European Journal of Trauma and Emergency Surgery (2020) 46:865–871
https://doi.org/10.1007/s00068-018-1050-4

ORIGINAL ARTICLE

Clinical and radiological short-term outcomes of pubic symphysis diastasis treated with modified pedicle screw–rod fixation

Jiandong Wang[1,2] · Lei Cao[2] · Jianhong Wu[2] · Qiugen Wang[1,2] · Chun Bi[2]

Received: 5 July 2018 / Accepted: 13 November 2018 / Published online: 15 November 2018

Abstract

Purpose Pubic symphysis diastasis with an incidence of approximately 20% in pelvic fractures is a severe lesion which needs to be treated properly. The objective of this retrospective study was to describe and evaluate the clinical and radiological outcomes including its advantages and limitations of this modified minimal invasive technique.

Methods Totally 29 patients with pubic symphysis diastasis, with or without posterior ring instability, were treated by modified pedicle screw–rod fixation (modified PSRF) between January 2010 and December 2016. The duration from injury to surgery, operation time, intraoperative blood loss as well as complications were recorded. During follow-up, the functional outcomes were assessed according to the Majeed evaluation criteria 1 year postoperatively. The evaluation of the postoperative reduction quality was carried out according to Matta criteria.

Results According to Tile classification, there were 9 cases of Type B1 underwent only anterior-modified PSRF and 20 cases of Type C1 experienced anterior-modified PSRF combined with posterior fixation. The duration from injury to operation, operation time and intraoperative blood loss were 3.27 days (range 1–6 days), 42.07 min (range 38–45 min), and 46.14 ml (range 40–55 ml). The results of reduction quality were rated as excellent in 16, good in 11 and fair in 2 based on Matta criteria. The Majeed functional scores ranged from 68 to 95 and there were excellent in 15, good in 12 and fair in 2. No patients experienced incision infection. Slight loosening of middle-two screws was verified during follow-up in one patient. Two patients underwent femoral nerve palsy. Irritation to the LFCN was detected in four patients.

Conclusions Modified PSRF can be performed as an alternative to manage pubic symphysis diastasis due to its merits of minimal invasive, less blood loss, less soft tissue injuries as well as shorter operation time, even with the early weight-bearing.

Trial registration Researchregistry3905.

Keywords Pubic symphysis diastasis · Modified pedicle screw–rod fixation

✉ Qiugen Wang
wangqiugen@yahoo.com

✉ Chun Bi
doctorbichun@126.com

Jiandong Wang
drwangjiandong@yahoo.com

Lei Cao
doctorcaolei@163.com

Jianhong Wu
wujianhong1978@163.com

[1] Nanjing Medical University, Nanjing, Jiangsu, People's Republic of China

[2] Department of Orthopedics Trauma, Trauma Center, Shanghai General Hospital, School of Medicine, Shanghai Jiao Tong University, 650 Xin Songjiang Road, Shanghai 201620, People's Republic of China

Abbreviations

PSD	Pubic symphysis diastasis
Modified PSRF	Modified pedicle screw–rod fixation
AIIS	Anterior inferior iliac spine
LFCN	Lateral femoral cutaneous nerve

Background

As a fibro-cartilaginous joint, the pubic symphysis functions as a key part to unite the bilateral pubis as well as the posterior sacroiliac joint. By dint of the gliding of its superior and inferior part during the axial loading, physiological movements across symphysis contribute to compensate for pelvic loading. This has been highlighted by Tile and Hearn [1–5].

Resulting from high-energy trauma, pubic symphysis diastasis (PSD) with an incidence of approximately 20%

in pelvic fractures is a severe lesion which needs to be treated properly [6]. Reduction and fixation of PSD have been acquired by means of a variety of methods such as external fixation, open reduction and plate fixation, cannulated screw fixation and so forth [7–10]. Although good evaluation results were presented, controversies regarding the optimal treating pattern still exist because of these non-complication-free techniques [11].

