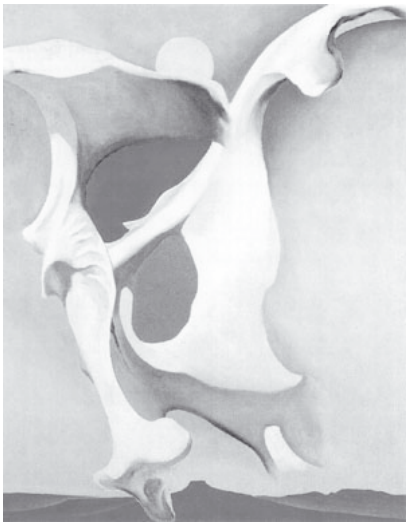
Chapter One

Review of the Literature



INTRODUCTION

A pelvic ring fracture is a relatively uncommon injury, sustained after major trauma. About 3 – 8% of the multitrauma patients acquire a pelvic ring fracture[1-3]. Especially if the fracture is compound or combined with major vessel injury, the mortality is reported as high as 70 % [4-6]. Concomitant injuries are common, e.g. intra-abdominal injury (up to 40%) and head injury (30%)[7-10]. Initial treatment of the patient should be according to the ATLS ® (Advanced Trauma Life Support) guidelines to ensure optimal survival chances for the patient. This thesis, however, does not deal with the initial life threatening aspects, like hypovolaemic shock, but focuses on the surgical technique of internal stabilization and long term outcome.

Especially for unstable pelvic ring fractures nonoperative treatment has poorer outcome compared to operative treatment and a more aggressive approach is therefore advocated[11-13]. External fixation, although by some still used as definitive treatment, does not seem to be able to retain long term reduction of the fracture parts in unstable fractures, which leads to increased discomfort for the patient[2,11,14,15]. Internal fixation has shown to improve both short term survival and long term quality of life[12,16-21]. Nevertheless, internal fixation of the anterior and especially the posterior pelvic ring is a demanding procedure. Despite an aggressive approach several aspects of daily life and the quality of life remain reduced compared to the general population[8,22,23].

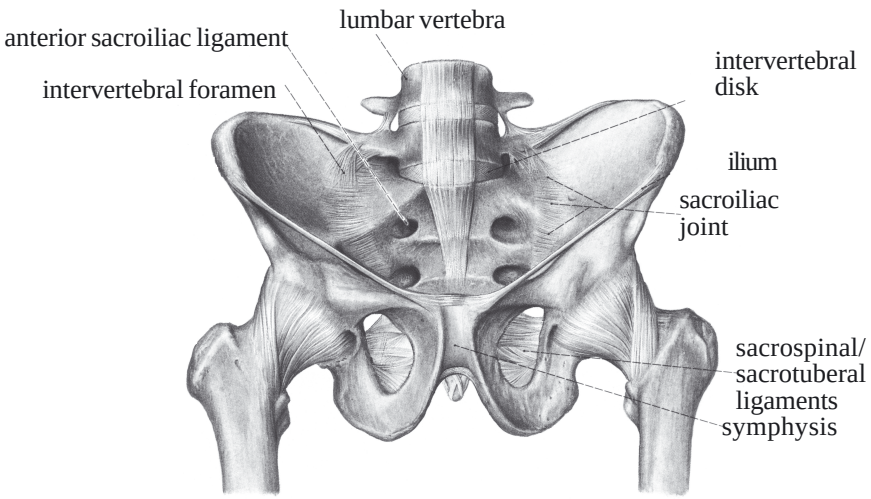


Figure 1. Pelvic anatomy

ANATOMY

The pelvis is a complete articulated bony ring formed by the sacrum and both innominate bones, which themselves are a fusion of the ilium, ischium and pubic bone. The bony parts of the pelvis are connected anteriorly by strong layers of fibrocartilage and fibrous tissue at the symphysis pubis. Posteriorly, the sacrum is connected to the iliac bones through strong fibrous ligaments at the sacroiliacal joint. Additional stability is obtained by the sacrotuberous, sacrospinous, iliolumbar and lateral lumbosacral ligaments. Most blood vessels for both arterial and venous supply of the lower extremities and of the peripelvic organs run close to the bony pelvis. Apart from its main biomechanical function, which is to connect the upper body to the lower extremities, the pelvis ring surrounds several organs, such as the bladder with the urethra, the anorectum and the reproductive organs in females. The sacrum also contains the sacral plexus that innervates most lower extremity muscles, anal and urethral sphincter and reproductive organs in both male and female.

FRACTURE CLASSIFICATION

Various classifications have been used for the descriptions of pelvic injuries. Malgaigne introduced one of the first classifications in 1847[24]. In this classification he distinguished five types of fractures ranging from simple anterior fractures to combinations with posterior pelvic ring fractures. Currently, the key towards fracture classification is the (in)stability of the pelvic ring. Ranging from the completely intact pelvis to the completely unstable pelvis, the different types of fractures require different treatment strategies. Tile sequentially dissected the ligaments to define the spectrum of stability[2]. After dissection of the symphysis and the creation of a diastase of more than 2.5 cm the sacrospinous and anterior sacroiliac ligaments rotational stability is created. By dissection of the posterior sacroiliac and sacrotuberous ligaments vertical instability is added. Bony injuries can create the same spectrum of stable, rotationally unstable and vertically unstable injuries.

