ORTHOPAEDIC MANAGEMENT OF PELVIC FRACTURES: A LITERATURE REVIEW

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ABSTRACT

Background: The incidence of pelvic fractures is increasing in many countries secondary to motor vehicle accidents and falls. It is important that the attending orthopaedic surgeon have a working system by which to classify these injuries and the Young and Burgess classification is commonly used. The orthopaedic management of these injuries is conceptually divided into emergency room measures, interim measures, and definitive measures.
Data source: We conducted a PubMed search using keywords "Orthopaedic pelvic fractures"; "Pelvic fracture management"; "Stable pelvic fractures"; "Unstable pelvic fractures"; "External fixation pelvic fractures"; "Internal fixation pelvic fractures"; "Infix pelvic fractures". The selection of articles included was subjective based on the discretion of the researchers. In total 36 articles were selected for inclusion in this review which is intended to assist orthopaedic surgeons involved in the management of these injuries.
Results: The mechanistic classification of Young and Burgess is not only useful to describe a pelvic fracture pattern, but furthermore reliably predicts associated intra-pelvic and extra-pelvic injuries. Regarding emergency room management circumferential pelvic sheeting, pelvic C-clamp, and the external pelvic fixation device, are all still useful in modern emergency room pelvic fracture management. Regarding interim measures the pelvic sling, external pelvic fixation device, and more recently the in-fix, are commonly used. In terms of definitive management complications from pin tract sepsis from prolonged application of an external pelvic fixation device, and the complexities of open pelvic plating, have resulted in new interest in the in-fix as a definitive measure.
Conclusion: While definitive open pelvic plating will always have an established role, the in-fix, with/without sacroiliac screws, is growing in popularity as an easier to perform definitive measure. Our review provides a concise overview of all the modalities currently in use, and as such is invaluable to trauma orthopaedic surgeons who will frequently need to manage this common problem.

Key words: Unstable pelvic fractures, Pelvic C-clamp, External pelvic fixator device, INFIX pelvic fixation

INTRODUCTION

While pelvic fractures account for 2% of all fractures their overall incidence in many countries is increasing secondary to motor vehicle accidents and falls (1). Several studies, including a national cross-sectional descriptive study of a North American computed database that considered over 63000 trauma patients, note that the presence of a pelvic ring fracture in a trauma patient demonstrated independent significance in predicting mortality of between 5-20% (2,3). Concomitant haemodynamic instability associated with the pelvic fracture increases the mortality rate to 20-50% in several series (3-5). Understanding that these patients often have other injuries is paramount and an association between anterior pelvic injuries occurring together with cardiovascular instability and lateral pelvic injuries occurring together with head and abdominal injuries is recognized (6). For this reason these patients are best acutely managed by a multi-disciplinary trauma team comprising a trauma surgeon, orthopaedic surgeon, radiologist with interventional radiology capabilities, urologist and a neurosurgeon (1). In fact, the injury severity score has demonstrated greater significance in predicting mortality than the specific type of pelvic fracture (7). The focus of early management should be on resuscitation according to the Advanced Trauma Life Support algorithm and for the purpose of haemorrhage control obtaining early pelvic reduction and stability is critical (8). How pelvic fractures specifically contribute to blood loss is noted in one study which demonstrated that during displacement pelvic fractures disrupt the presacral and pelvic floor venous plexus's causing significant blood loss within the pelvic and abdominal retroperitoneal spaces (9). Albeit less common another study demonstrated that pelvic arterial disruption does also occur and in pelvic fractures bleeding from the internal iliac arteries, obturator arteries, superior gluteal and even the pudendal arteries have all been described (10). Bleeding from displaced unopposed pelvic cancellous bony surfaces further contributes to the enormous blood loss these patients may experience. A cadaveric study demonstrated that with regards to an intact pelvis the retroperitoneal space can accommodate 5 liters of blood and that this

increases several times once an open book fracture pattern occurs (11). Further associated pelvic injuries needing exclusion or management are gastrointestinal, importantly rectal which have severe implications for sepsis, as well as urogenital. In patients that survive the implications of having suffered a pelvic fracture are recognized with the majority of patients incurring long-term impairments such as abnormal gait, neurological deficits, urinary problems, sexual problems and chronic pain. In terms of quantifying the social impact of this problem one study notes that 70-80% of patients who incurred a pelvic fracture never return to work (1).