Recently, some types of minimal invasive techniques with the merits of less intraoperative blood loss, less trauma to the surrounding tissue and less operation time have been described as alternatives to treat pelvic fractures [12–14]. Originally introduced by Kuttner in 2009, poly axial pedicle screw–rod fixation was applied for the treatment of anterior pelvic ring fractures with satisfactory clinical outcomes [15]. In their study, the fixator constituted two pedicle screws placed at the anterior inferior iliac spine (AIIS) and one connecting titanium rod. Inspired by this technique, we modified this construct in our clinical practice by adding another two polyaxial pedicle screws to treat the pubic symphysis diastasis with or without posterior ring fixation. The objective of this retrospective study was to describe and evaluate the clinical and radiological outcomes including its advantages and limitations of this modified minimal invasive technique.

Methods

Patients

This retrospective analysis included 29 patients with PSD in total, with or without posterior ring instability, treated by modified PSRF between January 2010 and December 2016 in our trauma center. There were 19 males and 10 females with an average age of 41.79 years (range from 20 to 63 years). The causes of injury were traffic accidents in 14 patients, crush in 12 cases, and fall from height in 3 patients. In conformity to Tile classification, there were 9 cases of type B1 (PSD) and 20 cases of Tile C1 (PSD with posterior ring fracture). Exclusion criteria included the following: type B2, B3, and C2, patients with serious osteoporosis, hemodynamic instability, open fractures with severe soft tissue defects and followed-up for less than 12 months. To better assess the patterns of the injuries, preoperative radiographs including anteroposterior (AP), inlet and outlet views of the pelvis followed by pelvic 3-D computed tomography (CT), if necessary, were carried out in all cases.

Ethics Committee of Shanghai General Hospital reviewed and approved the study, and each participant provided the written informed consent. This study has been performed according to the Declaration of Helsinki.

Operative techniques

Before operation, the external fixation was applied as an emergency treatment in cases of hemodynamic instability, if possible. Due to the significant role of posterior ring in maintaining the stability of pelvis, posterior fixation was taken as the priority to the patients with posterior ring instability (type C1). In view of the minimal invasive and easy of operation of pedicle screw–rod fixation, we utilized two pedicle screws and a connected rod for fixation. After marking the outline of bilateral sides of the iliac posterior superior spine, a 3–4-cm incision was made 1 cm lateral to the iliac posterior superior spine. After opening the back fascia and dissecting the crista iliaca, the pedicle screw opener was used at the junction of the back 2/3 and front 1/3 of the crista iliaca cortical bone to make an osseous tunnel between the cortexes of the ilium towards the iliac anterior inferior spine. After checking to ensure the tunnel did not penetrate the bony cortex of the medial or lateral sides, screws (Johnson & Johnson Co, USA) 60–80 mm long and 7 mm wide were inserted. The end of each screw (U-type clamp) was inserted into the cancellous bone to make it adjustable and no higher than the crista iliaca level. The proper length of the rod was selected after measuring the distance between the screws on both sides. After linking the screws on each side through the sub-back fascia, the rod was fixed. The adjustments of stretching or compressing of the pedicle screw–rod fixator was performed according to the dislocation conditions of the posterior pelvic ring to complete the reduction and fixation [16]. This procedure was carried out to patients being employed in prone position under general anesthesia. Then, the anterior fixation was addressed.

The supine position was applied for all patients. After the outline of anterior inferior iliac spine (AIIS) and the pubis symphysis as well as its centerline being marked, the bilateral incisions were made 2 cm below the AIIS with the length of 4 cm. By means of the blunt dissection between the space of iliopsoas and sartorius, the AIIS was exposed. The pedicle finder was applied to establish the bony corridor at the starting point located at one-third of lateral AIIS side. The placement of polyaxial pedicle screw (Johnson & Johnson Co, USA) with 7 mm diameter and a length of 80 mm was performed with the proper depth. The insertion tilt angle was set as 30° outward and 20° backward. The same procedure was applied to the site of contralateral AIIS.