Tile and the AO foundation specify three types of pelvic ring fractures based on the stability of the pelvic ring[2,25,26]. A-type describes lesions in which the pelvic ring is not interrupted. This is a stable lesion in which the pelvic floor is intact and the pelvis can withstand weight bearing without risk of dislocation.

In the B-type lesion the anterior pelvic ring is interrupted completely and the posterior ring incompletely. This leads to a rotational instability around a vertical axis. This lesion is partially instable and may include disruption of the pelvic floor. Since this lesion is more relevant to this thesis, the various subtypes are summarized briefly. A B1-type is an “open book” injury in which the dislocation of the symphysis pubis is such that the anterior sacroiliac ligaments are disrupted. A B2-type lesion is a “lateral compression” injury in which the pelvis is compressed by a lateral impacting trauma. A B3-lesion is a bilateral injury of either B1 or B2 type.

The C-type lesion is characterized by a completely unstable pelvic ring. There is a complete disruption of the ligamentous or bony continuity of the pelvis. This leads to a three-dimensionally unstable fracture. While in a C1 fracture the contralateral posterior ring is intact, in C2 fractures a contralateral B type injury is present and in a C3 type a bilateral C type lesion is present.

LOCOREGIONAL COMPLICATIONS

Bleeding is one of the acute lifethreatening injuries, which can be treated by either fracture stabilization, peripelvic packing with gauzes, or selective angiography and embolization in case of persistent bleeding. Embolization is shown to successfully stop arterial bleeding in up to 90% of the patients[12,27-29]. Disruption of the urethra or the anal canal may complicate the treatment of the fracture and is most commonly seen in Tile B1 or C lesions. In Tile B2 and C lesions perforation of the bladder and rectum by fracture parts may occur. In urogenital injuries treatment should be coordinated with a urologist and depending on the injury a urethral cath-

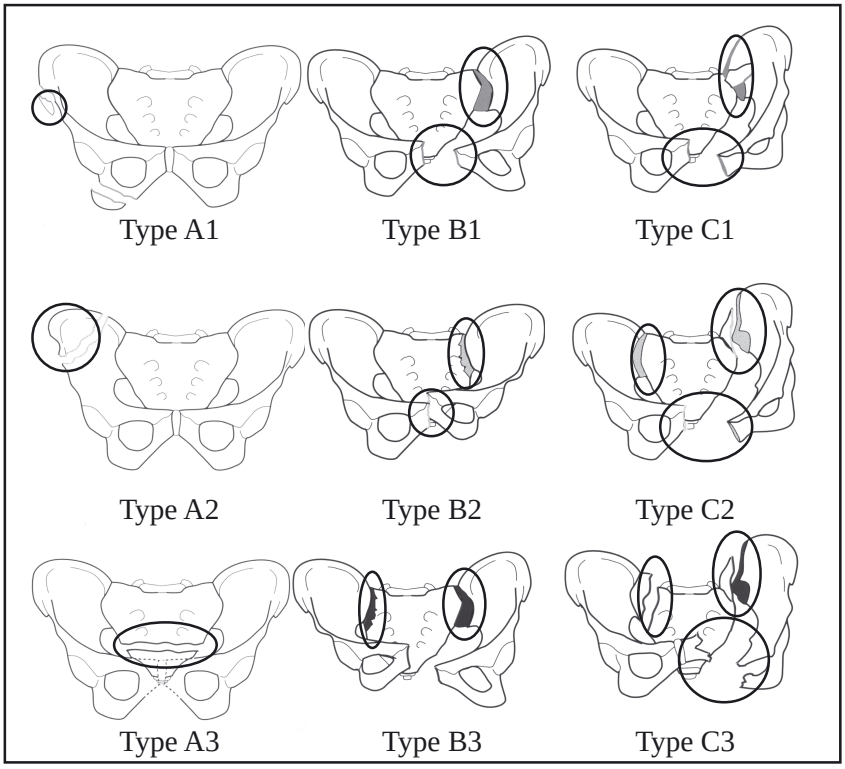


Figure 2. Tile classification. Explanation of the various types is given in the text.

eter or suprapubic catheter with secondary urethral reconstruction may be required[30]. Later urethral stenosis and impotence are not uncommon[30]. Anorectal injury also poses a significant problem, a diversing colostomy combined with extensive locoregional washout and secondary reconstruction may be required to prevent septic pelvic disease. Depending on the fracture type, in up to 63.6% of the patients with pelvic fractures permanent damage of the lumbosacral plexus could be detected[31]. Reposition of the fracture parts seldom leads to improvement [11,31-33]. In the direct postoperative phase common complications are deep venous thrombosis, pulmonary embolism and systemic complications commonly associated with major trauma like A.R.D.S. and M.O.F.. Subsequently morbidity is high and related to poor functional outcome in many cases.

INITIAL MANAGEMENT

Although several authors have described various strategies and techniques for the management of the acutely injured patient with a pelvic ring fracture, most agree that the stabilization in the first hour, using the guidelines of the ATLS®, is the most important part. Initial treatment should be aimed at stabilizing the vital aspects of airway, breathing and circulation, the latter being the most endangered by the pelvic ring fracture. Volume therapy plays an important role in reducing the effects of hypovolaemic shock, but additionally the blood loss due to pelvic fracture can be reduced using simple measures such as a tight sling around the pelvis or a pelvic C-clamp[34-36]. The use of P.A.S.G. (pneumatic anti shock garment) is controversial[37-39]. Since the initial management of unstable pelvic ring fractures is not the object of this thesis, this will not be discussed in detail. However, despite the fact that early internal fixation may not be possible in the unstable patient who requires multiple operations to stabilize his condition, we advocate definitive stabilization as soon as possible since it is easier to reduce the fracture parts and to achieve optimal results.