MATERIALS AND METHODS

We conducted a PubMed search using keywords "Orthopaedic pelvic fractures"; "Pelvic fracture management"; "Stable pelvic fractures"; "Unstable pelvic fractures"; "External fixation pelvic fractures"; "Internal fixation pelvic fractures"; "Infix pelvic fractures". The selection of articles included was subjective based on the discretion of the researchers however favored review articles which specifically concerned the orthopaedic management of this problem rather than general review articles. An abundance of articles considering the general trauma management of pelvic fractures was noted, as was a paucity of articles specifically considering the orthopaedic management of these injuries. We aimed to coalesce several of these articles into a specific review of the orthopaedic management of pelvic fractures in terms of what is currently practiced. Our aim is to provide a comprehensive and specific overview of the orthopaedic management of pelvic fractures to assist orthopaedic surgeons who manage these patients.

RESULTS

Regarding the orthopaedic considerations in pelvic fractures it is important that the attending orthopaedic surgeon have a working system by which to classify these injuries. The most widely used is the Young and Burgess system which is a mechanistic classification which has not only proved itself in inferring a specific fracture pattern, but also guides both immediate and definitive orthopaedic management (12,13).

Antero-posterior compression occurs for example in the setting of unrestrained head-on-collision motor-vehicle accidents whereby a direct force is applied to the anterior pelvic ring from a steering wheel or dashboard. Another less common mechanism is a significant external rotation force of one lower limb. During the injury the anterior pubic ring opens, hinging on the posterior ligamentous complex of the sacroiliac joints. These injuries are colloquially referred to as the 'open book' fracture type. A sub-classification of this antero-compression type considers the amount of diastasis and defines a Type 1 injury as less than 2.5cm of pubic diastasis with intact sacroiliac joints. This injury is regarded as stable. A Type 2 injury is defined as more than 2.5cm of diastasis with incomplete disruption of the sacroiliac joints. This injury is regarded as unstable. A Type 3 injury is defined as more than 2.5cm of diastasis with disrupted sacroiliac joints. These injuries are again regarded as unstable. The antero-posterior injury type greatly increases the volume of the pelvis and is hence especially associated with significant retroperitoneal bleeding (12,13).

Lateral compression is the most frequent mechanism of injury, commonly occurring in the context of a high-velocity side-impact motor vehicle accident. As the force occurs there is internal rotation of the hemipelvis to which the force is applied which, conversely to the antero-posterior compression type, closes the pelvis thereby reducing pelvic volume. This injury type is again sub-classified into a Type 1 injury defined as fractures of the superior and inferior pubic rami occurring together with an often incomplete sacral ala fracture. This injury may be stable or unstable depending on whether the sacral ala is incompletely fractured in which case it is stable, or completely fractured in which case it is unstable. A Type 2 injury refers to fractures of the superior and inferior pubic rami with disruption of the sacroiliac joint on the side of impact and is regarded as unstable. A Type 3 injury refers to the "windswept" pattern with fractures of the superior and inferior pubic rami on one side and disruption of the sacroiliac joint on the contralateral side which is again regarded as unstable. Although vascular injuries are less common in the lateral compression type if they do occur they are more often arterial rather than venous, as characterizes the antero-posterior type, and in patients that succumb to this injury the head and abdominal injuries are more often the cause (12).

Vertical shear injuries are the third injury type according to the Young and Burgess system and occur in the context of falls from a height where the individual lands with a symmetrical infero-superior force being applied to hemipelvis. Motor vehicle accidents are the second most common mechanism of injury. In this injury, which is inherently unstable as by definition two breaks in the pelvic ring have occurred, superior migration of one hemipelvis occurs secondary to bony fracturing and/or ligamentous rupture (12).

