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Application of internal fixator system for anterior pelvic ring with simultaneous application of sacroiliac screw internal fixation of the posterior pelvic ring in Tile C-type unstable pelvic fractures

Primena sistema unutrašnjeg fiksatora za prednji prsten karlice uz istovremenu unutrašnju fiksaciju zadnjeg prstena karlice sakroilijačnim zavrtnjem kod nestabilnih preloma karlice tipa C po Tile-u

Zhongbing Liu, Guoyou Zou

Yancheng No. 1 People's Hospital, Department of Orthopedics, Yancheng, Jiangsu Province, China

Abstract

Background/Aim. The number of pelvic traumas is increasing globally, mostly due to car accidents but also due to an increasing number of sports and recreational traumas. Tile C-type unstable pelvic trauma (TCUPT) is a kind of high-energy trauma that occurs during traffic accidents or accidents when falling from big heights. The aim of our study was to explore the application of the internal fixation (INFIX) system for the anterior pelvic ring (APR) with simultaneous application of sacroiliac screw (SS) INFIX of the posterior pelvic ring (PPR) in TCUPT. **Methods.** The subjects (89 of them in total) were recruited among patients with TCUPT from December 2020 to December 2023. A retrospective analysis of the subjects' data was performed, after which the subjects were divided into two groups based on different therapeutic regimens applied: group A (INFIX system for the APR + SS INFIX of the PPR, n = 46) and group B (external fixator for the APR + SS INFIX of the PPR, n = 43). **Results.** In comparison with group B, group A had a shorter period before the commencement of the first activity after surgery, shorter fracture healing time and joint function recovery time, as well as length of hospital stay (t = 6.623, 4.796, 7.992, and 5.227, respectively, $p < 0.05$). The surgery duration and bleeding volume showed no significant differences between the two groups (t = 1.433, 1.123, respectively, $p > 0.05$). The fracture reduction outcomes were better in group A than in group B (Z = 2.058, $p < 0.05$). The incidence rate of complications was lower in group A than in group B (2.17% vs. 18.60%) (χ^2 = 4.917, $p < 0.05$). **Conclusion.** For patients with TCUPT, the INFIX system for the APR with simultaneous application of SS INFIX of the PPR achieves good fracture reduction outcomes.

Key words:
bone screws; fractures, bone; fracture fixation, internal; open fracture reduction; pelvic bones; orthopedic procedures; treatment outcome.

Apstrakt

Uvod/Cilj. Broj slučajeva povrede karlice je u porastu na globalnom nivou, najviše zbog saobraćajnih nezgoda, ali i zbog sve većeg broja sportsko-rekreativnih povreda. Nestabilna povreda karlice tipa C po Tile-u (*Tile C-type unstable pelvic trauma*-TCUPT) je povreda koja se dešava tokom saobraćajnih nezgoda ili prilikom pada sa velike visine. Cilj rada bio je da se ispita primena sistema unutrašnje fiksacije (*internal fixation*-INFIX) za prednji karlični prsten (*anterior pelvic ring*-APR) uz istovremenu primenu INFIX zadnjeg karličnog prstena (*posterior pelvic ring*-PPR) primenom sakroilijačnog zavrtnja (*sacroiliac screw*-SS) (INFIX PPR SS) kod TCUPT. **Metode.** Ispitanici (ukupno 89) selektovani su među bolesnicima sa TCUPT u periodu od decembra 2020. do decembra 2023. godine. Izvršena je retrospektivna analiza podataka ispitanika, nakon čega su ispitanici podeljeni na dve grupe na osnovu različitih terapijskih protokola kojima su podvrgnuti: grupa A (INFIX sistem za APR + INFIX PPR SS, n = 46) i grupa B (spoljni fiksator za APR + INFIX PPR SS, n = 43). **Rezultati.** U poređenju sa grupom B, grupa A imala je kraće vreme: do početka prve aktivnosti nakon operacije, zarastanja preloma i oporavka funkcije zgloba, kao i kraću dužinu boravka u bolnici (t = 6,623, 4,796, 7,992 i 5,227, redom, $p < 0,05$). Nije bilo značajne razlike između dve grupe