OPERATIVE TECHNIQUES: ANTERIOR FIXATION

Surgery is seldom required for completely stable (type A) fractures. Operative treatment is suggested for rotationally or vertically unstable pelvic ring fractures (type B or C). One of the most important objectives of the operative treatment of the pelvic fracture is the reduction of the fracture parts, since this may reduce blood loss and thus mortality. The reduction of the anterior pelvic ring, either symphysis or pubic bones, followed by stabilization is a key element to achieve overall reduction. Several techniques and many implants, external fixators, tension bands, plates of different sizes and screws, have been studied[15,32,40-49]. External fixation seems to be inferior to internal fixation in obtaining the anatomical relationship of the fracture parts. Lindahl described loss of reduction using a trapezoid external fixator in 57% of 110 patients and recommended its use to be limited to the acute phase of resuscitation and not for definitive treatment[15]. For diastases of

the symphysis most authors concluded that plate fixation is treatment of first choice[15,40]. Hofman and Varga concluded that wiring was superior in the osteoporotic pelvis but Meissner found opposite results in 24 pelves undergoing dynamic loading[41,42,50]. Although most authors recommend plate fixation for symphysiolysis and for severely displaced pubic ramus fractures, the role of fixation in minimally displaced pubic ramus fractures is still discussed[14,40,44,51-54]. To avoid extensive ilioinguinal exposure retrograde medullary screw fixation can sometimes be used in lateral superior pubic ramus fractures[21,55].

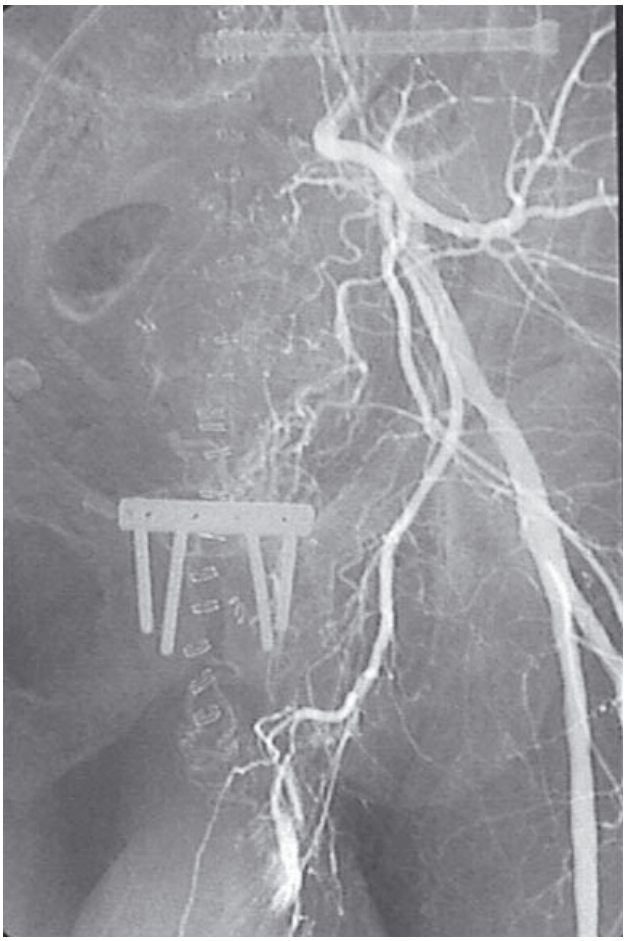


Figure 3. A Tile B1 fracture fixated with anterior plate fixation and a sacroiliac screw posteriorly. An angiography of the iliac artery is being performed.

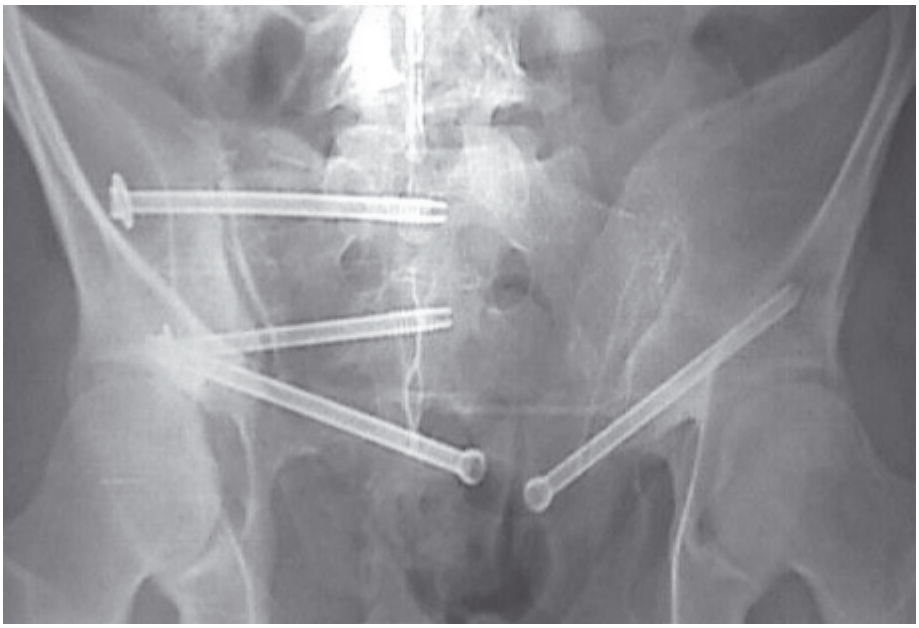


Figure 4. Bilateral pubic screws combined with unilateral sacroiliac screws for a Tile C fracture with bilateral pubic bone fractures and a unilateral sacral fracture.