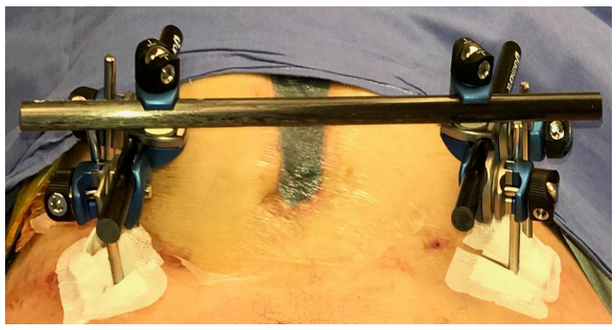
Mixed type injuries refer to injuries that occur through a combination of the above forces. In the mixed injury type the above forces are applied to the pelvis in varying degrees and thereby the fracture pattern is variable. Acetabular fractures are characteristic but not exclusive as they also characterize the lateral compression and the vertical shear types (14).

In terms of diagnosis initial ATLS assessment describes, as part of the cardiovascular assessment to confirm or exclude a pelvic fracture and retroperitoneal haemorrhage, grasping the iliac wings firmly between the hands and exerting inward compression. If no abnormal movement or pain occurs the next part of the clinical examination is to exert careful downward pressure by distracting the iliac ala from one another. Screening X-ray examination prescribed in these same guidelines includes performing an antero-posterior pelvic X-ray (8). The value of this is however challenged in one study which concluded that in alert patients with no clinical signs of a pelvic injury that the pelvic X-ray is not of value and can be omitted (15). In patients that on clinical examination demonstrate symptoms or signs of an unstable pelvic fracture initial management, besides resuscitation, includes early orthopaedic pelvic stabilization. Circumferential pelvic sheeting is still used to date as an early pelvic fracture stabilization method in a clinically unstable fracture, but mostly when the stability of a pelvic fracture has not yet been determined. The advantages of this are that it is readily available, effective, rapid to perform, and disposable (16,17). One study notes the controversy regarding the risk of pelvic sheeting in lateral compression injuries which may displace the fracture further rather than reduce it. This same study however concludes this risk to be low and advocates that a sheet should be applied in all cases of suspected pelvic fractures. Further points emphasized are that the sheet must be sited centrally over the greater trochanters and be secure. Post X-ray screening the need for pelvic sheeting should be re-assessed, as should an assessment of the degree of reduction in the presence of a pelvic fracture. In patients with clinical evidence of a pelvic injury, but with no bony injury being demonstrated on pelvic X-ray screening, screening X-rays should be repeated once the sheet is removed to exclude a purely ligamentous injury that was missed by the X-ray having being done with the injury reduced. An additional point needing mention is the risk of pressure ulcers and to avoid this, the sheet should not be kept for more than 24 hours (14). Computed tomographic pelvic scanning is the investigation of choice in these injuries, both for defining the exact nature of the injury, and as well as for classifying the injury as stable if only a single break in the pelvic ring has occurred or unstable if two or more breaks in the pelvic ring have occurred. This investigation should only be performed once a patient has been resuscitated and is stable (18).

Once diagnosed and stabilized with pelvic sheeting the next consideration, for orthopaedic and trauma surgeons in the emergency room setting in the context of a suspected unstable pelvic injury, is whether to apply a posterior pelvic C-clamp or perform anterior external pelvic fixation (Figure 1). In the early 1990's the pelvic C-clamp was popularized and today is present in most trauma centers as a reliable way to exert transverse pressure across the sacroiliac joints (19). Not without its own set of complications several studies have reported complications with this device which include trans-osseous pelvic penetration and device misplacement thereby penetrating the true pelvis via the sciatic notch (20,21). Despite this the effectiveness of the device cannot be disputed with a cadaver study recording 342N of force at the sacroiliac joints (21). In fact, the force that can be applied with this method is so great that a real risk of crushing the sacrum exists and the device should not be used in the setting of a comminuted sacral fracture (18). The anterior pelvic external fixation frame is another means by which to achieve rapid pelvic stability and has the advantages of being able to be applied in under 30 minutes in either the emergency room, intensive care unit, or in the operating theatre. A further advantage of this frame is that manipulation of the fractured pelvis to achieve a reduction can be performed in all planes making it suitable for all types of unstable fractures (21). This has directly translated into improved outcome with one study by Magnone *et al* (22) reporting a decreased mortality rate in unstable pelvic fractures from 22%-8% post the introduction of this device. Several other studies have further recognized the decreased need for blood transfusion in these patients as well as a decreased mortality rate with the use of the device (23,24).