Correspondence to: Guoyou Zou, Yancheng No. 1 People's Hospital, Department of Orthopedics, Yancheng 224 001, Jiangsu Province, China. E-mail: zougyyn1ph@ecu-edu.cn

po pitanju dužine trajanja operacije i obima krvarenja (t = 1,433, 1,123, redom, p > 0,05). Rezultati redukcije preloma bili su bolji u grupi A nego u grupi B (Z = 2,058, p < 0,05). Stopa incidencije komplikacija bila je niža u grupi A nego u grupi B (2,17% vs. 18,60%) (χ^2 = 4,917; p < 0,05). **Zaključak.** Kod bolesnika sa TCUPT, primenom INFIX sistema za APR sa istovremenom primenom INFIX PRR SS, postižu se dobri rezultati redukcije preloma.

Ključne reči:
zavrtnji za kost; prelomi; prelomi, fiksacija, unutrašnja; prelom, otvorena redukcija; karlične kosti; ortopedske procedure; lečenje, ishod.

Introduction

As a kind of high-energy pelvic trauma, Tile C-type pelvic fractures (TCPF) are unstable fractures and are mostly attributed to traffic accidents and fall accidents from a high place, belonging to the fracture types of a high mortality rate [1]. In the case of TCPF, the structure of the anterior pelvic ring (APR) and posterior pelvic ring (PPR) is completely destroyed, giving rise to rotational and vertical instability of pelvic rings, which will result in pain, unbalanced sitting posture, and abnormal gait. TCPF are mainly treated by surgery in clinical practice. Traditional surgical methods include posterior trans-bilateral sacroiliac joint fixation with reconstruction plates plus external fixation (EXFIX) of the APR using the Phannenstiel approach and fixation of the PPR using the iliac approach [2, 3]. However, these surgical methods have many shortcomings. For instance, as to open reduction and combined anterior and posterior fixation, the mechanical stability of the posterior plate is poor, and the patient's position needs to be changed during surgery, which is detrimental to postoperative recovery. For APR EXFIX, the time needed for getting out of bed is long, the recovery of joint function is slow, and the incidence rate of postoperative delirium screw track infection is high. Anterior open reduction and internal fixation (INFIX) will cause a relatively large operative wound to patients, as well as more blood loss, which can easily result in various postoperative complications [4, 5]. In recent years, imaging and minimally invasive technologies have developed rapidly, and sacroiliac screw (SS) INFIX has been widely applied in injuries of sacroiliac joint complex, with good reduction outcomes [6]. APR INFIX and EXFIX systems are minimally invasive fixation methods commonly used for APR fractures, but there are still some disputes about their comparative effects in China and abroad.

In this study, the data of 89 patients with TCPF treated with EXFIX or INFIX system for the APR plus SS INFIX of the PPR were retrospectively analyzed, and the effects of applying the two methods were compared.

Methods

Collection of general data

A retrospective study was approved by the local Ethics Committee and performed on the data of 89 patients with TCPF in our hospital from December 2020 to December 2023. These patients were then assigned to group A (INFIX system for the APR + SS INFIX of the PPR, n = 46) and group B (EXFIX for the APR + SS INFIX of the PPR, n = 43) based on different therapeutic regimens. The sex, age, body mass index, time from injury to surgery, hemoglobin, platelet count, white blood cell count, causes of injury, and complications were comparable between the two groups (p > 0.05) (Table 1).