OPERATIVE TECHNIQUE: POSTERIOR RING

For sacroiliac joint disruptions and fractures of the sacrum the same principles apply. For unstable fractures or dislocations internal fixation can be carried out through an anterior or posterior approach. Although traditionally the major disadvantage of the posterior approach was the high risk of wound infection, percutaneous techniques currently allow positioning of lag screws through minimal incisions. Biomechanically, screws have the same stability as sacroiliac plates, while external fixation is less stable[43-45]. Other fixation techniques of the posterior ring include sacral bars, small fragment implants and pre-bent plate across bilateral fractures[2,44,56].

In several studies posterior pelvic ring fixation was combined with anterior fixation, either using plate or screw fixation[32,41,43,46-49,57]. However, others have used isolated sacroiliac screw fixation[32,46,57], or used a combination with an external fixator[32,46,57-59]. In a series of 127 patients treated with sacroiliac screws Routt recommends applying anterior fixation if anterior fracture dislocation exceeds 1 cm in any direction[47]. Anterior fixation allows early reduction of the fracture which makes percutaneous posterior screw fixation less complicated and also provides additional stability and reduces malunion and nonunion in the long term[60]. It is not sufficient to stabilize Tile C fractures without posterior fixation[32,41,53]. After the anterior fixation, performed in a supine position, it is possible to perform sacroiliac

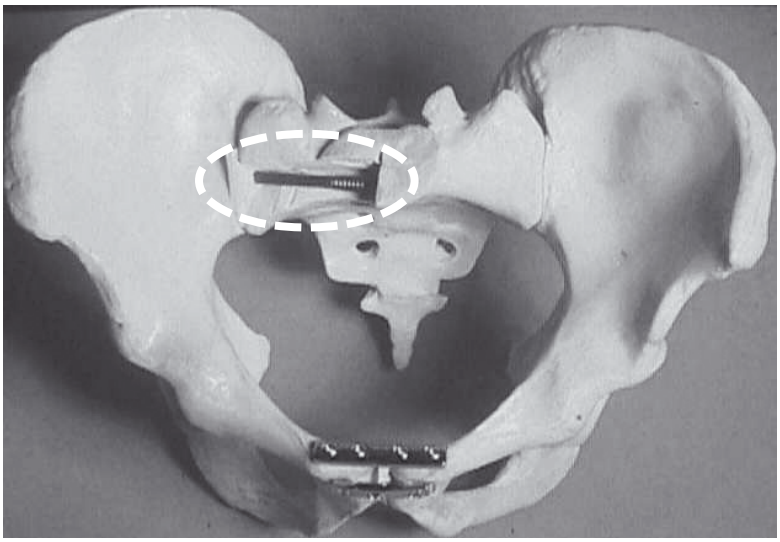


Figure 5. Example of a sacroiliac screw in a plastic pelvic. Part of the sacral ala and the vertebral body have been removed to clarify the exact position of the screw.

screw positioning in the same position. However, especially in bilateral cases sacroiliac screw positioning is technically easier in prone position, despite the risk this carries in trauma patients[46,61]. Intra-operatively the posterior pelvic ring is evaluated through inlet, outlet and lateral views using C-arm fluoroscopy[61]. After the correct position of a K-wire in the body of the first or second sacral vertebra is confirmed, the sacroiliac screw is inserted. When two sacroiliac screws are used they can be inserted parallel into the first and second vertebral body but also converging into the first vertebral body. Because there are indications of an increased risk of sacral foramina intrusion when positioning the lower screw into the second vertebral body, currently both screws are positioned into the first vertebral body, unless sacral abnormalities prevent the use of this technique[62]. Although positioning sacroiliac screws using an open technique is easier because it makes a smaller demand on the accuracy of the surgeon's hand[63], percutaneous positioning results in less tissue damage, which leads to improved wound healing and decreases infection risk. A similar positioning technique has been described using computed tomography or computer navigated fluoroscopy[48,48,59,64-67]. Although these techniques promise superior results due to the improved quality of the imaging techniques, malpositioning is still possible[48].

Optimally, internal fixation is a technique that stops bleeding (by decreasing the volume of the pelvis, preventing clot dislodgement by limiting movement and approximating fracture surfaces) and prevents late complications such as nonunion, malunion, chronic pain, and leg length difference.

