin?

☐ Ja, hvis ja fyll ut rosa ark (del 4)
☐ Nei

Del 1

2.2.1 Later du alltid vannet viljemessig?

☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken

2.2.2 I løpet av en dag, hvor ofte later du vanligvis vannet?

☐ 1 - 6 ganger
☐ 7 - 8 ganger
☐ 9 - 10 ganger
☐ 11 - 12 ganger
☐ 13 ganger eller mer

2.2.3 Er det et problem for deg dersom du må late vannet ofte?

☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

2.2.4 I løpet av en natt, hvor ofte må du vanligvis stå opp for å late vannet?
- ☐ Ingen
- ☐ 1 gang
- ☐ 2 ganger
- ☐ 3 ganger
- ☐ 4 ganger eller mer

2.2.5 Er dette et problem for deg?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.6 Er **du nødt til å skynde deg til toalettet for å late vannet?**
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.2.7 Er **dette et problem for deg ?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort. problem
- ☐ Et alvorlig problem

2.2.8 Lekker det urin før du når fram til toalettet ?
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.2.9 Er dette et problem for deg ?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.10 Tar det tid før du klarer å sette i gang vannlatingen ?
- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

2.2.11 Er dette et problem for deg ?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.12 Er du nødt til å anstrenge deg for å late vannet ?

- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

2.2.13 Er dette et problem for deg ?

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.14 Stopper og starter du (uten å ønske det) mer enn én gang mens du later vannet ?

- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

2.2.15 Er dette et problem for deg ?

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.16 Svir det når du later vannet ?

- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

2.2.17 Er dette et problem for deg ?

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.2.18 Kan du stoppe vannlatingen hvis du ønsker det ?

- ☐ Ja, uten problemer
- ☐ Ja, med problemer
- ☐ Ja, med store problemer
- ☐ Nei, kan ikke stoppe vannlatingen

Del 2

2.3.1 Hvor ofte later du vannet ved å banke over nedre del av magen?

- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.3.2 Er **dette et problem for deg ?**

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.4.1 Hvor ofte later du vannet ved å presse med magemusklene eller hendene over nedre del av magen?

- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.4.2 Er **dette et problem for deg?**

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Del 3

2.5.1 Trenger du hjelp til å kateterisere (kryss av ett eller flere alternativer) ?

- ☐ Nei, gjør det selv uten hjelp av andre
- ☐ Foreldre
- ☐ Hjemmesykepleie
- ☐ Personlig assistent
- ☐ Samboer / ektefelle
- ☐ Annen person

2.5.2 Er **det vanskelig å få kateteret inn i blæren?**

- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.5.3 Er dette et problem for deg?

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.5.4 I **løpet av dagen, hvor ofte tømmer du blæren med kateter ?**
- ☐ 1 - 2 ganger
- ☐ 3 - 4 ganger
- ☐ 5 - 6 ganger
- ☐ Mer enn 6 ganger

2.5.5 Er **dette et problem for deg?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.5.6 I **løpet av natten, hvor ofte tømmer du blæren med et kateter?**
- ☐ Tømmer aldri med kateter om natten
- ☐ 1 gang
- ☐ 2 ganger
- ☐ 3 ganger
- ☐ Mer enn 3 ganger

2.5.7 Er **dette et problem for deg?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.5.8 Svir det når du kateteriserer deg?
- ☐ Aldri
- ☐ Sjelden
- ☐ Av og til
- ☐ Som oftest
- ☐ Alltid

2.5.9 Er **dette et problem for deg?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Del 4

2.6.1 Hvor ofte har du urinlekkasje?
☐ Alltid, det vil si at urinblæren ikke tømmer seg på andre måter
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

2.6.2 Er **dette et problem for deg ?**
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

2.6.3 Har **du urinlekkasje når du er fysisk aktiv, anstrenger deg, hoster eller nyser?**
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

2.6.4 Er **dette et problem for deg ?**
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

2.6.5 Lekker det noen gang urin uten grunn og uten at du har vannlatingstrang?
☐ Alltid
☐ En eller flere ganger om dagen
☐ Ikke daglig, men en eller flere ganger i løpet av uken
☐ Av og til, men ikke så ofte som en gang i uken
☐ Aldri

2.6.6 Er dette et problem for deg ?
☐ Ikke noe problem
☐ Et mindre problem
☐ Et temmelig stort problem
☐ Et alvorlig problem

2.6.7 Hvor **stor urinlekkasje har du?**
☐ Ingen lekkasje
☐ Ubetydelig lekkasje
☐ Enkelte dråper så undertøyet blir fuktig
☐ Drypper så undertøyet vætes ut
☐ Sterk urinlekkasje, må bruke bleier (eller uridom)

2.6.8 Er **dette et problem for deg ?**
☐ Ikke noe problem
☐ Et mindre problem

- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.9 Hvor ofte må du bytte undertøy på grunn av urinlekkasje?

- ☐ Aldri
- ☐ En gang i uken
- ☐ Flere ganger i uken
- ☐ Vanligvis en gang om dagen
- ☐ Mer enn en gang om dagen

2.6.10 Er dette et problem for deg?

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.11 Hvor ofte må du bytte mer enn undertøy p.g.a urinlekkasje?

- ☐ Aldri
- ☐ En gang i uken
- ☐ Flere ganger i uken
- ☐ Vanligvis en gang om dagen
- ☐ Mer enn en gang om dagen

2.6.12 Er **dette et problem for deg?**

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.13 Trenger du hjelp til å bytte tøy (kryss av ett eller flere alternativer)?