Table 1

General data

Parameters	Group A (n = 46)	Group B (n = 43)	Statistical value	*p*-value
Sex				
male	27 (58.70)	24 (55.81)	χ^2 = 0.075	0.784
female	19 (41.30)	19 (44.19)		
Age, year	42.16 ± 6.57	41.82 ± 7.54	t = 0.227	0.821
Body mass index, kg/m^2	24.97 ± 2.03	25.10 ± 2.12	t = 0.296	0.768
Time from injury to surgery, hrs	9.43 ± 2.79	9.24 ± 3.06	t = 0.306	0.761
Hemoglobin, g/L (RR: 110–175)	119.42 ± 15.36	120.37 ± 16.18	t = 0.284	0.777
Platelet count, ×10^9/L (RR: 90–320)	186.54 ± 31.52	188.25 ± 34.69	t = 0.244	0.808
White blood cell count, ×10^9/L (RR: 3.9–9.1)	7.41 ± 2.06	7.62 ± 1.94	t = 0.494	0.622
Cause of injury				
traffic accident	24 (52.17)	22 (51.16)	χ^2 = 0.278	0.964
fall accident from a high place	13 (28.26)	14 (32.56)		
bruise by heavy objects	5 (10.87)	4 (9.30)		
others	4 (8.70)	3 (6.98)		
Complications				
chest injury	5 (10.87)	4 (9.30)	χ^2 = 0.011	0.915
craniocerebral injury	6 (13.04)	5 (11.63)	χ^2 = 0.041	0.839
limb fracture	9 (19.57)	7 (16.28)	χ^2 = 0.163	0.687
urethral injury	3 (6.52)	3 (6.98)	χ^2 = 0.114	0.736
others	5 (10.87)	3 (6.98)	χ^2 = 0.073	0.787

RR – reference range. Results are shown as numbers (percentages) or mean ± standard deviation.

Inclusion and exclusion criteria

The following inclusion criteria were used for this study: 1) patients diagnosed with TCPF based on X-ray examinations; 2) patients with basically normal coagulation function; 3) patients who/whose family members signed the informed consent; 4) patients with displacement corrected by pre-operative traction/manual reduction or without obvious displacement. The exclusion criteria involved: 1) patient status complicated by severe osteoporosis; 2) patients with open pelvic fractures; 3) patients with unstable hemodynamics; 4) patients with soft tissue infection at the screw implantation site; 5) patients with pubic symphysis separation; 6) patients with pathological fractures; 7) patient status complicated by severe internal diseases.

Treatment

General anesthesia with tracheal intubation was implemented in both groups. Patients lay on the fluoroscopic operating table in the supine position, with a 2 cm-thick cushion under the sacrum. Thereafter, a pelvic reduction frame was installed, and the reduction of pelvic fractures was carried out through bone traction and Scan screws.

The therapeutic regimen of the INFIX system for the APR plus SS INFIX of the PPR was adopted in group A. In brief, an INFIX system was employed to fix the APR, and 1-2 SS (7.3 mm or 6.5 mm, Shandong Wego Orthopedic Materials Co., Ltd., China) was/were used for the fixation of the PPR. Before surgery, a fluoroscopy of the pelvis was carried out to mark the rotation angle and position of the C-arm. With the axis of the femoral shaft and the vertical line of the anterior superior iliac spine as the insertion points of SS, a 1.5 mm Kirschner wire was first placed. The distance and direction were then adjusted according to the position of the guide wire, followed by the insertion of a 2.5 mm guide wire by tapping with a bone hammer. When the guide wire passed through the sacroiliac joint and sacral foramina, the outlet, entrance, and lateral fluoroscopy of the pelvis were conducted many times to ensure that the guide wire was in an ideal position. Next, an opening was drilled by a hollow drill, in which a hollow screw was inserted. Thereafter, an incision (about 3 cm) was made on the skin 1 cm outside the body surface projection of the anterior inferior iliac spine for fixing the INFIX system for the APR, followed by blunt dissection to the anterior inferior iliac spine, during which attention should be paid to avoid damaging or straining peripheral nerves and blood vessels. After that, a pedicle screw opener was utilized to make an incision at the position 5 mm outside the apex of the anterior inferior iliac spine, with the awl inclined outward by 30° and toward the tail end by 20°, and the tissue was cut apart along the inner and outer sides of the iliac bone. After confirming that the four walls of the channel were complete through probes, the exit position and oblique position of the iliac bone were observed by fluoroscopy to ensure that the position of the guide wire was ideal. Afterward, iliac screws with a length of 75–85 mm and a diameter of 7.5–8.0 mm were inserted. A transverse titanium rod arc with a diameter of 5.5 mm manufactured according to the body shape of patients in advance was then used to connect and fix the iliac screws on both sides. Then, the spreading or hugging device of the foresaid screw-rod system was locked onto the femoral neck with small screws, the screw cap was tightened to complete the fixation of the INFIX system and fluoroscopy of the C-arm was implemented to confirm that the fixation was firm.