A 3-cm incision was made over the pubic symphysis. Two polyaxial pedicle screws, with the size of 6.5 mm diameter and the length of 45–50 mm, were inserted into the bilateral pubic tubercle with the suitable depth without the fixation. From the bilateral AIIS to pubic tubercle, a

corridor superficial to the fascia was created by a long hemostat. A 6-mm diameter titanium rod was pre-contoured in accordance with the shape of anterior ring. Then, the placement of the titanium rod passing through the sartorius and the front of medial iliopsoas was performed. The rod was laid in the subcutaneous layer. Whereafter, these four pedicle screws were connected by the remolded titanium rod. Reduction of the diastasis was performed with a compressor attached to the middle-two screws to reduce the anterior pelvis by feat of the rod. The screw caps were tightened with screwdriver after the rod being adjusted to the right site and the absolutely reduction being achieved. After carefully being irrigated layer by layer, the incision was closed and coated with gauze (Fig. 1).

Postoperative management and follow-up

Intravenously antibiotics were managed for 24 h to all patients after the surgery. The non-weight-bearing status was maintained during the first 24 h, postoperatively. The patients commenced active as well as positive movements under the instruction on condition that the pain could be tolerated from postoperative day three. Crutch-assisted walking was allowed for type B1 from 3 days to 2 weeks and at 1 week for type C1, postoperatively. The partial weight-bearing was gradually increased after 2 weeks for type B1 and 4 weeks for type C1. Full weight-bearing of all patients was advocated at 6 weeks for type B1 and at 2 months for type C1, postoperatively. Postoperative follow-up occurred for all patients at every 6 weeks in the first 6 months, every 3 months until 1 year, and then once half a year.

Clinical evaluation

During clinical appointments, the physical examination and routine pelvic radiographs were taken to evaluate the reduction and the union for all cases. The functional outcomes were assessed according to the Majeed evaluation criteria 1 year postoperatively. The evaluation of the postoperative reduction quality was carried out according to Matta criteria with the following rating: excellent (0–4 mm), good (5–10 mm), fair (11–20 mm), and poor (> 20 mm).

Results

Patients characteristics

Among 29 patients, 9 cases (Type B1) underwent only anterior-modified PSRF, whereas 20 patients (Type C1) experienced anterior-modified PSRF combined with posterior fixation. The time from injury to surgery ranged from 1 to 6 days with an average of 3.27 days. The intraoperative blood loss ranged from 40 to 55 ml with the mean amount of 46.14 ml. No patients received the blood transfusion due to the minimally invasive nature of this procedure (Table 1).

Table 1 Patient demographics

	Modified PSRF	Range/percentage
Age (years)	41.79 ± 12.78	20–63
Gender (male:female)	19:10	65.5%:34.5%
Fracture type (B1:C1)	9:20	31.0%:69.0%
Mechanism of injury		
Traffic accidents (*n*)	14	48.3%
Crush (*n*)	12	41.3%
Fall from height (*n*)	3	10.3%
Time from injury to operation (days)	3.27 ± 1.33	1–6
Operation time (min)	42.07 ± 3.31	35–48
Intraoperative blood loss (ml)	46.14 ± 4.68	40–55
Additional posterior fixation (*n*)	20	64.7%
Follow-up (months)	18.72 ± 2.44	13–24
Majeed evaluation score	85.17 ± 7.25	68–95