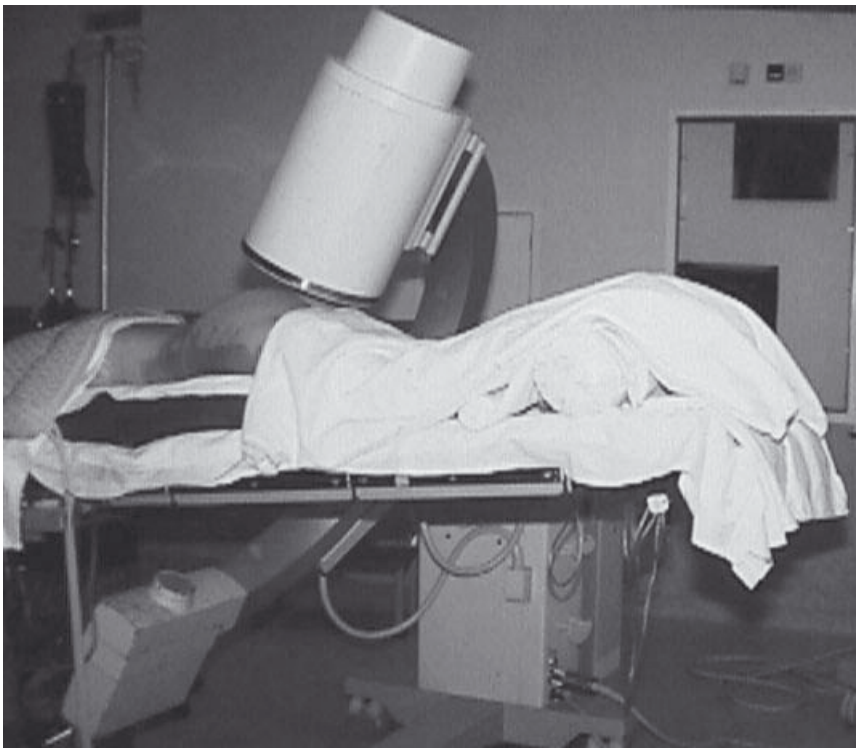


Figure 6. Patient positioned prone for sacroiliac screw fixation. A C-arm is set for inlet view.

SHORT TERM COMPLICATIONS

Although several life threatening complications, such as hemorrhaging and secondary multi organ failure, can occur in the multitrauma patients, some are related more closely to the pelvic ring injury and its treatment. Complications due to the pelvic ring injury occurring shortly after the injury are injury to bladder, urethra, genitals and anorectum are described previously. Complications of sacroiliac screw fixation include poor posterior reduction, wound infection, which is seen less frequently after percutaneous technique compared to open technique, intrusion into the intervertebral foramina with possible nerve injury, loosening of the fixation, peroperative guidewire breakage and screw breakage[46-49,57,58,61]. One case of superior gluteal artery injury, requiring embolization, is described[68]. In about 0.5 to 13 % of the patients in whom the posterior pelvic ring has been stabilized using screws, a neurological injury due to intrusion of the screws into the sacral canal of the sacral foramina occurs[19,32,46,47,49,57,58].

Some authors advise to limit weight bearing after internal fixation on the injured side for 10 to 12 weeks[7,10,32,49,57,69]. This, however, is shown to compromise pulmonary function increasing the risk of (ventilator associated) pneumonia and adult respiratory distress syndrome[7,9]. Surgical intervention and early mobilization improves bronchial toilet and results in earlier weaning from the ventilator, while protecting the neurovascular structures through stable internal fixation[7,70,71].

LONG TERM OUTCOME

Most studies show that the functional outcome after unstable pelvic ring injuries is limited[1,3,8,12,19,22,23,72-77]. However most patients also have several associated injuries that may influence outcome. The outcome after conservative treatment is poor. About 40% of the patients suffered persistent pain and only 50% were able to return to work[12,19,72-74]. Tile reported on 218 patients treated nonoperatively and found in 60% of the patients complaints of pain[75]. Pohleman used his own outcome scale and reported that 79% of Tile-B type lesions had excellent or good results compared to 27% of Tile-C type lesions, although 50% of the patients healed anatomically[1,76]. Others used the SF-36 which was designed and validated for use in a clinical setting and for monitoring the health of a general population[78-80]. Oliver et al. reported both decreased physical and mental scores after pelvic ring fracture[3]. McCarthy and Cole evaluated the outcome after pelvic ring injuries and, except for mental health, all scales were significantly lower[8,22]. Miranda examined the relationship between the Tile-fracture classification and SF-36 outcome and found no difference between A and B/C type fractures[23].

Majeed evaluated the result of external fixation for unstable pelvic fracture in 42 patients and concluded that the functional results were better than the anatomical results, measured by criteria adjusted from Slätis and Karaharju[81,82]. Functional results improved the first 18 months and were stable thereafter.

Although no randomized clinical trials exist which compare long-term results of operative versus nonoperative treatment, there are indications that operative treatment may have superior results. Tornetta showed that after operative treatment all fractures were reduced to < 1 cm residual displacement, which was related to fewer pain complaints[33].

NONUNION

Although few data about incidence, optimal treatment and outcome of nonunion after fractures of the pelvic ring can be found in the literature, there are indications that nonunion is not as rare as was once thought[83]. Lindahl reports up to 5% nonunion and 58% malunion (defined as more than 10 mm dislocation) after external fixation[15]. In a series of 42 patients Pennal described their main complaints to be pain (98%) and having a limp (69%). Compared to conservatively

treated patients, the operatively treated patients with nonunion had significantly earlier consolidation and could return to work earlier. Non-union was commonly found in patients in which short immobilization (average immobilization 8.4 weeks) seemed to fail into maintaining reduction of the fracture parts[83]. Data by Ebraheim et al. also suggest pain as the main complaint and they reported considerable improvement after internal fixation in four patients[84]. Matta used a technique with sacroiliac screws in 37 patients. Using combined anterior and posterior fixation overall results were good with 32 patients were satisfied after nearly four years. Four patients suffered loss of reduction and in two patients persistent nonunion required reintervention[60].