- ☐ Nei, gjør det selv uten hjelp av andre
- ☐ Foreldre
- ☐ Hjemmesykepleie
- ☐ Personlig assistent
- ☐ Samboer
- ☐ Annen

2.6.14 Må **du bruke bleier om dagen?**

- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.6.15 Er **dette et problem for deg?**

- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.16 Bruker du bleier om natten?
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.6.17 Er **dette et problem for deg?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.18 Trenger du hjelp til å bytte bleier (kryss av ett eller flere alternativer) ?
- ☐ Nei, gjør det selv uten hjelp av andre
- ☐ Foreldre
- ☐ Hjemmesykepleie / personlig assistent
- ☐ Samboer / ektefelle
- ☐ Annen

For mannlige pasienter som bruker uridom :

2.6.19 Bruker du uridom om dagen?
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.6.20 Er dette et problem for deg ?
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.21 Bruker **du uridom om natten?**
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.6.22 Er **dette et problem for deg ?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

2.6.23 Trenger du hjelp til bytte å uridom ?
- ☐ Nei, gjør det selv uten hjelp av andre
- ☐ Foreldre
- ☐ Hjemmesykepleie
- ☐ Personlig assistent
- ☐ Samboer
- ☐ Annen

2.6.24 Lekker det urin mens du sover ?
- ☐ Alltid
- ☐ En eller flere ganger om dagen
- ☐ Ikke daglig, men en eller flere ganger i løpet av uken
- ☐ Av og til, men ikke så ofte som en gang i uken
- ☐ Aldri

2.6.25 Er **dette et problem for deg ?**
- ☐ Ikke noe problem
- ☐ Et mindre problem
- ☐ Et temmelig stort problem
- ☐ Et alvorlig problem

Versjon 2.2, 04.04.99

Appendix IV

The International Index of Erectile Function (IIEF)[218] (Norwegian version)

Følgende spørsmål gjelder hvordan dine ereksjonsproblemer har virket inn på sexlivet ditt **i løpet av de siste 4 ukene**. Vennligst svar på spørsmålene så oppriktig og klart som mulig. Vennligst svar på hvert av spørsmålene ved å merke av én rute med et kryss [×]. Hvis du er usikker på hva du skal svare, svar så godt du kan.

Følgende definisjoner gjelder når du svarer på disse spørsmålene:

* **Samleie**
Defineres som inntrengning (innføring) i partnerens skjede.

** **Seksuell aktivitet**
Omfatter samleie, kjærtegn, forspill og onani.

*** **Sæduttømming**
Defineres som uttømming av sæd fra penis (eller fornemmelsen av dette).

**** **Seksuell stimulering**
Omfatter slike situasjoner som erotisk lek med en partner, det å se på erotiske bilder, osv.

1. **I løpet av de siste 4 ukene** hvor ofte var du i stand til å få ereksjon under seksuell aktivitet**?
Vennligst kryss av i bare én rute.
Ingen seksuell aktivitet……………………………………………………......☐
Nesten alltid eller alltid………………………………………………….......☐
De fleste gangene (mye mer enn halvparten av gangene)..........................☐
Iblant (omtrent halvparten av gangene)...☐
Noen få ganger (mye mindre enn halvparten av gangene).........................☐
Nesten aldri eller aldri…………………………………………..………......☐

2. **I løpet av de siste 4 ukene** når du fikk ereksjon med seksuell stimulering****, hvor ofte var ereksjonene stive nok til inntrengning?
Vennligst kryss av i bare én rute.
Ingen seksuell stimulering………………………………………………......☐
Nesten alltid eller alltid…………………………..…………………….......☐
De fleste gangene (mye mer enn halvparten av gangene)...........................☐
Iblant (omtrent halvparten av gangene)...☐
Noen få ganger (mye mindre enn halvparten av gangene)..........................☐
Nesten aldri eller aldri...☐

De 3 neste spørsmålene gjelder de ereksjonene du eventuelt har hatt under samleie*.

3. **I løpet av de siste 4 ukene** når du forsøkte å ha samleie*, hvor ofte var du i stand til å trenge inn i partneren?
Vennligst kryss av i bare én rute.
Har ikke forsøkt å ha samleie...☐
Nesten alltid eller alltid..☐
De fleste gangene (mye mer enn halvparten av gangene)............................☐
Iblant (omtrent halvparten av gangene)..☐
Noen få ganger (mye mindre enn halvparten av gangene)...........................☐
Nesten aldri eller aldri..☐

4. **I løpet av de siste 4 ukene** under samleie* **hvor ofte** var du i stand til å beholde ereksjonen etter inntrengning i partneren?
Vennligst kryss av i bare én rute.
Har ikke forsøkt å ha samleie..□
Nesten alltid eller alltid...□
De fleste gangene (mye mer enn halvparten av gangene) ....□
Iblant (omtrent halvparten av gangene)...□
Noen få ganger (mye mindre enn halvparten av gangene)............................□
Nesten aldri eller aldri..□

5. **I løpet av de siste 4 ukene** under samleie* **hvor vanskelig** var det å beholde ereksjonen til samleiet var fullført?
Vennligst kryss av i bare én rute.
Har ikke forsøkt å ha samleie..□
Ekstremt vanskelig...□
Svært vanskelig...□
Vanskelig..□
Litt vanskelig..□
Ikke vanskelig...□

6. **I løpet av de siste 4 ukene** hvor mange ganger har du forsøkt å ha samleie*?
Vennligst kryss av i bare én rute.
Ingen forsøk..□
1-2 forsøk..□
3-4 forsøk..□
5-6 forsøk..□
7-10 forsøk..□
11 eller flere forsøk...□