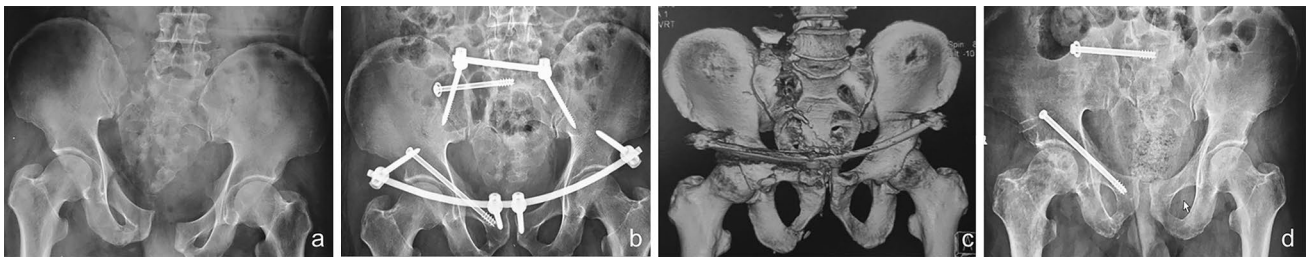

Fig. 1 A 46-year-old male patient (Type C1) with the pubic symphysis diastasis as well as posterior ring instability due to crush. Preoperative anteroposterior radiographs showing the pubic symphysis diastasis and posterior ring instability (**a**). X-ray film and 3-D CT showing the satisfactory reduction with modified pedicle screw–rod fixation for anterior and posterior pelvic ring (modified PSRF) (**b, c**). Postoperative X-ray film showing the healed pubic symphysis and posterior ring at 13 months postoperative during the follow-up (**d**)

Follow-up and assessments

Follow-up appointments were performed to all patients from 13 to 24 months with an average of 18.72 months. A typical patient with pubic symphysis diastasis treated by modified PSRF was presented in Fig. 2. The reduction quality of diastasis was evaluated by means of the Matta criteria as well as the postoperative radiography. The results were rated as excellent in 16, good in 11 and fair in 2. Majeed evaluation was performed to all cases. The scores ranged from 68 to 95 and there were excellent in 15, good in 12 and fair in 2.

Surgical complications

No patients experienced a surgical-site infection in this clinical series. Slight loosening of middle-two pubic-inserted screws was verified by pelvic radiographs during the follow-up in one patient. Nevertheless, no further intervention was performed as no symptom was shown. Two patients underwent femoral nerve palsy, and the emergency measurement with operative revision was taken to re-adjust the fixation. Irritation to the LFCN was detected in four patients. The symptoms spontaneously disappeared after three months, postoperatively. Assessments of clinical outcomes were presented in Table 2.

Table 2 Assessments of clinical outcomes

	Modified PSRF	Percentage (%)
Majeed evaluation		
Excellent (*n*)	15	51.7
Good (*n*)	12	41.4
Fair (*n*)	2	6.9
Matta reduction criteria		
Excellent (*n*)	16	55.2
Good (*n*)	11	37.9
Fair (*n*)	2	6.9
Complications		
Loosening of screws (*n*)	1	3.4
Femoral nerve palsy (*n*)	2	6.9
LFCN irritation (*n*)	4	13.8

Discussion

The pubic symphysis is an amphiarthrodial joint, consisting of two pubic bones and an intercalated disc. It participates in maintaining the stability of the anterior pelvic ring and protecting the inner organs of the small pelvis [1–5]. Pubic symphysis diastasis, defined as open-book AO B1 lesion, is typically resulted from high-energy injuries with the incidence of 13–16% of all pelvic fractures [6]. Proper surgical intervention regarding reduction and fixation to restore the integrity of pelvic ring need to be taken. Although controversies still existed regarding the optimal management to this type of injury, consensus has been achieved that once