REFERENCES

1. Pohlemann T, Gansslen A, Schellwald O, Culemann U, Tscherne H. Outcome after pelvic ring injuries. *Injury*. 1996;27 Suppl 2:B31-B38.
2. Tile M. *Fractures of the pelvis and actabulum.* Baltimore: Williams & Wilkins; 1995.
3. Oliver CW, Twaddle B, Agel J, Routt ML, Jr. Outcome after pelvic ring fractures: evaluation using the medical outcomes short form SF-36. *Injury*. 1996;27:635-641.
4. Birolini D, Steinman E, Utiyama EM, Arroyo AA. Open pelviperineal trauma. *J Trauma*. 1990;30:492-495.
5. Govender S, Sham A, Singh B. Open pelvic fractures. *Injury*. 1990;21:373-376.
6. Hanson PB, Milne JC, Chapman MW. Open fractures of the pelvis. Review of 43 cases. *J Bone Joint Surg [Br]*. 1991;73:325-329.
7. Routt ML, Jr., Simonian PT. Closed reduction and percutaneous skeletal fixation of sacral fractures. *Clin Orthop*. 1996;121-128.
8. Cole JD, Blum DA, Ansel LJ. Outcome after fixation of unstable posterior pelvic ring injuries. *Clin Orthop*. 1996;160-179.
9. Wolinsky PR. Assessment and management of pelvic fracture in the hemodynamically unstable patient. *Orthop Clin North Am*. 1997;28:321-329.
10. Blake-Toker AM, Hawkins L, Nadalo L et al. C.T. guided percutaneous fixation of sacroiliac fractures in trauma patients. *J Trauma*. 2001;51:1117-1121.
11. Tile M. Pelvic ring fractures: should they be fixed? *J Bone Joint Surg Br*. 1988;70:1-12.
12. Goldstein A, Phillips T, Sclafani SJ et al. Early open reduction and internal fixation of the disrupted pelvic ring. *J Trauma*. 1986;26:325-333.
13. Hesp WL, van der WC, Keunen RW, Goris RJ. Unstable fractures and dislocations of the pelvic ring—results of treatment in relation to the severity of injury. *Neth J Surg*. 1985;37:148-152.
14. Stocks GW, Gabel GT, Noble PC, Hanson GW, Tullos HS. Anterior and posterior internal fixation of vertical shear fractures of the pelvis. *J Orthop Res*. 1991;9:237-45.
15. Lindahl J, Hirvensalo E, Bostman O, Santavirta S. Failure of reduction with an external fixator in the management of injuries of the pelvic ring. Long-term evaluation of 110 patients. *J Bone Joint Surg Br*. 1999;81:955-962.
16. Ward EF, Tomasin J, Vander Griend RA. Open reduction and internal fixation of vertical shear pelvic fractures. *J Trauma*. 1987;27:291-295.
17. Bosch U, Pohlemann T, Tscherne H. [Primary management of pelvic injuries]. *Orthopade*. 1992;21:385-392.
18. Tornetta P, III, Dickson K, Matta JM. Outcome of rotationally unstable pelvic ring injuries treated operatively. *Clin Orthop*. 1996;147-151.
19. Matta JM, Saucedo T. Internal fixation of pelvic ring fractures. *Clin Orthop*. 1989;83-97.

20. Latenser BA, Gentilello LM, Tarver AA, Thalgott JS, Batdorf JW. Improved outcome with early fixation of skeletally unstable pelvic fractures. *J Trauma*. 1991;31:28-31.

21. Routt ML, Jr., Simonian PT. Internal fixation of pelvic ring disruptions. *Injury*. 1996;27 Suppl 2:B20-B30.

22. McCarthy ML, MacKenzie EJ, Bosse MJ, Copeland CE, Hash CS, Burgess AR. Functional status following orthopedic trauma in young women. *J Trauma*. 1995;39:828-836.

23. Miranda MA, Riemer BL, Butterfield SL, Burke CJ, III. Pelvic ring injuries. A long term functional outcome study. *Clin Orthop*. 1996;152-159.

24. Malgaigne JF. *Traite des fractures et des luxations*. Paris: J.B. Bailliere; 1847:771-772.

25. Tile M. Fractures of the pelvis. In: Schatzker J, Tile M, eds. *The rationale of operative fracture care*. Berlin: Springer-Verlag; 1996:221-269.

26. Tile M. Acute Pelvic Fractures: I. Causation and Classification. *J Am Acad Orthop Surg*. 1996;4:143-151.

27. Piotin M, Herbreteau D, Guichard JP et al. Percutaneous transcatheter embolization in multiply injured patients with pelvic ring disruption associated with severe haemorrhage and coagulopathy. *Injury*. 1995;26:677-680.

28. Agolini SF, Shah K, Jaffe J, Newcomb J, Rhodes M, Reed JF, III. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. *J Trauma*. 1997;43:395-399.

29. Biffl WL, Smith WR, Moore EE et al. Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures. *Ann Surg*. 2001;233:843-850.

30. Routt ML, Simonian PT, Defalco AJ, Miller J, Clarke T. Internal fixation in pelvic fractures and primary repairs of associated genitourinary disruptions: a team approach. *J Trauma*. 1996;40:784-790.

