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Original article

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Analysis of the use of original metal structures for anterior pelvic ring fixation

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Abstract

Introduction Stabilization of chronic injuries of the pelvic ring with standard methods may result in plate breach, destabilization of the implant and the need for repeated operations. Therefore, it has become necessary to use special tactical approaches in surgical treatment of chronic injuries for fixing traumatic foci and searching for adapted implant designs for such cases. Thus, an original plate has been developed. **Purpose** To study the features of fixation of chronic injuries of the pelvic ring using an original plate in comparison with the standard approach. **Materials and methods** We conducted a retrospective analysis of the surgical treatment performed using the developed plate (Group 2) and a group of patients who underwent fixation of the anterior pelvic ring with two reconstruction plates (Group 1). **Results** In group 1, four patients (16.7 %) had failed osteosynthesis within two weeks to two months after the operation. In group 2, thirty patients underwent surgical treatment using the developed design, and destabilization of the metal construct was detected only in 2 patients (6.6 %). In one case, migration of plate screws was detected after 3 years during routine X-ray study while the patient was not bothered by pain and did not feel any instability. **Discussion** Analyzing the positive and negative aspects of the methods used, we made a choice in favor of internal plating. Due to cases of destabilization of fixation using one or two plates, an original metal structure was developed and applied to strengthen fixation. **Conclusion** Changing the standard approaches to the treatment of chronic injuries (after 3 weeks since injury) of the anterior pelvic ring enables to create conditions for stable fixation, using the original monolithic plate, despite the rigidity of the pelvic ring in chronic injuries.

Keywords: pelvis, pelvic ring, chronic pelvic injury, pelvic osteosynthesis

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INTRODUCTION

In recent years, the number of high-energy injuries continues increasing. The incidence of pelvic ring injuries is 5 to 20 % of those cases [1-6]. High-energy injuries are multiple in up to 80-90 % and are often accompanied by traumatic shock. Traumatic shock in these victims determines the severity of the general condition, and urgent therapeutic measures are needed in the first hours after the injury to preserve the vital functions of the injured person [3, 5-7]. Nonunion or mal-union of the joints and bones of the pelvic ring is usually associated with inadequate primary treatment of unstable pelvic injuries (Tile type B and C) [8-12]. Type B and C pelvic ring injuries account for up to 50 % of pelvic injuries and occur under high-energy mechanical impact [1-5, 7, 13-17]. By the time the patient's vital functions are stabilized, the pelvic ring injury becomes chronic and requires a special approach to assess its severity, tactics of surgical treatment, and choosing an adequate method for further rehabilitation [6, 8-12, 18].

A separate and a particularly difficult problem is the surgical treatment of the pelvic ring articulations, especially the pubic symphysis. Stabilization of chronic injuries of the pelvic ring with standard methods used in the treatment of patients with acute injuries results in several problems such as plate breach, destabilization of the implant structure and the need for repeated operations [19]. The methods of surgical treatment of the anterior pelvic ring developed in modern medicine are mainly aimed at the treatment of acute pelvic injuries and are of little use for the treatment of chronic injuries [20-22]. Therefore, it became necessary to use special tactical approaches for fixing traumatic foci and searching for adapted implants for surgical treatment of chronic injuries; in this regard, a plate was developed for reconstruction of the anterior pelvic ring in chronic injuries.

Our work was **aim**ed at studying the features of fixation of chronic pelvic ring injuries with an original plate in comparison with the standard approach and assessment of the results of the fixation method with this new design.

MATERIALS AND METHODS

A retrospective analysis of the outcomes of surgical treatment using an original horseshoe-shaped plate and a group of patients who underwent fixation of the anterior part with two reconstructive plates was carried out. The choice was due to the need to achieve increased fixation strength in the anterior pelvis.

Criteria for inclusion in the study:

• Injury of the anterior pelvic ring, three weeks and more old (since the moment of injury);

• Poor result of its conservative and surgical treatment;

• Injuries of the pelvic ring type B and C (Tile classification);

• Instability of the pelvic ring.

Exclusion criteria:

• Injury of the anterior pelvic that occurred less than 3 weeks since the moment of injury;

• Mental disorders in patients, inadequacy;

• Injuries of the pelvic ring type A (Tile classification);

• Associated infectious and inflammatory processes in the pelvic ring.