7. **I løpet av de siste 4 ukene** når du forsøkte å ha samleie*, hvor ofte var det tilfredsstillende for **deg**?
Vennligst kryss av i bare én rute.
Har ikke forsøkt å ha samleie..□
Nesten alltid eller alltid...□
De fleste gangene (mye mer enn halvparten av gangene)............................□
Iblant (omtrent halvparten av gangene)...□
Noen få ganger (mye mindre enn halvparten av gangene)............................□
Nesten aldri eller aldri..□

8. **I løpet av de siste 4 ukene** hvor mye glede har du hatt av samleie*?
Vennligst kryss av i bare én rute.
Ikke samleie..□
Svært mye glede..□
Mye glede..□
En del glede...□
Lite glede...□
Ingen glede..□

9. **I løpet av de siste 4 ukene** under seksuell stimulering**** **eller** samleie* hvor ofte hadde du sæduttømming***?
Vennligst kryss av i bare én rute.
Ingen seksuell stimulering eller samleie..□
Nesten alltid eller alltid...□
De fleste gangene (mye mer enn halvparten av gangene)............................□
Iblant (omtrent halvparten av gangene)...□
Noen få ganger (mye mindre enn halvparten av gangene)............................□
Nesten aldri eller aldri..□

10. **I løpet av de siste 4 ukene** under seksuell stimulering**** **eller** samleie* hvor ofte hadde du følelsen av orgasme med eller uten sæduttømming***?
Vennligst kryss av i bare én rute.
Ingen seksuell stimulering eller samleie...☐
Nesten alltid eller alltid..☐
De fleste gangene (mye mer enn halvparten av gangene)..........................☐
Iblant (omtrent halvparten av gangene)..☐
Noen få ganger (mye mindre enn halvparten av gangene).........................☐
Nesten aldri eller aldri...☐

De 2 neste spørsmålene gjelder seksuelt begjær. La oss definere seksuelt begjær som en følelse som kan omfatte et ønske om å ha en seksuell opplevelse (f.eks. onani eller samleie*), å tenke på sex eller å være frustrert over mangel på sex.

11. **I løpet av de siste 4 ukene** hvor ofte har du følt **seksuelt begjær**?
Vennligst kryss av i bare én rute.
Nesten alltid eller alltid..☐
Svært ofte (svært mye av tiden)...☐
Av og til (en del av tiden)..☐
Sjelden (litt av tiden)...☐
Nesten aldri eller aldri...☐

12. **I løpet av de siste 4 ukene** hvordan vil du beskrive nivået på ditt **seksuelle begjær**?
Vennligst kryss av i bare én rute.
Svært høyt...☐
Høyt..☐
Middels...☐
Lavt...☐
Svært lavt eller intet...☐

13. **I løpet av de siste 4 ukene** hvor tilfreds har du vært med **sexlivet** ditt alt i alt?
Vennligst kryss av i bare én rute.
Svært tilfreds...☐
Ganske tilfreds...☐
Omtrent like mye tilfreds som utilfreds...☐
Ganske utilfreds...☐
Svært utilfreds..☐

14. **I løpet av de siste 4 ukene** hvor tilfreds har du vært med ditt **seksuelle forhold** til din partner?
Vennligst kryss av i bare én rute.
Svært tilfreds...☐
Ganske tilfreds...☐
Omtrent like mye tilfreds som utilfreds...☐
Ganske utilfreds...☐
Svært utilfreds..☐

15. **I løpet av de siste 4 ukene** hvordan vil du beskrive din **tiltro** til å kunne få og beholde en ereksjon?
Vennligst kryss av i bare én rute.
Svært stor...☐
Stor..☐
Middels..☐
Liten..☐
Svært liten..☐

Din helse og trivsel

Dette spørreskjemaet handler om hvordan du ser på din egen helse. Disse opplysningene vil hjelpe oss til å få vite hvordan du har det og hvordan du er i stand til å utføre dine daglige gjøremål. *Takk for at du fyller ut dette spørreskjemaet!*

For hvert av de følgende spørsmålene vennligst sett et ☒ i den ene luken som best beskriver ditt svar.

1. Stort sett, vil du si at din helse er:

Utmerket	Meget god	God	Nokså god	Dårlig
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

2. <u>Sammenlignet med for ett år siden</u>, hvordan vil du si at din helse stort sett er <u>nå</u>?

Mye bedre nå enn for ett år siden	Litt bedre nå enn for ett år siden	Omtrent den samme som for ett år siden	Litt dårligere nå enn for ett år siden	Mye dårligere nå enn for ett år siden
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

3 De neste spørsmålene handler om aktiviteter som du kanskje utfører i løpet av en vanlig dag. Er din helse slik at den begrenser deg i utførelsen av disse aktivitetene nå? Hvis ja, hvor mye?

		Ja, begrenser meg mye	Ja, begrenser meg litt	Nei, begrenser meg ikke i det hele tatt
a	Anstrengende aktiviteter som å løpe, løfte tunge gjenstander, delta i anstrengende idrett	☐ 1	☐ 2	☐ 3
b	Moderate aktiviteter som å flytte et bord, støvsuge, gå en tur eller drive med hagearbeid	☐ 1	☐ 2	☐ 3
c	Løfte eller bære en handlekurv	☐ 1	☐ 2	☐ 3
d	Gå opp trappen flere etasjer	☐ 1	☐ 2	☐ 3
e	Gå opp trappen én etasje	☐ 1	☐ 2	☐ 3
f	Bøye deg eller sitte på huk	☐ 1	☐ 2	☐ 3
g	Gå mer enn to kilometer	☐ 1	☐ 2	☐ 3
h	Gå noen hundre meter	☐ 1	☐ 2	☐ 3
i	Gå hundre meter	☐ 1	☐ 2	☐ 3
j	Vaske eller kle på deg	☐ 1	☐ 2	☐ 3