Patients in group B were treated with EXFIX for the APR plus SS INFIX of the PPR. Specifically, with the area between the bilateral anterior inferior iliac spine and iliac crest as the insertion point, an incision with a length of about 1 cm was made along the insertion point while trying not to expose the lateral femoral nerve, followed by blunt dissection of the tissue to the bone cortex. As to insertion into the anterior inferior iliac spine, the anterior superior iliac spine, posterior superior iliac spine, and posterior inferior iliac spine were taken as the insertion direction of Schanz screws, with an angle of 30° to the sagittal plane. For insertion into the iliac crest, the insertion direction of the Schanz screws was the iliac tubercle above the acetabulum, with an angle of 15–20° to the sagittal plane. After completing the fixation, the signs of bilateral iliac oblique position and pelvic outlet position were observed by fluoroscopy to confirm that screws were inserted accurately. An EXFIX (Tianjin Xinzhong Medical Devices Co., Ltd., China) was adopted to fix the APR, which was installed in an inverted splay pattern, and the connecting rod and the fixation clamp were fixed together. The proximal end was connected to the abdomen at an angle of 140° by two connecting rods or a single transverse rod, and the distal end was connected by a single transverse rod. The fixation clamp was tightened after a distraction or compression reduction of the pelvis.

Postoperative management

Simultaneous or second-stage surgery was conducted in both groups to treat complications. After surgery, cefazolin (0.5g 2–3 times/day) was administrated for three consecutive days to prevent infections. About two weeks later, stitches were taken out according to the healing of incisions. Patients took such functional exercises as bed exercises, off-bed activities, and weight-bearing training step by step based on their tolerance degree and fracture healing, and received re-examinations in the hospital regularly. At three months after surgery, the INFIX system for the APR was taken out.

Observation of indicators

General surgery indicators and rehabilitation indicators recorded were: surgery duration, bleeding volume, time of the first activity, length of hospital stay, fracture healing time, and joint function recovery time in the two groups.

The fracture reduction outcomes in the two groups were assessed using the Majeed pelvic fracture scoring system, which consisted of five items: pain, sitting, standing, intercourse, and work, with a total score of 100 points. The scores ≥ 85 points, 70–84 points, 55–69 points, and < 55 points

suggested excellent, good, medium, and poor outcomes, respectively [7].

Complications recorded were: the incidence rates of screw track infection, SS withdrawal, fixator breakage, lateral femoral cutaneous nerve injury, and deep vein thrombosis of lower extremities in the two groups.

The Visual Analog Scale was utilized to evaluate pain degree at 1 and 12 weeks after surgery [8], with a score of 0–10 points (10 points denoting severe and unbearable pain).

Statistical analysis

Statistical analysis was done with SPSS 23.0 software. Continuous value data (surgery indicators and rehabilitation indicators) were expressed by mean ± standard deviation and subjected to the *t*-test. Discreet value data (reduction outcomes, complications, and pain degree) were expressed by numbers (percentages) and subjected to the Chi-squared (χ^2) test. For ranked data, the rank sum test was performed. The value of $p < 0.05$ was considered a statistically significant difference.

Results

Preoperative and postoperative images of patients

The preoperative and postoperative images of a patient from group A and a patient from group B are shown in Figure 1.

Surgery and rehabilitation indicators

Group A displayed a shorter period till the first activity, fracture healing time, joint function recovery time, and length of hospital stay ($t = 6.623$, 4.796, 7.992, and 5.227, respectively, $p < 0.05$), but similar surgery duration and bleeding volume ($t = 1.433$, 1.123, respectively, $p > 0.05$) in comparison with group B (Table 2).