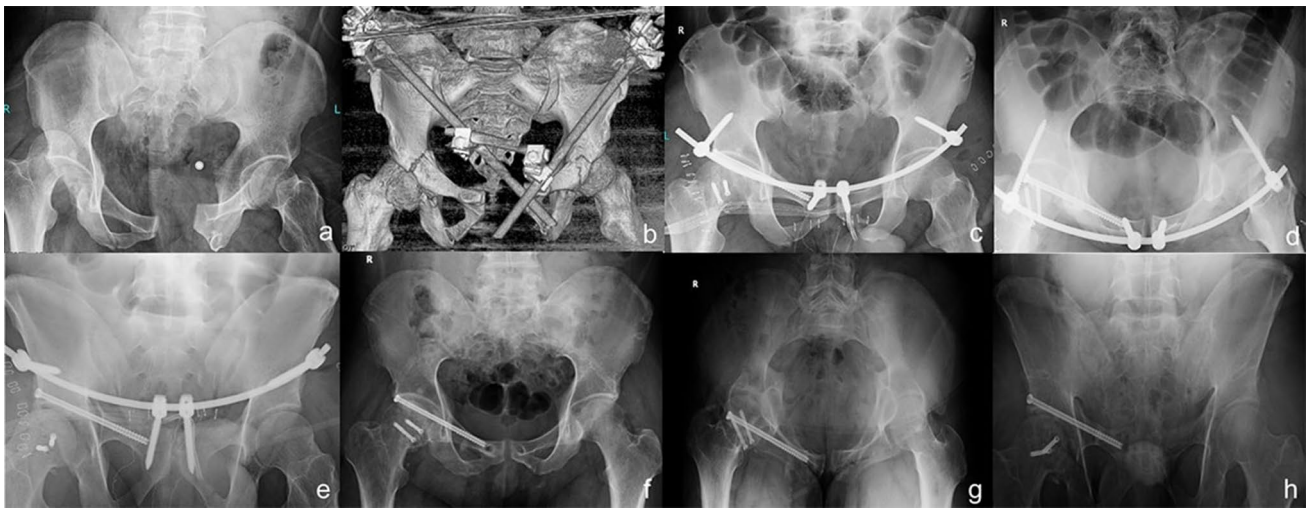

Fig. 2 A 45-year-old male patient (Type B1) with the pubic symphysis diastasis because of traffic accident. Preoperative anteroposterior radiographs showing the pubic symphysis diastasis (**a**). Preoperative external fixator was performed for the initial stabilization (**b**). Immediate postoperative anteroposterior (**c**), inlet (**d**) and outlet (**e**) X-ray films showing the satisfactory reduction with modified pedicle screw–rod fixation (modified PSRF). Postoperative anteroposterior (**e**) inlet (**f**) and outlet (**g**) X-ray films showing the healed pubic symphysis at postoperative 15 months during the follow-up

the distance of diastasis exceeds 25 mm, firm fixation should be performed as the necessary procedure [17].

A wide range of surgical managements including external fixation and internal plate fixation have been employed during the past decades to treat symphysis pubis diastasis [7–10]. Although it has advantages of ease-of-operation and quick fixation, external fixation always concerns with complication of pin-site infection and relatively inferior stability compared with plate fixation [18–22]. Accepted as the preferred technique, internal plate fixation is currently performed for pubis diastasis [23]. Yet, it is not an application without concerns. The extensive exposure to pubic symphysis, trauma to surrounding soft tissues together with the intraoperative blood loss are the most common complications. Besides, repeated fluoroscopy needs to be taken to verify the reduction and fixation during the surgical procedure which makes a large amount of X-radiation to the patient and surgeons [24–28]. Recently, considerable progress regarding the minimally invasive techniques employed in pelvic fractures have been acquired which make its application as an alternative to above-mentioned techniques, as well as for treating pubic symphysis [12–14].

In 2009, Kuttner first described a new minimal invasive technique to treat anterior pelvic ring fractures [15]. In his clinical series, a construct formed by two pedicle screws and one connecting rod was applied. To treat anterior ring fractures, two pedicle screws were implanted into the site of supra-acetabulum below the anterior inferior iliac spine (AIIS), then, these two screws were connected by a curved rod. Reduction and fixation of injured anterior ring can be acquired by means of this construct. Nevertheless, the subcutaneously connecting rod was placed crossing the bilateral AIIS above the abdomen making some patients, especially the obese patients, feel discomfort [12, 18].