4. **I løpet av de siste 4 ukene, hvor ofte har du hatt noen av de følgende problemer i ditt arbeid eller i andre av dine daglige gjøremål på grunn av din fysiske helse?**

	Hele tiden	Mye av tiden	En del av tiden	Litt av tiden	Ikke i det hele tatt
a Du har måttet redusere tiden du har brukt på arbeid eller på andre gjøremål	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Du har utrettet mindre enn du hadde ønsket	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Du har vært hindret i å utføre visse typer arbeid eller gjøremål	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Du har hatt problemer med å gjennomføre arbeidet eller andre gjøremål (f.eks. det krevde ekstra anstrengelser)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

5. **I løpet av de siste 4 ukene, hvor ofte har du hatt noen av de følgende problemer i ditt arbeid eller i andre av dine daglige gjøremål på grunn av følelsesmessige problemer (som f.eks. å være deprimert eller engstelig)?**

	Hele tiden	Mye av tiden	En del av tiden	Litt av tiden	Ikke i det hele tatt
a Du har måttet redusere tiden du har brukt på arbeid eller på andre gjøremål	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Du har utrettet mindre enn du hadde ønsket	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Du har utført arbeidet eller andre gjøremål mindre grundig enn vanlig	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. I løpet av de siste 4 ukene, i hvilken grad har din fysiske helse eller følelsesmessige problemer hatt innvirkning på din vanlige sosiale omgang med familie, venner, naboer eller foreninger?

Ikke i det hele tatt	Litt	En del	Mye	Svært mye
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

7. Hvor sterke kroppslige smerter har du hatt i løpet av de siste 4 ukene?

Ingen	Meget svake	Svake	Moderate	Sterke	Meget sterke
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6

8. I løpet av de siste 4 ukene, hvor mye har smerter påvirket ditt vanlige arbeid (gjelder både arbeid utenfor hjemmet og husarbeid)?

Ikke i det hele tatt	Litt	En del	Mye	Svært mye
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

9. **Disse spørsmålene handler om hvordan du har følt deg og hvordan du har hatt det <u>de siste 4 ukene</u>. For hvert spørsmål, vennligst velg det svaralternativet som best beskriver hvordan du har hatt det. Hvor ofte i løpet av <u>de siste 4 ukene</u> har du…**

	Hele tiden	Mye av tiden	En del av tiden	Litt av tiden	Ikke i det hele tatt
a Følt deg full av liv?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Følt deg veldig nervøs?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Vært så langt nede at ingenting har kunnet muntre deg opp?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Følt deg rolig og harmonisk?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
e Hatt mye overskudd?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
f Følt deg nedfor og deprimert?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
g Følt deg sliten?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
h Følt deg glad?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
i Følt deg trett?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

10. **I løpet av <u>de siste 4 ukene</u>, hvor ofte har din <u>fysiske helse eller følelsesmessige problemer</u> påvirket din sosiale omgang (som det å besøke venner, slektninger osv.)?**

Hele tiden	Mye av tiden	En del av tiden	Litt av tiden	Ikke i det hele tatt
▼	▼	▼	▼	▼
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

11. Hvor RIKTIG eller GAL er hver av de følgende påstander for deg?

	Helt riktig	Delvis riktig	Vet ikke	Delvis gal	Helt gal
a Det virker som om jeg blir syk litt lettere enn andre	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
b Jeg er like frisk som de fleste jeg kjenner	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
c Jeg tror at helsen min vil forverres	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
d Jeg har utmerket helse	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Takk for at du fylte ut dette spørreskjemaet!

1

2

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Radiological findings correlate with neurological deficits but not with pain after operatively treated sacral fractures

An 11-year follow-up study of 28 patients

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Background and purpose — **Neurological deficits and pain are common after displaced sacral fractures. However, little is known about the association between the long-term clinical outcomes and radiological findings. We examined the long-term radiological findings and their correlations with lumbosacral pain and neurological deficits in the lower extremities after surgery for sacral fractures.**

Methods — **28 consecutive patients with operatively treated displaced sacral fractures were followed for mean 11 (8–13) years. Sensorimotor impairments of the lower extremities were classified according to the American Spinal Injury Association (ASIA). Pain was assessed using a visual analog scale (VAS). All patients underwent conventional radiographic examination and CT, and the images were scrutinized for nonunion, residual displacement, narrowing of the sacral foramina, and post-foraminal encroachment of the L5 and S1 nerves.**

Results — **There was residual displacement of ≥ 10 mm in 16 of the 28 patients. 26 patients had narrowing of 1 or more neural root foramina in L5-S4. 8 patients reported having no pain, 11 had pain only in the lumbosacral area, and 9 had pain in combination with radiating leg pain. Statistically significant correlations were found between narrowing of the sacral foramina and neurological deficits in the corresponding dermatomes. Significant correlations were also found between post-foraminal encroachment of L5 nerves and both sensory and motor deficits. No correlations were found between pain and radiological findings.**

Interpretation — **Pathological radiological findings are common 11 years after operatively treated displaced sacral fractures. Sacral foraminal and L5 post-foraminal bony encroachments were common findings and correlated with neurological deficits. However, lumbosacral pain did not correlate with radiological sequelae after fracture healing.**

■

High-energy trauma with displaced sacral fracture is frequently associated with concomitant injuries to the intrapelvic soft tissue structures, including the lumbosacral plexus (Huittinen 1972, Denis et al. 1988, Majeed 1992). These injuries may cause considerable morbidity (Pohlemann et al. 1994, Tornetta and Matta 1996, Tötterman et al. 2006). However, little is known about which factors determine long-term clinical outcome in these patients, or what may explain the progression of neurological symptoms observed in a small proportion of patients (Adelved et al. 2012). Pelvic malunions and nonunions have been put forward as prognostic factors for impaired long-term outcome (Matta et al. 1996, Mears and Velyvis 2003, Oransky and Tortora 2007), but long-term structural changes of the sacrum after fracture healing have not been explored.