31. Pohlemann T, Gansslen A, Tscherne H. [The problem of the sacrum fracture. Clinical analysis of 377 cases]. *Orthopade*. 1992;21:400-412.

32. Keating JF, Werier J, Blachut P, Broekhuyse H, Meek RN, O'Brien PJ. Early fixation of the vertically unstable pelvis: the role of iliosacral screw fixation of the posterior lesion. *J Orthop Trauma*. 1999;13:107-113.

33. Matta JM, Tornetta P, III. Internal fixation of unstable pelvic ring injuries. *Clin Orthop*. 1996;129-140.

34. Schutz M, Stockle U, Hoffmann R, Sudkamp N, Haas N. Clinical experience with two types of pelvic C-clamps for unstable pelvic ring injuries. *Injury*. 1996;27 Suppl 1:S-50.

35. Heini PF, Witt J, Ganz R. The pelvic C-clamp for the emergency treatment of unstable pelvic ring injuries. A report on clinical experience of 30 cases. *Injury*. 1996;27 Suppl 1:S-45.

36. Ganz R, Krushell RJ, Jakob RP, Kuffer J. The antishock pelvic clamp. *Clin Orthop*. 1991;71-78.

37. Bruining HA, Eeftinck SM, De Vries JE, Van Urk H, Obertop H. Clinical experience with the medical anti-shock trousers (MAST) treatment of hemorrhage, especially from compound pelvic fracture. *Neth J Surg*. 1980;32:102-107.

38. Evers BM, Cryer HM, Miller FB. Pelvic fracture hemorrhage. Priorities in management. *Arch Surg*. 1989;124:422-424.

39. Moreno C, Moore EE, Rosenberger A, Cleveland HC. Hemorrhage associated with major pelvic fracture: a multispecialty challenge. *J Trauma*. 1986;26:987-994.

40. Matta JM. Indications for anterior fixation of pelvic fractures. *Clin Orthop*. 1996;88-96.

41. Varga E, Hearn T, Powell J, Tile M. Effects of method of internal fixation of symphyseal disruptions on stability of the pelvic ring. *Injury*. 1995;26:75-80.

42. Meissner A, Fell M, Wilk R, Boenick U, Rahmanzadeh R. [Comparison of internal fixation methods for the symphysis in multi-directional dynamic gait simulation]Vergleich interner Stabilisierungsverfahren fur die Symphyse im multidirektionalen dynamischen Gangbedingungssimulator. *Unfallchirurg*. 1998;101:18-25.

43. Simonian PT, Routt ML, Jr., Harrington RM, Tencer AF. Internal fixation of the unstable anterior pelvic ring: a biomechanical comparison of standard plating techniques and the retrograde medullary superior pubic ramus screw. *J Orthop Trauma*. 1994;8:476-82.

44. Pohlemann T, Culemann U, Tscherne H. [Comparative biomechanical studies of internal stabilization of trans- foraminal sacrum fractures]. *Orthopade*. 1992;21:413-421.

45. Comstock CP, van der Meulen MC, Goodman SB. Biomechanical comparison of posterior internal fixation techniques for unstable pelvic fractures. *J Orthop Trauma*. 1996;10:517-522.

46. Routt ML, Jr., Kregor PJ, Simonian PT, Mayo KA. Early results of percutaneous iliosacral screws placed with the patient in the supine position. *J Orthop Trauma*. 1995;9:207-214.

47. Routt ML, Jr., Simonian PT, Mills WJ. Iliosacral screw fixation: early complications of the percutaneous technique. *J Orthop Trauma*. 1997;11:584-589.

48. Jacob AL, Messmer P, Stock KW et al. Posterior pelvic ring fractures: closed reduction and percutaneous C.T.- guided sacroiliac screw fixation. *Cardiovasc Intervent Radiol*. 1997;20:285-294.

49. Templeman D, Goulet J, Duwelius PJ, Olson S, Davidson M. Internal fixation of displaced fractures of the sacrum. *Clin Orthop*. 1996;180-185.

50. Hofmann D. [Comparative study of various stabilization procedures in dislocation of the pelvic half joint]Vergleichende Untersuchung verschiedener Stabilisierungsverfahren bei der Luxation der Beckenhalbgelenke. *Unfallchirurgie*. 1991;17:247-52.

51. Leighton RK, Waddell JP, Bray TJ et al. Biomechanical testing of new and old fixation devices for vertical shear fractures of the pelvis. *J Orthop Trauma*. 1991;5:313-7.

52. Pohlemann T, Angst M, Schneider E, Ganz R, Tscherne H. Fixation of transforaminal sacrum fractures: a biomechanical study. *J Orthop Trauma*. 1993;7:107-117.

53. Simonian PT, Routt ML, Jr., Harrington RM, Mayo KA, Tencer AF. Biomechanical simulation of the anteroposterior compression injury of the pelvis. An understanding of instability and fixation. *Clin Orthop*. 1994;245-256.

54. MacAvoy MC, McClellan RT, Goodman SB, Chien CR, Allen WA, van der Meulen MC. Stability of open-book pelvic fractures using a new biomechanical model of single-limb stance. *J Orthop Trauma*. 1997;11:590-3.

55. Routt ML, Jr., Nork SE, Mills WJ. Percutaneous fixation of pelvic ring disruptions. *Clin Orthop*. 2000;15-29.

56. Tscherne H, Pohlemann T. *Becken und Acetabulum*. Berlin: Springer-Verlag; 1998.

57. Shuler TE, Boone DC, Gruen GS, Peitzman AB. Percutaneous iliosacral screw fixation: early treatment for unstable posterior pelvic ring disruptions. *J Trauma*. 1995;38:453-458.