Considering these shortcomings, we performed modification to this technique during our clinical practice. Additional two pedicle screws were placed into bilateral pubic tubercles with one in each side, thus, totally four screws and one curved rod constituted the modified PSRF. The rod was curved according to the arc anatomical shaping of anterior ring, and it was assembled along the superior border of anterior pelvic ring to eliminate its abdominal compression. The rod was laid in the subcutaneous layer. With its four fixed pedicle screws and one connected rod, this construct frame provided firm stability to PSD. It can offer special merit to reduce the diastasis by means of the relative slide between the screws and rod. Via shortening the connecting titanium rod, the reduction of this open-book lesion as well as the fixation can be acquired at the same time. To PSD patients combined with injuries of bladder and urethra, application of this minimally invasive technique could avoid aggravating the existing urinary lesion. This less-invasive technique may be of special interest in stabilizing fragility fractures of the pelvic ring, which is an upcoming entity in elderly persons [29].

The average operation time 41.8 min and intraoperative blood loss 46.6 ml in our clinical series were lower than those reported cases fixed with other methods. We assumed these advantages should be attributed the modifications to minimally invasive PSRF as well as the proficiency in operating by surgeons. By dint of firm arch structure of this modified construct, the active and positive activities can be carried out early under instruction as long as the pain could be tolerated, postoperatively. Besides, the early weight-bearing can be advocated as a superiority of its application compared with other methods. There was no operation-associated complication of site infection in the present clinical series. One 65-year-old male patient experienced the loosening of middle-two pubic-inserted screws which was defined as partly fixation loss. Its occurrence, we speculated after carefully examining the pelvic radiographs, resulted from osteoporosis. Iatrogenic femoral nerve injury, first reported by Hesse [30], can lead to the weakness or loss of patellar reflex as well as the impairment of sense at anterior and medial thigh. Only two patients in the current clinical series experienced iatrogenic femoral nerve injury, immediately action was taken for implant revision. The symptom gradually relieved, and ultimately disappeared after the removal of PSRF. Its occurrence is associated with the restricted space between the rectus and screw. To avoid it, refined manipulation and careful physical examination should be taken as the necessary and significant procedure. On the basis of our clinical experience, it is not convenient to place the pedicle screws via superior anterior iliac spine. The end cap of the pedicle screw may cause soft tissue irritation. However, via the inferior anterior iliac spine, in our clinical series, the bone corridor of pedicle screw is long, the placement and the direction of screws are relative easy to operate. As to avoid femoral nerve palsy, our experience is to make the cap of pedicle screw not too close to the bone surface. The space between the bone surface and the screw cap should be kept about one-finger width. Meanwhile, the end cap of screw should not be exceeded the skin surface to avoid the soft tissue irritation. LFCN irritation, with incidence rate ranged from 27 to 30%, is another common concern following modified PSRF, which was reported previously by Kuttner, Vaidya and Hesse [12, 15, 30]. In the current study, four patients were found to experience this complication. According to our experience, the rod end may have a direct relationship to the irritation of LFCN. The overlong screw end will easily compress and irritate the nerve during the rod placement. Thus, the rod should be applied as short as possible to free more space for LFCN, meanwhile, we recommend performing polyaxial screws for easy connecting to the rod.

After being discharged, all 17 patients treated with modified PSRF in our series came back to normal work and daily

activities without evident negative influence. The removal procedure of pedicle screw–rod fixation need to be taken as second surgery which is a shortcoming of this technique [12]. There was one female case concerned about discomfort of pubic region in sexual activities postoperatively, then, we removed the fixation at 7 months postoperatively. The routine time we suggest for its removal should be arranged at 12 months after operation to promote better healing of the diastasis, if no apparent uncomfortable symptom appeared. Clinical appointments and radiographs during the follow-up showed the healing symphysis diastasis were present in all patients, thus verifying the effectiveness and reliability of application with this modified technique.