The ethics board of the Federal State Budgetary Institution Priorov NMRC for TO discussed the use of original plates for surgical treatment and gave their approval. Ethics Board protocol of the LEC of the Priorov National Medical Research Center of the Ministry of Health of Russia No. 3 dated 09/22/2020.

Patients were informed about the nature of the operation, the implant used, possible risks and complications, and the written consent of the patients was obtained.

Two groups were formed for the study.

Group 1 consisted of patients in whom the fixation method used was two plates in the anterior ring. The surgical intervention was performed using the standard technique: one of the plates was located on the upper surface of the pubic bones while the second plate was fixed on the anterior surface of the pubic bones. The sample consisted of 36 cases treated in the range period from 2002 to 2017.

Group 2 included patients who underwent fixation of the anterior pelvic ring with original horseshoe-shaped plates manufactured by ChM. The sample consisted of 30 cases observed from 2015 to 2019. The arc of the plate was fixed along the upper surface of the pubic bone, and the arch passed to the anterior surface of the vertical branches of the pubic bones. The holes in the plate corresponded to the location of the bones. The screws were fixed along the upper and front surfaces on both sides.

The patients observed in the groups complained of pain mainly in the anterior pelvis, aggravated by physical exertion, and had gait disorders. The period of treatment of patients after receiving a pelvic ring injury before hospitalization ranged from 4 weeks to 7 years after conservative treatment or osteosynthesis.

All patients underwent a thorough examination: a detailed medical history survey, radiographic multi-projection study of radiographs in the anteroposterior, caudal and cranial projections, as well as functional images, and a CT of the pelvic ring.

Conservative treatment was carried out in the postoperative period that included antibacterial, anticoagulant and anti-inflammatory therapy, early activation of patients, walking with crutches up to 2 months after the operation. Patients were followed up on an outpatient basis within 3-6-12 months after surgical treatment.

The results of treatment were evaluated in both groups using the Majeed system [23].

For statistical data processing, IBM SPSS Statistics 26 software was used. For statistical data analysis, the Mann-Whitney U-test was used to assess the differences in the results in the study groups. The threshold of statistical significance corresponded to $p = 0.05$.

RESULTS

Four patients of group 1 (16.7 %) developed failure of osteosynthesis within the period from two weeks to two months after the operation and required repeated interventions.

Case 1

A patient, 44 years old, sustained injury three months prior to admission due to a fall of a heavy metal object on the patient. In the hospital at the site of injury, conservative treatment of injured pelvic ring in a hammock was carried out for 35 days that failed. Combined osteosynthesis with a half-pin external fixator and plating with a lag screw was performed. The patient was prescribed bed rest for 42 days. After admission to the Federal State Budgetary Institution Priorov NMRC for TO, the apparatus was dismantled, and the patient was activated on the 1st day after its dismantling and failure of osteosynthesis was detected (Fig. 1). Diagnosis at admission: non-united ruptures of the pubic and left sacroiliac joints; condition after fixation of the pubic symphysis with a plate and screws, migration of metal structures; delayed union of the fracture of the anterior column of the right acetabulum.

After the examination, tactics were determined. The patient underwent re-osteosynthesis of the anterior pelvic ring with two plates (Fig. 2).

On the 5th day after the operation, the patient was activated, trained to walk with additional support on a walker. On the 34th day after the operation, the patient complained of pain in the anterior pelvic ring. The X-rays detected migration of the plate screws (Fig. 3).

Frequent incidence of destabilization of metal implants, which occur after surgical treatment of chronic injuries of the pelvic ring with standard methods, raised the question of developing a new internal implant structure, the design of which would be able to reduce the number of fixation failure to a minimum. The staff of the department developed a monolithic plate with polyaxial locking for fixing injuries of the anterior pelvic ring.