Our primary aim was to assess long-term radiological findings after surgically treated displaced sacral fractures. In addition, we wanted to assess whether pathological radiological findings, including bony structural changes of the sacrum, may contribute to neurological dysfunctions of the lower extremities or to the occurrence of pelvis-related pain.

Patients and methods

From July 1996 through October 2001, 39 consecutive patients with operatively treated displaced sacral fractures were prospectively registered at Oslo University Hospital, Ullevaal. Tötterman et al. (2006) conducted a 1-year follow-up study of these patients, where 32 patients were available for follow-up.

In the present long-term study, 28 of these 32 patients were available for clinical and radiological follow-up. Of the 4 patients who were lost to follow-up, 1 died, 2 declined to participate, and 1 patient was excluded due to a complete spinal

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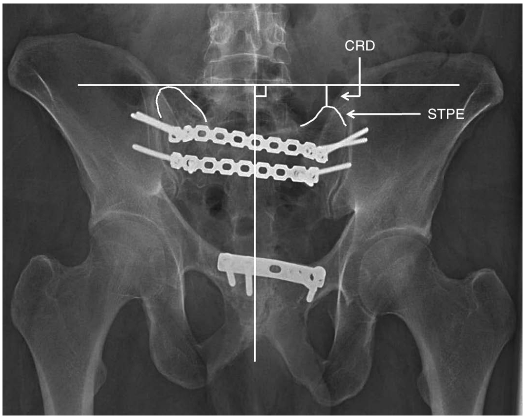

Figure 1. Measurement of cephalad residual displacement (CRD) of the right hemipelvis and sacrum illustrated on a pelvic outlet image. A midline vertical line is drawn along the axis of the central portion of the sacrum. A horizontal line, perpendicular to the vertical line, is drawn on the highest of the 2 measurement points—in this case, the lateral top points of the sacral transverse process elements (STPE). The difference in height between the horizontal line and the lowest of the 2 measurement points is the CRD.

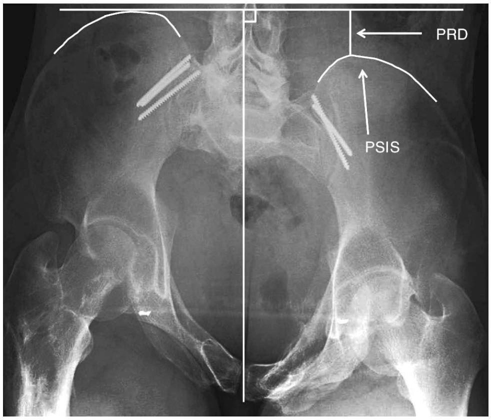

Figure 2. Measurement of posterior residual displacement (PRD) of the right hemipelvis and sacrum illustrated on a pelvic inlet image. A midline vertical line is drawn along the axis of the central portion of the sacrum. A horizontal line, perpendicular to the vertical line, is drawn on the highest of the 2 measurement points—in this case the posterior superior iliac spines (PSIS). The difference in height between the 2 PSIS is the PRD.

cord injury with paraplegia. Of the patients included, 1 was excluded from the neurological examination in the study protocol due to hemiparesthesia after a head injury, but fulfilled the rest of the protocol. Mean follow-up time was 11 (8–13) years, female-to-male ratio was 7:21, and mean age was 43 (26–67) years. The mechanisms of injury included 20 motor vehicle accidents, 7 falls from heights, and 1 crush injury. Pelvic ring injuries were classified according to the AO/OTA fracture classification (Fracture and dislocation compendium. Orthopaedic Trauma Association Committee for Coding and Classification 1996). In 26 cases, the sacral fractures were part of a vertical shear pelvic ring disruption, classified as AO/OTA type-C injuries, and 2 patients had H-shaped sacral fractures. The sacral fractures were further classified according to Denis et al. (1988) as zone I (n = 1), zone II (n = 20), and zone III (n = 7). All fractures were treated operatively: 22 with open reduction and internal fixation, 12 with concomitant sacral laminectomy, and 6 with closed reduction and percutaneous SI-screw fixation (Adelved et al. 2012). Additional anterior plating was performed in 14 patients. The functional outcome of these patients after a mean of 11 years post injury has already been reported (Adelved et al. 2012).

Radiological examination

At follow-up, all patients underwent conventional radiographic examination of the pelvis and the lumbar spine. This included pelvic anteroposterior, inlet, and outlet views according to standard radiographic protocol (Bontrager and Lampignano 2005).

Residual displacement (RD) was defined as a cephalad or posterior displacement of the hemipelvis and sacrum, and was graded as < 10 mm or ≥ 10 mm. In the outlet views, cephalad residual displacement (CRD) was recorded by measuring the difference in height between the top lateral prominences of the 2 sacral transverse process elements (Standring et al. 2008) (Figure 1). In the inlet views, posterior residual displacement (PRD) was recorded by measuring the difference in height between the posterior superior iliac spines (Mears and Velyvis 2003) (Figure 2). In 4 cases, PRD was determined using the difference in height between the ischial spines in the inlet views, since in these images the posterior pelvic borders were not sufficiently visualized in the films.

All patients were also examined with a 64-channel multidetector computer tomography (MDCT). The CT images were scrutinized for nonunion, ankylosis, osteoarthritis (OA) in the L5-S1 facet joints and the SI-joints, and heterotopic ossification. Fracture healing was confirmed by the presence of bridging trabecular bone across the fracture lines on CT.