Figure 1

Intra-operative photograph of the external pelvic fixator device



In terms of definitive orthopaedic management stable pelvic fractures are generally treated non-operatively and unstable fractures are commonly taken for surgery (25). In patients with antero-posterior Type 2 (unstable) and Type 3 (unstable) fractures awaiting surgery these patients are best nursed supine in a pelvic sling, or flat in bed if an external pelvic fixator device is in place, and maintaining the reduction. In lateral compression Type 1 unstable injuries with a completely fractured ala and all Type 2 and all Type 3 injuries these patients are again kept flat in bed if an external pelvic fixator device is in place and maintaining the reduction. In vertical shear injuries skeletal traction on the side of

the superiorly migrated hemipelvis is employed to obtain a reduction or maintained with a pelvic external fixator if reduction has been achieved, as these patients await surgery.

Open reduction and fixation, if employed, is done as an elective procedure in a stable patient. Several studies (18,26) advocated this be done between 7 and 12 weeks post injury to avoid the "second hit" of an inherently extensive open operative intervention. Even with this interval one study concludes that the open procedures should be reserved for selected patients in whom a satisfactory reduction has not been achieved in which case the surgical intervention may be scheduled earlier, or for those whom demonstrate ongoing pelvic instability despite conservative treatment. An understanding of this reasoning put forth in another study is to appreciate the surgical morbidity associated with the extensive open procedures which should if possible be avoided if a satisfactory result can be obtained with less invasive means (27). In another study by Falzarano *et al* (18), definitive open surgical intervention was performed in a series of 406 patients utilizing fracture plating and wiring and a 4.5% complication rate was reported. Critical considerations are the experience and expertise of the orthopaedic surgeons who perform these open procedures and they should not be undertaken without acquiring specific training.

Utilizing external pelvic fixation as a definitive measure for 6-12 weeks is widely performed to avoid the morbidity of the open approaches however, with the long-term use necessary, a complication rate of as high as 62% has been reported (28). Several studies (28,29) echo this thinking noting the most frequent complications of pin site infections, pin loosening, and poor patient tolerance. One study by Lee and Sciadini (30) noted a pin site infection rate as high as 18% and concluded that the external pelvic fixator should only be used as an emergency room measure or definitively when no other option exists (Figure 2).

Figure 2

Showing intra-operative photograph of pin site sepsis associated with the external pelvic fixator device in an obese patient

Definitive minimally invasive stabilization of unstable pelvic fractures is growing in popularity as orthopaedic surgeons increasing seek to avoid the morbidity of the open approaches. One such method is the recently re-named INFIX which is a percutaneous procedure growing in popularity for the stabilization of unstable pelvic fractures. The first record of this procedure being performed was in a 2009 publication from Germany where the procedure was termed a "pelvic internal fixator". A follow-up publication 4 years later in 2013 looked at outcome in these same patients and reported good intermediate-term outcome with the procedure (31,32). In 2013 the procedure was re-named the INFIX in another study (33).