Limitations of current study should be identified. This is a retrospective study in our single medical center with small sample size. More cases and long-term follow-up will benefit the present clinical evaluation to be more meaningful. Moreover, the results were based on our clinical analysis, hence, accurate biomechanical investigation should be performed to offer firm theoretical proof.

Conclusions

In summary, modified PSRF applied to patients with pubic symphysis diastasis provided satisfactory clinical outcomes. This technique can be performed as an alternative to managing pubic symphysis diastasis due to its merits of being minimally invasive, with less blood loss, less soft tissue injuries as well as shorter operation time, even with the early weight-bearing.

Author contributions JW performed the study design, analyzed the results, and contributed to the manuscript. QW and CB contributed to collecting the cases. LC made some meaningful suggestions. CB and JW helped in the drafting and revising of the manuscript. All authors reviewed and approved the final submitted version.

Funding The current study was supported by grants from the National Natural Science Foundation of China (no. 71432007).

Compliance with ethical standards

Ethics approval Shanghai General Hospital's Ethics Committee reviewed and approved this retrospective study. Each participant signed the written informed consent.

Informed consent Written informed consent was obtained from individual participants.

Availability of data and materials The datasets during and/or analyzed during the current study are available from the corresponding author on a reasonable request.

Conflict of interest The authors declare that they have no competing interests.

References

1. 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(2):75–80.
2. Vrahas M, Hern TC, Diangelo D, Kellam J, Tile M. Ligamentous contributions to pelvic stability. Orthopedics. 1995;18(3):271–4.
3. Walheim G, Olerud S, Ribbe T. Mobility of the pubic symphysis. Measurements by an electromechanical method. Acta Orthop Scand. 1984;55(2):203–8.
4. Walheim GG, Selvik G. Mobility of the pubic symphysis. In vivo measurements with an electromechanic method and a roentgen stereophotogrammetric method. Clin Orthop Relat Res. 1984(191):129–35.
5. Meissner A, Fell M, Wilk R, Boenick U, Rahmanzadeh R. Biomechanics of the pubic symphysis. Which forces lead to mobility of the symphysis in physiological conditions?. Unfallchirurg. 1996;99(6):415–21.
6. Aggarwal S, Bali K, Krishnan V, Kumar V, Meena D, Sen RK. Management outcomes in pubic diastasis: our experience with 19 patients. J Orthop Surg Res. 2011;6:21. https://doi.org/10.1186/1749-799X-6-21.
7. Bircher MD. Indications and techniques of external fixation of the injured pelvis. Injury. 1996;27(Suppl 2):B3–19.
8. Chen L, Zhang G, Song D, Guo X, Yuan W. A comparison of percutaneous reduction and screw fixation versus open reduction and plate fixation of traumatic symphysis pubis diastasis. Arch Orthop Trauma Surg. 2012;132(2):265–70. https://doi.org/10.1007/s00402-011-1414-2.
9. Yu KH, Hong JJ, Guo XS, Zhou DS. Comparison of reconstruction plate screw fixation and percutaneous cannulated screw fixation in treatment of Tile B1 type pubic symphysis diastasis: a finite element analysis and 10-year clinical experience. J Orthop Surg Res. 2015;10:151. https://doi.org/10.1186/s13018-015-0272-y.
10. Chen L, Ouyang Y, Huang G, Lu X, Ye XS, Hong J. Endobutton technique for dynamic fixation of traumatic symphysis pubis disruption. Acta Orthop Belg. 2013;79(1):54–9.
11. Hamad A, Pavlou G, Dwyer J, Lim J. Management of pubic symphysis diastasis with locking plates: a report of 11 cases. Injury. 2013;44(7):947–51. https://doi.org/10.1016/j.injury.2012.12.018.
12. Vaidya R, Colen R, Vigdorchik J, Tonnos F, Sethi A. Treatment of unstable pelvic ring injuries with an internal anterior fixator and posterior fixation: initial clinical series. J Orthop Trauma. 2012;26(1):1–8. https://doi.org/10.1097/BOT.0b013e318233b8a7.
13. Routt ML Jr, Simonian PT, Grujic L. The retrograde medullary superior pubic ramus screw for the treatment of anterior pelvic ring disruptions: a new technique. J Orthop Trauma. 1995;9(1):35–44.
14. Gardner MJ, Mehta S, Mirza A, Ricci WM. Anterior pelvic reduction and fixation using a subcutaneous internal fixator. J Orthop Trauma. 2012;26(5):314–21. https://doi.org/10.1097/BOT.0b013e318220bb22.
15. Kuttner M, Klaiber A, Lorenz T, Fuchtmeier B, Neugebauer R. The pelvic subcutaneous cross-over internal fixator. Unfallchirurg. 2009;112(7):661–9. https://doi.org/10.1007/s00113-009-1623-0.
16. Bi C, Wang Q, Nagelli C, Wu J, Wang Q, Wang J. Treatment of unstable posterior pelvic ring fracture with pedicle screw–rod fixator versus locking compression plate: a comparative study. Med Sci Monit. 2016;22:3764–70.
17. Young JW, Burgess AR, Brumback RJ, Poka A. Pelvic fractures: value of plain radiography in early assessment and management. Radiology. 1986;160(2):445–51. https://doi.org/10.1148/radiology.160.2.3726125.