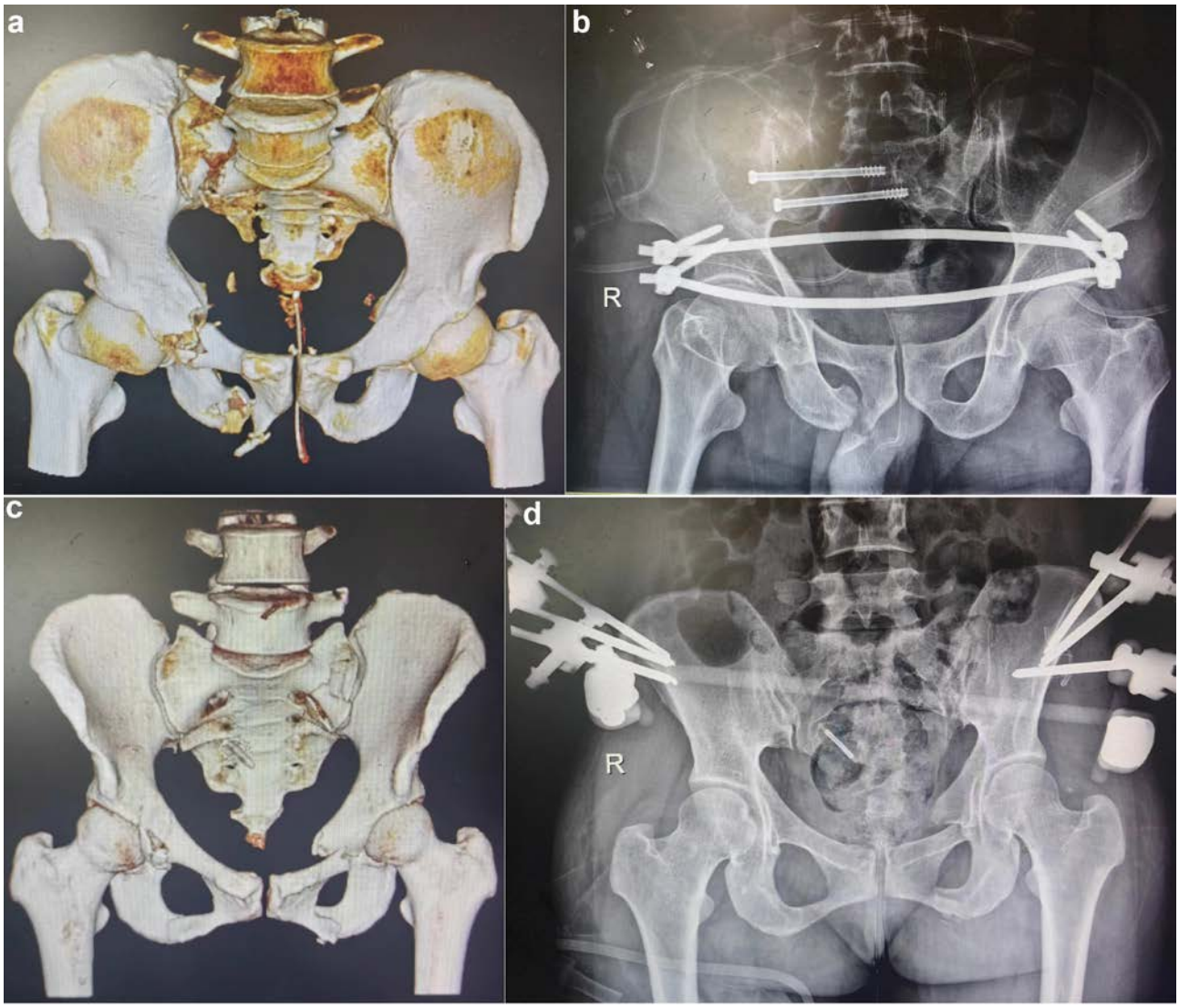

Fig. 1 – Preoperative and postoperative images of the pelvic bone ring: a) Preoperative computed tomography (CT) image of a patient from group A; b) postoperative X-ray image of a patient from group A; c) preoperative CT image of a patient from group B; d) postoperative X-ray image of a patient from group B.