To identify any bony entrapment of the nerves, all 3 sets of 2D CT images were used, following each nerve from the spinal canal to the point where the nerve was peripheral to the sacrum. Narrowing of the neural foramina were recorded and then divided into 4 categories: 1: no narrowing; 2: less than 50% narrowing; 3: more than 50% narrowing; and 4: total occlusion of the foramen (Figure 3).

L5 and S1 nerves were then followed in their post-foraminal course and any changes in their path were recorded—i.e. displacement of the nerves by pathological bony structures and

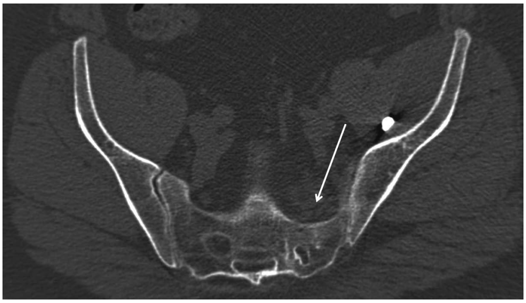

Figure 3. Considerable distortion and narrowing of the left S1 neural foramen, marked with an arrow. Note the unaffected contralateral foramen for comparison.

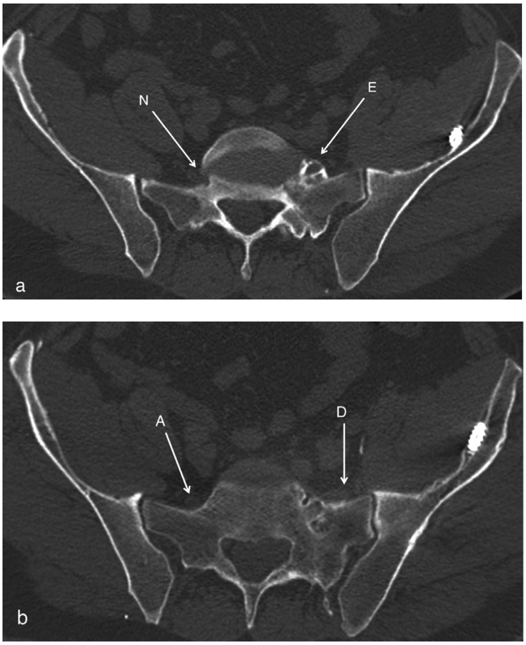

Figure 4. a. Bony encroachment of the left L5 nerve post-foraminally (E). The contralateral L5 is unaffected in its post-foraminal path (N). b. A few slices more distally. The left L5 is dislocated laterally from its anatomical path (D), running through the area with fracture sequelae, with topographical changes of the adjacent bony surface. (A) shows the unaffected contralateral L5 nerve running in its anatomic path.

thus diversion from the assumed anatomical course or entrapment/overgrowth of the nerves by bony structures (Figure 4). The S2-S4 nerves were not as readily identifiable post-foraminally as L5 and S1, and they were therefore not included in the post-foraminal assessment. Finally, any narrowing of the spinal canal was recorded, using the midline sagittal images evaluating the inner tapering AP diameter.

A radiologist who was experienced in pelvic traumatology (JCH) reviewed all the radiographs and CT scans. He was blinded regarding the clinical information.

Clinical examination

Sensorimotor impairments were classified according to the American Spinal Injury Association (ASIA) score (Maynard et al. 1997, Adelved et al. 2012). The clinical assessment focused on neurological function in the lower extremities and the perineum.

Pain was assessed using a visual analog scale (VAS) ranging from 0 to 10, where zero represented no pain and 10 the most severe pain. The patients were asked to grade their average pain specifically in the lower back and posterior pelvic area. When present, radiating pain to the lower extremities was also recorded. Peripheral pain in the lower limbs was not considered when there were sequelae after lower extremity injuries.

Statistics

Due to small sample size and skewed distribution, non-parametric methods (namely, Spearman correlation coefficients) were used and p-values of ≤ 0.05 were considered to be statistically significant. We used PASW Statistics 18 software.

Ethics

The study was reviewed and approved by the Regional Committee for Medical and Health Research Ethics, Region South-East Norway. All patients signed an informed consent document at follow-up.

Results

Radiological findings

Residual displacement of more than 10 mm was observed in 16 patients: 6 with CRD, 3 with PRD, and 7 with a combination of CRD and PRD. In the remaining 12 patients with residual displacement of less than 10 mm, 10 had a combination of CRD and PRD, 1 had a pure CRD, and the other a pure PRD (Table 1). The average CRD of ≥ 10 mm was 15 (10–28) mm and the average PRD of ≥ 10 mm was 19 (11–35) mm. The average CRD of < 10 mm was 4 mm and the average PRD of < 10 mm was 6 mm (Table 2).

Nonunions were seen in only 2 patients, both of them occurring in the anterior pelvic ring. These patients were operated with both anterior and posterior fixation: in 1 of them all the implants were intact, while both anterior and posterior implant failure was noted in the other patient. All sacral fractures were healed.

Table 1. Residual displacements in the posterior pelvic ring assessed with inlet- and outlet radiographs at 11 years; n = 28

	n
RD ≥ 10 mm	16
Combination of CRD and PRD	7
CRD	6
combined with PRD < 10 mm	5
pure CRD	1
PRD	3
combined with CRD < 10 mm	2
pure PRD	1
RD < 10 mm	12
Combination of CRD and PRD	10
Pure CRD	1
Pure PRD	1

RD: residual displacement;
CRD: cephalad residual displacement;
PRD: posterior residual displacement.