58. Ebraheim NA, Coombs R, Jackson WT, Rusin JJ. Percutaneous computed tomography-guided stabilization of posterior pelvic fractures. *Clin Orthop*. 1994;222-228.

59. Duwelius PJ, Van Allen M, Bray TJ, Nelson D. Computed tomography-guided fixation of unstable posterior pelvic ring disruptions. *J Orthop Trauma*. 1992;6:420-426.

60. Matta JM, Dickson KF, Markovich GD. Surgical treatment of pelvic nonunions and malunions. *Clin Orthop*. 1996;199-206.

61. Routt ML, Jr., Meier MC, Kregor PJ, Mayo KA. Percutaneous iliosacral screws with the patients supine technique. *Operative techniques in orthopaedics*. 1993;3:35-45.

62. Gautier E, Bachler R, Heini PF, Nolte LP. Accuracy of computer-guided screw fixation of the sacroiliac joint. *Clin Orthop*. 2001;310-317.

63. Templeman D, Schmidt A, Freese J, Weisman I. Proximity of iliosacral screws to neurovascular structures after internal fixation. *Clin Orthop*. 1996;194-198.

64. Barrick EF, O'Mara JW, Lane HE, III. Iliosacral screw insertion using computer-assisted C.T. image guidance: a laboratory study. *Comput Aided Surg*. 1998;3:289-296.

65. Ebraheim NA, Coombs R, Rusin JJ, Hoeflinger MJ, Jackson WT. Percutaneous C.T.-guided stabilization of complex sacroiliac joint disruption with threaded compression bars. *Orthopedics*. 1992;15:1427-1430.

66. Nelson DW, Duwelius PJ. C.T.-guided fixation of sacral fractures and sacroiliac joint disruptions. *Radiology*. 1991;180:527-532.

67. Tonetti J, Carrat L, Lavallee S, Pittet L, Merloz P, Chirossel JP. Percutaneous iliosacral screw placement using image guided techniques. *Clin Orthop*. 1998;103-110.

68. Altman DT, Jones CB, Routt ML, Jr. Superior gluteal artery injury during iliosacral screw placement. *J Orthop Trauma*. 1999;13:220-227.

69. Leung KS, Chien P, Shen WY, So WS. Operative treatment of unstable pelvic fractures. *Injury*. 1992;23:31-37.

70. Goris RJ, Gimbrere JS, van Niekerk JL, Schoots FJ, Booy LH. Early osteosynthesis and prophylactic mechanical ventilation in the multitrauma patient. *J Trauma*. 1982;22:895-903.

71. Goris RJ, Gimbrere JS, van Niekerk JL, Schoots FJ, Booy LH. Improved survival of multiply injured patients by early internal fixation and prophylactic mechanical ventilation. *Injury*. 1982;14:39-43.

72. Fell M, Meissner A, Rahmanzadeh R. [Long-term outcome after conservative treatment of pelvic ring injuries and conclusions for current management]. *Zentralbl Chir*. 1995;120:899-904.

73. Pohlemann T, Tscherne H, Baumgartel F et al. [Pelvic fractures: epidemiology, therapy and long-term outcome. Overview of the multicenter study of the Pelvis Study Group]. *Unfallchirurg*. 1996;99:160-167.

74. Henderson RC. The long-term results of nonoperatively treated major pelvic disruptions. *J Orthop Trauma*. 1989;3:41-47.

75. Tile M. Pelvic fractures: operative versus nonoperative treatment. *Orthop Clin North Am*. 1980;11:423-464.

76. Pohlemann T, Gansslen A, Schellwald O, Culemann U, Tscherne H. [Outcome evaluation after unstable injuries of the pelvic ring]. *Unfallchirurg*. 1996;99:249-259.

77. Brenneman FD, Katyal D, Boulanger BR, Tile M, Redelmeier DA. Long-term outcomes in open pelvic fractures. *J Trauma*. 1997;42:773-777.

78. VanderZee KI, Sanderman R, Heyink J. A comparison of two multidimensional measures of health status: the Nottingham Health Profile and the RAND 36-Item Health Survey 1.0. *Qual Life Res*. 1996;5:165-174.

79. VanderZee, KI and Sanderman R. Het meten van de Algemene gezondheidstoestand met de RAND-36: een handleiding. Groningen, The Netherlands. Noordelijk centrum voor Gezondheidsvraagstukken , 1-28. 1990.

80. Brazier JE, Harper R, Jones NM et al. Validating the SF-36 health survey questionnaire: new outcome measure for primary care. *BMJ*. 1992;305:160-164.

81. Majeed SA. External fixation of the injured pelvis. The functional outcome. *J Bone Joint Surg [Br]*. 1990;72:612-614.

82. Slatis P, Karaharju EO. External fixation of unstable pelvic fractures: experiences in 22 patients treated with a trapezoid compression frame. *Clin Orthop*. 1980;73-80.

83. Pennal GF, Massiah KA. Nonunion and delayed union of fractures of the pelvis. *Clin Orthop*. 1980;124-129.

84. Ebraheim NA, Biyani A, Wong F. Nonunion of pelvic fractures. *J Trauma*. 1998;44:202-204.