Fracture reduction outcomes

The fracture reduction outcomes in group A were superior to those in group B ($Z = 2.058$, $p < 0.05$) (Table 3).

Postoperative complications

Group A displayed a lower incidence rate of complications than group B (2.17% vs. 18.60%; $p < 0.05$) (Table 4).

Pain degree after surgery

The pain in group A was milder than that in group B at 1 and 12 weeks after surgery ($p < 0.05$) (Table 5).

Discussion

As a kind of fracture relatively difficult to treat, pelvic fractures are accompanied by severe trauma, more complications, and a lower survival rate. According to the Tile classification, they can be classified into three types: Tile A, Tile B, and Tile C, based on the fracture stability, differences in radiological manifestations, and injury mechanisms. TCPF are mainly characterized by vertical and rotational instability, hence the reconstruction of pelvic ring stability is the key to treating patients with TCPF [9].

A study denoted that 40% of stability comes from the APR, and the remaining 60% relies on the PPR when people are in a standing position, thus reduction and fixation of the

Table 2

Surgery and rehabilitation indicators

Parameters	Group A (n = 46)	Group B (n = 43)	*t*	*p*-value
Surgery duration (min)	62.57 ± 12.96	58.82 ± 11.64	1.433	0.156
Bleeding volume (mL)	50.13 ± 7.41	48.39 ± 7.19	1.123	0.265
Elapsed time until first activity (day)	6.93 ± 1.54	9.71 ± 2.36	6.623	< 0.001
Hospital stay length (day)	12.84 ± 2.17	15.23 ± 2.14	5.227	< 0.001
Fracture healing time (week)	10.98 ± 1.32	12.43 ± 1.53	4.796	< 0.001
Joint function recovery time (week)	12.17 ± 1.60	14.85 ± 1.56	7.992	< 0.001

***t* – statistical value. Results are shown as mean ± standard deviation.**

Table 3

Fracture reduction outcomes

Characteristic	Group A (n = 46)	Group B (n = 43)	Z	*p*-value
Excellent	31 (67.39)	21 (48.84)	2.058	0.040
Good	12 (26.09)	13 (30.23)		
Medium	3 (6.52)	7 (16.28)		
Poor	0 (0.00)	2 (4.65)		

Z – statistical value. Results are shown as numbers (percentages).

Table 4

Postoperative complications

Parameter	Group A (n = 46)	Group B (n = 43)	χ^2	*p*-value
Screw track infection	0 (0.00)	2 (4.65)		
Sacroiliac screw withdrawal	0 (0.00)	3 (6.98)		
Fixator breakage	0 (0.00)	1 (2.33)		
Lateral femoral cutaneous nerve injury	1 (2.17)	0 (0.00)		
Deep vein thrombosis of lower extremities	0 (0.00)	2 (4.65)		
Total	1 (2.17)	8 (18.60)	4.917	0.027

χ^2 – Chi-square. Results are shown as numbers (percentages).

Table 5

Pain degree after surgery

Parameter	1 week after surgery		12 weeks after surgery	
	group A (n = 46)	group B (n = 43)	group A (n = 46)	group B (n = 43)
Painless	0 (0.00)	0 (0.00)	39 (84.78)	27 (62.79)
Mild	15 (32.61)	8 (18.60)	5 (10.87)	11 (25.58)
Moderate	29 (63.04)	26 (60.47)	2 (4.35)	5 (11.63)
Severe	2 (4.35)	9 (20.93)	0 (0.00)	0 (0.00)
Z	2.312		2.349	
p-value	0.021		0.019	

Z – statistical value. Results are shown as numbers (percentages).