Although long-term studies are lacking, the INFIX has demonstrated significant advantages over the pelvic external fixator by firstly offering more rigid pelvic support due to its low profile and shorter level arm, reduced pin site infection, and improved patient comfort (33-35). The procedure is performed by making two 2cm incisions over the anterior inferior iliac spines to ensure enough soft tissue coverage of the pedicle screw heads. Thereafter blunt dissection is performed between the sartorius muscle medially and the tensor fascia lata laterally. A standard pedicle screw is then inserted bilaterally into the dense supra-acetabular bone and is directed towards the posterior superior iliac spine. A curved rod is advanced subcutaneously under fluoroscopic control and connected to the pedicle screw head on the contralateral side. Manipulation of the unstable pelvic fracture is then performed until a satisfactory reduction has been achieved. Once the reduction has been achieved the rod is fixed to the pedicle screw heads and the wounds closed in layers (Figure 3-6).

Figure 3

Intra-operative photograph of pedicle screw being inserted into supra-acetabular bone in INFIX

Figure 4
Intra-operative photograph of rod being advanced within the subcutaneous tissue towards the contralateral pedicle screw

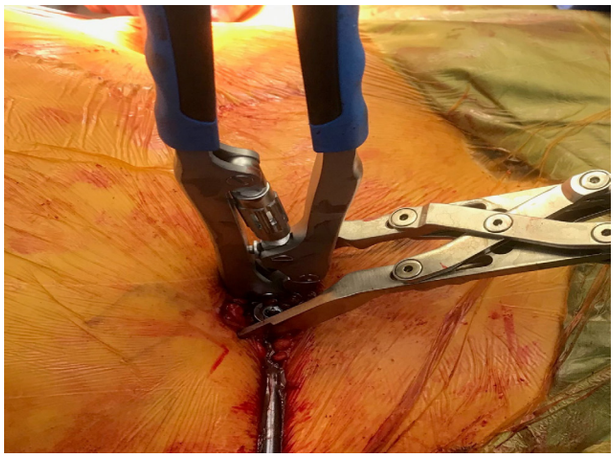
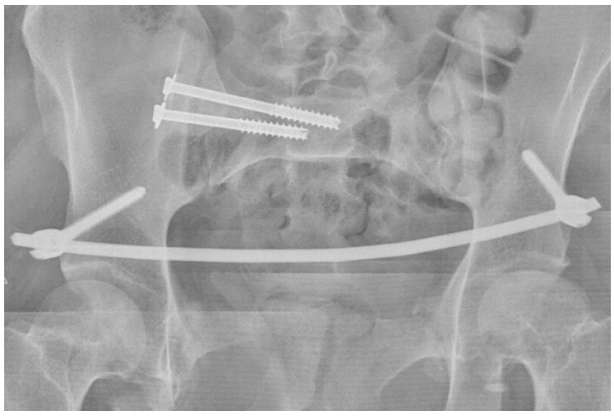


Figure 5
Intra-operative photograph of rod that has been advanced

Figure 6
Intra-operative photograph of antero-posterior pelvic X-ray showing INFIX in situ



The device is commonly removed at 3 months once fracture healing has occurred, failing which open reduction and plating is still an option (31). Additional surgical options are to augment the construct with sacro-iliac screws posteriorly to afford 360-degree stability if needed. Complications being reported by the device are thigh pain due to irritation of the lateral femoral cutaneous nerve and subcutaneous infection of the rod in patients with a suprapubic catheter in place which should be viewed as a contra-indication to performing the procedure (36).

CONCLUSIONS

Pelvic fractures are a common referral to orthopaedic surgeons and assessing and acutely reducing and maintaining pelvic stability is an important concern before it has been determined. Once pelvic instability has been confirmed further concerns for the orthopaedic surgeon are the interim management before elective definitive management can be performed. Definitive surgery is moving away from the open procedures as newer, effective, less invasive surgical options become more popular and easier to perform. Open plating will continue to have a role in the management of a specific sub-set of these patients but should be reserved for senior orthopedic surgeons familiar with the complexities of these operations.