Table 2. Residual displacement in the posterior pelvic ring at 11 years, measured on the inlet- and outlet radiographs; n = 28

	Average (range)
CRD ≥ 10 mm	15 (10–28) mm
PRD ≥ 10 mm	19 (11–35) mm
CRD < 10 mm	4 mm
PRD < 10 mm	6 mm

CRD: cephalad residual displacement;
PRD: posterior residual displacement.

Table 3. Radiological findings assessed with CT: changes in the lumbosacral area and the SI-joints, and bony structural changes in L5 and sacrum; n = 28

	n
L5-S1	
Ankylosis, facet joints	9
bilateral	4
with OA in contralateral joint	3
with normal contralateral joint	2
L5-TP fusion to sacrum	3
L5-S1 disc space narrowing	14
OA, facet joints	18
SI-joint(s)	
Ankylosis	8
unilateral	6
bilateral	2
OA	12
bilateral	2
with ankylosis in contralateral joint	2
with normal contralateral joint	8
Heterotopic ossification	13
Ilio-lumbar ligaments (ILL)	4
Pelvic floor (PF)	5
Both in PF and ILL	4
Sacral canal narrowing	8
L5 vertebral canal narrowing [a]	1
Neural root foramen narrowing	26
L5	17
S1	20
S2	15
S3	9
S4	9
Post-foraminal bony encroachment, L5 nerve	22
Post-foraminal bony encroachment, S1 nerve	16

[a] sequelae after unstable L5 fracture.
SI: sacro-iliac; OA: osteoarthritis;
TP: transverse process.

26 of 28 patients had narrowing of 1 or more neural foramina from L5 to S4. Post-foraminal bony encroachment of the L5 nerve was observed in 22 patients (Table 3).

In 9 patients, the implants had been removed due to posterior pelvic pain. In the remaining 19, breakage or loosening of implants was seen in 8 cases (involving anterior implant failure in 3 cases, posterior implant failure in 3, and both anterior and posterior implant failure in 2 cases).

Clinical findings

Neurological assessment in 1 patient was not possible due to sensory impairments in the right side of the body after a head injury. In the remaining 27 patients, 26 had neurological deficits in the lower extremities. 12 had minor to moderate sensory deficits affecting the L5-S4/S5 dermatomes. The L5-S1 dermatomes were mainly affected. Combined sensory deficits and muscle weakness were present in 14 patients. The deficits were unilateral in 9 and bilateral in 14. Uni- or bilaterality of neurological deficits could not be assessed in 3 patients who had undergone unilateral amputation below the knee: 2 initially due to crush injuries and 1 due to sequelae after severe foot and ankle fractures 5 years post injury.

8 patients reported having no pain at the long-term follow-up. Of the remaining 20 patients, 11 reported pain limited to the lumbosacral area while 9 reported both lumbosacral pain and radiating pain involving the L5-S2 dermatomes. However, 15 patients had scores of ≤ 2 on the VAS scale, indicating slight or no pain. Of the remaining 13 patients, 5 had VAS scores between 4 and 7, and 5 had scores of ≥ 8.

Correlation of clinical and radiological findings

Narrowing of the sacral foramina in S1-S3 had a statistically significant correlation with neurologic deficits in the corresponding dermatomes. Similarly, there was a correlation between narrowing of the sacral canal and neurological deficits at the S2 level. Post-foraminal involvement of the L5 nerves was significantly correlated with both sensory and motor deficits in the corresponding dermatomes (Table 4). No significant correlations were found between any of the radiological findings and posterior pelvic pain (Table 5).

Table 4. Correlation between the radiologically verified narrowing of the neural foramina and neurological deficits in corresponding dermatomes; n = 27

	Spearman's correlation coefficient	p-value
Narrowing of the sacral central canal	0.42	0.03 [a]
Neural foramen level		
L5		
sensory	0.22	0.1
motor	0.08	0.6
S1		
sensory	0.30	0.03
motor	0.15	0.3
S2	0.50	< 0.001
S3	0.45	0.001
S4	0.22	0.1
L5-post-foraminal boney encroachment		
Sensory	0.31	0.03
Motor	0.35	0.01

[a] significance only at S2-level.

Table 5. Correlation between radiological findings and lumbosacral pain; n = 28

	Spearman's correlation coefficient	p-value
L5-S1		
Disc space narrowing	0.09	0.7
Facet joint osteoarthritis	0.28	0.2
Facet joint ankylosis	0.27	0.2
SI-joint		
Ankylosis	0.01	1.0
Osteoarthritis	0.05	0.8
Presence of implants	0.29	0.1
Residual displacement ≥ 10 mm		
Cephalad	0.14	0.5
Posterior	0.005	1.0

Discussion

There are no established validated protocols for radiological quantification and measurement of pelvic deformities and other sequelae after pelvic ring disruptions (Lefaivre et al. 2012). For measurement of residual displacement, we used conventional radiographs, since they are readily available and are most commonly used by most orthopedic surgeons in outpatient clinical settings. We used the methods described by Mears and Velyvis (2003), but modified the landmarks for the CRD measurements on the outlet films; we were mainly interested in the sacral fracture and any displacements of the sacral bone. In addition, a few patients sustained sequelae after iliac wing fractures, resulting in inaccurate measurements when the tops of the iliac wings were used as reference landmarks. We therefore used the sacral transverse process elements of the lateral masses as CRD landmarks.

Malunion is imprecisely defined after pelvic ring injuries, but most authors have considered displacement in any dimension of less than 10 mm, with no gross rotational malalignment, to be a satisfactory result (Tornetta and Matta 1996, Lindahl et al. 1999). The consequences and treatment of sacral malunions after surgery are poorly documented. Most reports have been case reports or small case series, and late surgical decompression of the neural roots in these patients has seldom been described in the literature (Alexander et al. 2013).