PPR are more important [10]. Currently, percutaneous SS fixation, splay steel plate fixation in front of the sacral joint, and posterior sacral rod fixation are common fixation methods for pelvic fractures. Related research suggests that percutaneous SS fixation is more stable and less invasive than transsacral plate fixation and sacral rod fixation, and it is also less traumatic with similar stability in contrast with splay steel plate fixation in front of the sacral joint [11, 12]. Since the APR and PPR of patients with TCPF have been seriously damaged, simultaneous fixation of both the APR and PPR is required. There are many approaches to fixing the APR and PPR in clinical practice at present. However, no conclusion has yet been reached on the best fixation method, and some researchers believe that minimally invasive fixation is the tendency in treating these kinds of fractures [13]. In this study, patients with TCPF were treated with EXFIX or INFIX system for the APR plus SS INFIX of the PPR. It was found that group A exhibited shorter time until first activity, fracture healing time, joint function recovery time, length of hospital stay, better reduction outcomes, and a lower incidence rate of complications than group B (2.17% vs. 18.60%). These results indicate that compared with the surgical scheme of EXFIX for the APR, the surgical scheme of the INFIX system for the APR achieves better reduction outcomes, which can promote fracture healing, shorten length of hospital stay and joint function recovery time, and reduce complications.

SS INFIX of the PPR is a central fixation method with biological stability similar to that of steel plate fixation, and intramedullary fixation can shorten fracture healing time, facilitate early activities of patients, and avoid deep vein thrombosis of lower extremities and other complications, improving the quality of life of patients [14]. It is worth noting that in SS INFIX of the PPR, fluoroscopy should be conducted with patience, and the angle and position of the C-arm should be marked to ensure the correct direction of the guide wire and reduce the damage to peripheral blood vessels and nerves [15]. The INFIX system, a novel INFIX method for treating unstable APR fractures, is minimally invasive and safe, which is conducive to the postoperative rehabilitation of patients [16, 17]. Because the ischial groove between the anterior inferior iliac spine and the posterior superior iliac spine is relatively wide, fixation of iliac screws can be realized by the pedicle screw technique. To ensure the stability of pedicle screws, the length of iliac screws in bone should not be less than 50 mm. The bottom of the iliac screw groove should be slightly higher than the deep fascia layer to reduce the pressure on nerves and blood vessels, and both ends of the connecting rod should exceed the fixed screws to avoid damage to the lateral femoral cutaneous nerve [18, 19]. The EXFIX for the APR has many shortcomings. First of all, it has poor biomechanical stability and only offers limited marginal fixation without internal fixation effects. Second, the reduction loss of the APR is likely to cause the SS withdrawal in the posterior ring, leading to delayed healing or even non-union of fractures. Last, the screw loosening of the EXFIX may lead to further displacement of fractures, thus affecting the healing of fractures [20, 21]. Biomechanical research results denoted that the INFIX system has an advantage in overall axial mechanics compared with EXFIX in the process of APR fixation for patients with unstable pelvic ring injuries, which can reduce discomfort and the incidence rate of complications [22]. Moreover, it was discovered in this study that the pain in group A was milder than that in group B at 1 and 12 weeks after surgery, signifying that the INFIX system for the APR plus SS INFIX of the PPR is capable of relieving the postoperative pain of patients with TCPF. This may be ascribed to the fact that intramedullary fixation enables the compression fixation of the broken ends of a fractured bone, increasing the stability of the APR and PPR and thereby avoiding the postoperative pain caused by pelvic instability. Not only does the INFIX system have the advantages of traditional EXFIX, but it also achieves the strength of steel plate fixation, which is helpful for early functional exercise and postoperative body recovery.

Conclusion

Internal fixation system for the anterior pelvic ring plus sacroiliac screw internal fixation of the posterior pelvic ring achieves good reduction outcomes for patients with Tile C-type pelvic fractures, which promotes fracture healing, reduces the recovery time of joint function, alleviates pain, and decreases complications.

Conflict of interest

The authors declare no conflict of interest.

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