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REFERENCES

1. Grubor, P., Milicevic, S., Biscevic, M. and Tanjga, R. Selection of treatment method for pelvic ring fractures. *Med Arh*. 2011; **65**(5): 278-282.
2. Sathy, A., Starr, A., Smith, W., Elliott, A., Agudelo, J. and Reinert, C. The effect of pelvic fracture on mortality after trauma: an analysis of 63,000 trauma patients. *J Bone Joint Surg Am*. 2009; **91**:2803–10.
3. Starr, A., Griffin, D., Reinert, C., Frawley, W., Walker, J. and Whitlock, S. Pelvic ring disruptions: prediction of associated injuries, transfusion requirement, pelvic arteriography, complications, and mortality. *J Orthop Trauma.* 2002; **16**(8):553–561.
4. Dente, C., Feliciano, D., Rozycki, G., Wyrzykowski, A., Nicholas, J. and Salomone, J. The outcome of open pelvic fractures in the modern era. *Am J Surg*. 2005; **190**(6):831–837.
5. Duchesne, J., Bharmal, H., Dini, A., Islam, T., Schmieg, R. and Simmons, J. Open-book pelvic fractures with perineal open wounds: a significant morbid combination. *Am Surg.* 2009; **75**(12):1227–33.

6. Siegel, J., Dalal, S., Burgess, A. and Young, J. Pattern of organ injuries in pelvic fracture: impact force implications for survival and death in motor vehicle injuries. *Accid Anal Prev.* 1990; **22**(5):457–466.
7. Lunsjo, K., Tadros, A., Hauggaard, A., Blomgren, R., Kopke, J. and Abu-Zidan, F. Associated injuries and not fracture instability predict mortality in pelvic fractures: a prospective study of 100 patients. *J Trauma*. 2007; **62**(3):687-691.
8. ATLS Subcommittee, American College of Surgeons' Committee on Trauma, International ATLS working group. Advanced Trauma Life Support (ATLS): the ninth edition. *J Trauma Acute Care Surg*. 2013; 74(5):1363–66.
9. White, C., Hsu, J. and Holcomb, J. Haemodynamically unstable pelvic fractures. *Int J Care Injured*. 2009; **40**(10): 1023–30.
10. O'Neill, P., Riina, J., Sclafani, S. and Tornetta, P. Angiographic findings in pelvic fractures. *Clin Orthop Relat Res.* 1996; **329**;60-67.
11. Grimm, M., Vrahas, M. and Thomas, K. Pressure-volume characteristics of the intact and disrupted pelvic retroperitoneum. *J Trauma*. 1998; 44(3):454–459.
12. Dalal, S., Burgess, A., Siegel, J., Young, J.W., Brumback, R. and Poka, A. Pelvic fracture in multiple trauma: classification by mechanism is key to pattern of organ injury, resuscitative requirements, and outcome. *J Trauma.* 1989; **29**(7):981–1002.
13. Siegel, J., Dalal, S., Burgess, A. and Young, J. Pattern of organ injuries in pelvic fracture: impact force implications for survival and death in motor vehicle injuries. *Accid Anal Prev*. 1990; **22**(5):457–466.
14. Weaver, M. and Heng, M. Orthopedic approach to the early management of pelvic injuries. *Curr Trauma Rep*. 2015; **1**:16–25. doi 10.1007/s40719-014-0005-4.
15. den Boer, T., Geurts, M., van Hulsteijn, L., Mubarak, A., Slingerland, J., Zwart, B., van der Heijden, G. and Blokhuis, T. The value of clinical examination in diagnosing pelvic fractures in blunt trauma patients: a brief review. *Eur J Trauma Emerg Surg*. 2011; **37**(4): 373–377. doi: 10.1007/s00068-011-0076-7.
16. Routt, M., Falicov, A., Woodhouse, E. and Schildhauer, T. Circumferential pelvic anti-shock sheeting: a temporary resuscitation aid. *J Orthop Trauma*. 2006; **16**(1):45-48.
17. Rajab, T., Weaver, M. and Havens, J. Technique for temporary pelvic stabilization after trauma. *N Engl J Med*. 2013; **369**: e22:1–4.
18. Falzarano, G., Medici, A., Carta, S., Grubor, P., Fortina, M., Meccariello, L. and Ferrata, P. The orthopedic damage control in pelvic ring fractures: when and why- a multicenter experience of 10 years treatment. *J Acute Dis.* 2014; **3**(3):201-206. https://doi.org/10.1016/S2221-6189(14)60044-45.
19. Ganz, R., Krushell, R., Jakob, R. and Kuffer, J. The antishock pelvic clamp. *Clin Orthop Rel Res.* 1991; **267**:71-78.
20. Marsh, J., Slongo, T., Agel, J., Broderick, J., Creevey, W. and De Coster, T. Fracture and dislocation classification compendium-2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007; **21**(10):S1-S133.
21. Mohanty, K., Musso, D., Powell, J., Kortbeek, J. and Kirkpatrick, A. Emergent management of pelvic ring injuries: an update. *Can J Surg*. 2005; **48**(1):49-56.
22. Magnone, S., Coccolini, F., Manfredi, R., Piazzalunga, D., Agazzi, R. and Arici, C. Management of hemodynamically unstable pelvic trauma: results of the first Italian consensus conference. *World J Emerg Surg*. 2014; **9**(1):18.
23. Ghaemmaghami , V., Sperry, J., Gunst, M., Friese, R., Starr, A., Frankel, H., *et al.* Effects of early use of external pelvic compression on transfusion requirements and mortality in pelvic fractures. *Am J Surg*. 2007; **194**(6): 720-723.
24. Kellam, J. The role of external fixation in pelvic disruptions. *Clin Orthop Relat Res*. 1989; **241**: 66-82.
25. Miller, M. and Thompson, S. Miller's review of orthopaedics. Elsevier Health Sciences, Philadelphia, USA. 2016.
26. Pape, H., van Griensven, M., Rice, J., Gänsslen, A., Hildebrand, F. and Zech, S. Major secondary surgery in blunt trauma patients and perioperative cytokine liberation: determination of the clinical relevance of biochemical markers. *J Trauma*. 2001; **50**(6): 989-1000.
27. Majeed, S. Grading the outcome of pelvic fracture. *J Bone Joint Surg Br*. 1989; **71**:304–306.
28. Mason, W., Khan, S. and James, C. Complications of temporary and definitive external fixation of pelvic ring injuries. *Injury*. 2005; **36**: 599–604.
29. Chaus, G. and Weaver, M. Anterior subcutaneous internal fixation of the pelvis: Placement of the INFIX. *Oper Tech Orthop*. 2015; **25**: 262–269.
30. Lee, C. and Sciadini, M. The use of external fixation for the management of the unstable anterior pelvic ring. *J Orthop Trauma*. 2018; **32**: S14–S17.