There have been a few publications describing clinical manifestations and surgical treatment of pelvic malunions and nonunions (Pennal and Massiah 1980, Matta et al. 1996, Mears and Velyvis 2003, Oransky and Tortora 2007). In these series, the initial treatment of the fractures consisted of either nonoperative treatment or external fixation in the majority of cases, resulting in inadequate posterior pelvic stability (Lindahl et al. 1999, Kanakaris et al. 2009). A substantial number of the patients in these reports had major pelvic ring deformities with considerable morbidity related to the deformity.

Our series is therefore not directly comparable to these studies. All our patients were initially treated with internal fixation, and at the long-term follow-up, none of them had major deformities or nonunions in the posterior pelvic ring. As reported in our previous publication, 26 of our 28 patients were able to walk independently (Adelved et al. 2012).

Numerous authors have considered a residual cephalad displacement of more than 10 mm to be a poor prognostic factor (McLaren et al. 1990, Matta and Tornetta 1996, Matta et al. 1996, Tornetta and Matta 1996, Lindahl and Hirvensalo 2005) and have recommended accurate reduction of a displaced vertically unstable sacral fracture.

Other studies have shown conflicting results. Nepola et al. (1999) presented the results of 33 patients with type-C vertical shear injuries, treated with external fixation or nonoperatively, with residual displacement ranging from 2 mm to 52 mm. They found no correlation between residual displacement and functional outcome, including pain. Pohlemann et al. (1996) reported the results of 30 patients with type-C, vertically unstable pelvic ring fractures, treated with internal and/or external fixation. 18 had slight pain or no pain, 28 had residual displacement of < 10 mm, and only 8 had good or excellent outcome.

Displaced unstable sacral fractures are frequently associated with neurological lesions (Huittinen 1972, Gibbons et al. 1990, Majeed 1992). The configuration and size of the anterior sacral foramina may be altered, either due to insufficient reduction, or later due to callus formation during the bone-healing process. In the present study, narrowing of the sacral foramina was observed in several patients and correlated with neurological deficits. As opposed to sacral foramina, structural changes in the L5 neural foramina did not appear to have any effect on neurological deficits. However, post-foraminal encroachment of the L5 nerves correlated well with neurological deficits in the corresponding dermatomes. Post-foraminally, impingement of the L5 nerve may be caused by several structures, formed by the lumbosacral ligament (Nathan et al. 1982). Also, it runs distally along the anterior aspect of the lateral mass between the SI-joint and the sacral foramina. This path is usually the main fracture area in a vertically unstable sacral fracture, and the L5 nerve may thus be avulsed or stretched by bony fragments in cases of severe fracture displacement (Huittinen 1972, Denis et al. 1988). Later, during fracture healing, bony encroachment caused by callus or ectopic bone formation may contribute to further neurological dysfunction. However, the exact cause of L5 pathology observed in our patients cannot be determined from this study.

Several studies have shown limited long-term recovery of the neurological injuries after pelvic fractures (Matta and Saucedo 1989, Tornetta and Matta 1996, Rommens and Hessmann 2002). To our knowledge, changes in the sacral topography—including changes in the shape and diameter of the anterior sacral foramina after fracture healing—have not been studied in detail. In the present study, with no CT scans from previous follow-ups, comparison with earlier radiographs and recording of changes over time was not possible. Thus, we cannot determine whether the neurological deficits were caused or deteriorated by gradual changes in the topography of the bony structures, although we found a close relationship between boney impingement/encroachment of neural structures and neurological deficits.

We observed a substantial proportion of patients with osteoarthritis of the facet joints, the lumbosacral junction, and the SI-joints. Degenerative processes in the lumbosacral spine, including facet joint OA and L5-S1 disc space reduction, are often reported in epidemiological and cadaveric studies (Eubanks et al. 2007, Kalichman et al. 2010). These studies also suggest that the association between these findings and low back pain is variable. There are no epidemiological data on the prevalence of OA in SI-joints. Radiological changes in the SI-joints have been suggested to contribute to low back pain (Hodge and Bessette 1999). Yet, other authors have shown normal variations in the appearance of the SI-joints, depending on factors such as sex and age (Vogler et al. 1984, Faflia et al. 1998). In these studies, degenerative changes were frequent with increasing age in individuals without back pain. Our results back up these studies. 15 out of 28 of our patients had no pain or only slight pain in the posterior pelvic area (VAS ≤ 2). For the remaining 13 with moderate to severe pain, no correlations were found between pain and any of the radiologic findings, including residual displacement.

There were some methodological differences between our study and the studies mentioned: all our patients were treated with internal fixation and we used a VAS scale to quantify pain. Despite these differences, our results support the results of the studies indicating a lack of association between residual displacement and pain. Our results indicate that foraminal architecture and bony changes around the fracture area may play a greater role in the long-term outcome than the overall pelvic alignment.

The present study had some limitations. The number of patients was low, so the results of the statistical analyses should be interpreted with caution. In addition, due to limited access to postoperative and 1-year follow-up radiographs, comparison of the 11-year radiological results with the earlier images was not possible. The strength of the study lies in the long-term follow-up and high response rate, and also the thorough neurological and radiological assessments.

In summary, pathological radiological findings are common after operatively treated displaced sacral fractures. Sacral foraminal and L5 post-foraminal encroachments correlated with neurologic deficits. Lumbosacral pain did not correlate with radiological sequelae after fracture healing, including residual displacement.

AA: Design, data collection, examination of all patients, data analysis, and writing of the manuscript. AT: design, surgery, and critical review of the manuscript. JCH: analysis and interpretation of the radiographs and CT scans. TG: data collection, examination of all patients, data analysis, statistical assistance, and critical review of the manuscript. JEM and OR: design, surgery, and critical review of the manuscript.

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