18. Bi C, Wang Q, Wu J, Zhou F, Zhang F, Liang H, et al. Modified pedicle screw–rod fixation versus anterior pelvic external fixation for the management of anterior pelvic ring fractures: a comparative study. J Orthop Surg Res. 2017;12(1):185. https://doi.org/10.1186/s13018-017-0688-7.
19. Mason WT, Khan SN, James CL, Chesser TJ, Ward AJ. Complications of temporary and definitive external fixation of pelvic ring injuries. Injury. 2005;36(5):599–604. https://doi.org/10.1016/j.injury.2004.11.016.
20. Routt ML Jr, Simonian PT, Swiontkowski MF. Stabilization of pelvic ring disruptions. Orthop Clin N Am. 1997;28(3):369–88.
21. 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 Jt Surg Br. 1999;81(6):955–62.
22. Palmer S, Fairbank AC, Bircher M. Surgical complications and implications of external fixation of pelvic fractures. Injury. 1997;28(9–10):649–53.
23. Sagi HC, Papp S. Comparative radiographic and clinical outcome of two-hole and multi-hole symphyseal plating. J Orthop Trauma. 2008;22(6):373–8. https://doi.org/10.1097/BOT.0b013e31817e49ee.
24. Luijendijk RW, Jeekel J, Storm RK, Schutte PJ, Hop WC, Drogendijk AC, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg. 1997;225(4):365–9.
25. Rubel IF, Seligson D, Mudd L, Willinghurst C. Endoscopy for anterior pelvis fixation. J Orthop Trauma. 2002;16(7):507–14.
26. Wilson CJ, Edwards R. Massive extraperitoneal hemorrhage after soft tissue trauma to the pubic branch of the inferior epigastric artery. J Trauma. 2000;48(4):779–80.
27. Sippo WC, Burghardt A, Gomez AC. Nerve entrapment after Pfannenstiel incision. Am J Obstet Gynecol. 1987;157(2):420–1.
28. Raman R, Roberts CS, Pape HC, Giannoudis PV. Implant retention and removal after internal fixation of the symphysis pubis. Injury. 2005;36(7):827–31. https://doi.org/10.1016/j.injury.2004.11.012.
29. Rommens PM, Wagner D, Hofmann A. Fragility fractures of the pelvis. JBJS Rev. 2017;5(3). https://doi.org/10.2106/JBJS.RVW.16.00057.
30. Hesse D, Kandmir U, Solberg B, Stroh A, Osgood G, Sems SA, et al. Femoral nerve palsy after pelvic fracture treated with INFIX: a case series. J Orthop Trauma. 2015;29(3):138–43. https://doi.org/10.1097/BOT.0000000000000193.