31. Kuttner, M., Klaiber, A. and Lorenz, T. The pelvic subcutaneous cross-over internal fixator. *Der Unfallchirurg.* 2019; **112**: 661–669.
32. Müller, F., Stosiek, W. and Zellner, M. The anterior subcutaneous internal fixator (ASIF) for unstable pelvic ring fractures. Clinical and radiological mid-term results. *Int Orthop*. 2013; **37**: 2239–45.
33. Vaidya, R., Oliphant, B., Jain, R., Nasr, K., Siwiec, R. and Onwudiwe, N. The bikini area and bikiniline as a location for anterior subcutaneous pelvic fixation: An anatomic and clinical investigation. *Clin Anat*. 2013; **26**:392–399.
34. Vigdorchik, J., Esquivel, A., Jin, X., Yang, K., Onwudiwe, N. and Vaidya, R. Biomechanical stability of a supra-acetabular pedicle screw internal fixation device (INFIX) vs external fixation and plates for vertically unstable pelvic fractures. *J Orthop Surg Res*. 2012; **27**:31.
35. Moazzam, C., Heddings, A., Moodie, P. and Cole, P. Anterior pelvic subcutaneous internal fixator application: An anatomic study. *J Orthop Trauma.* 2012; **26**:263–268.
36. Vaidya, R., Martin, A.J., Roth, M., Nasr, K., Gheraibeh, P. and Tonnos, F. INFIX versus plating for pelvic fractures with disruption of the symphysis pubis. *Int Orthop*. 2017; **41**:1671–678.