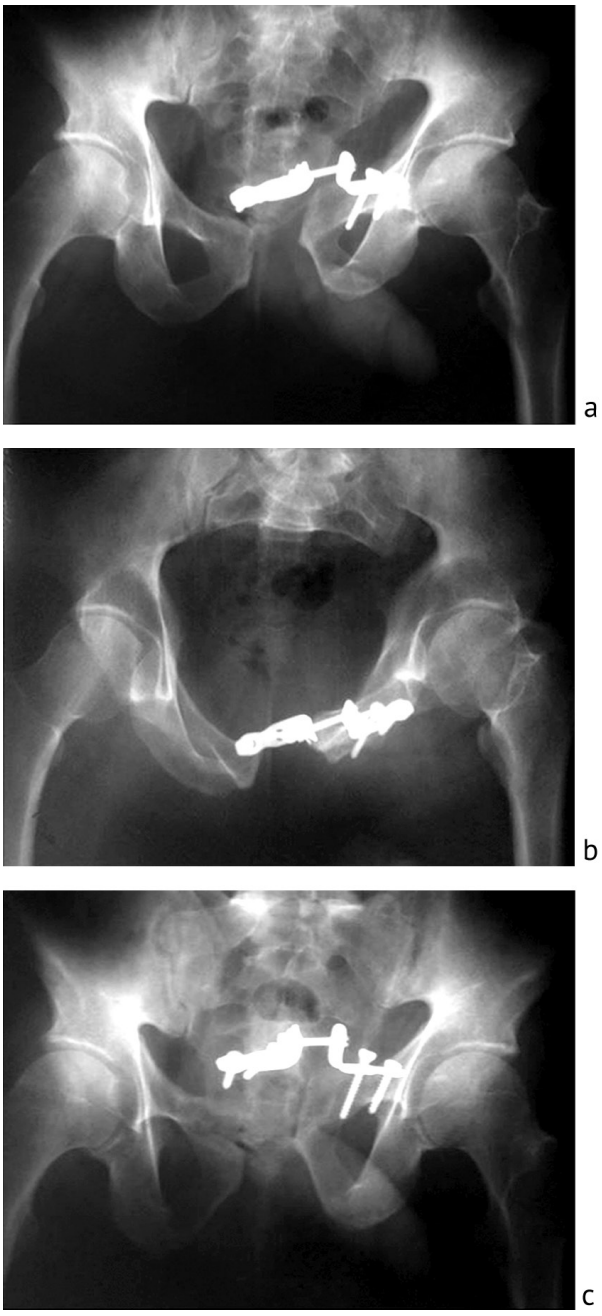

Fig. 1 Radiographs of the pelvis of group1 patient at admission: *a* AP view; *b* caudal projection; *c* cranial projection

Fig. 2 AP radiograph of the pelvis of the group 1 patient after re-osteosynthesis of the anterior pelvic ring with two plates

Fig. 3 AP radiograph of the pelvis of the group 1 patient shows migration of the plate screws 34 days after the operation

In the study group 2, two cases of destabilization of the metal structure (6.6 %) were identified. In one case, migration of the plate screws was detected after 3 years during routine X-ray examination at VTEC referral, but the patient was not feeling pain or sense of instability (Fig. 4).

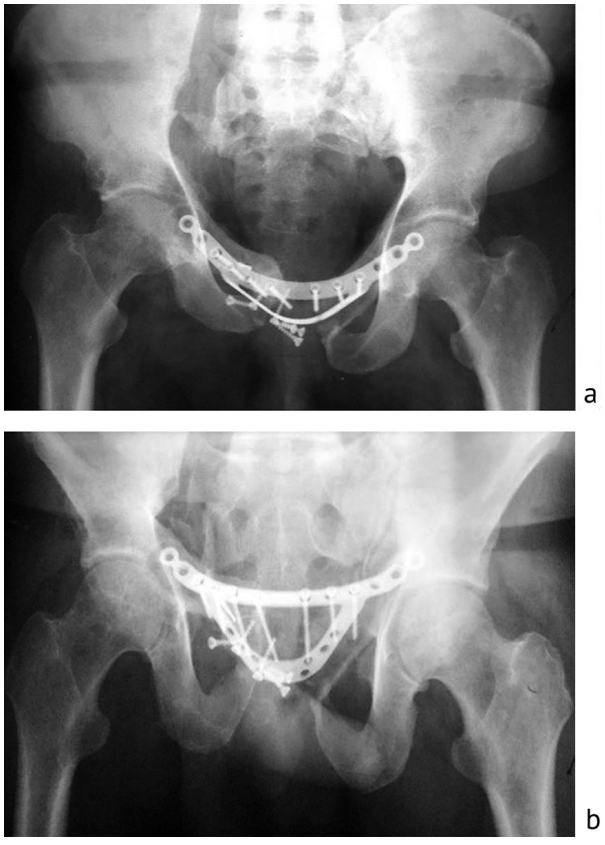

Fig. 4 Radiographs of pelvis of a group 2 patient three years after the surgical treatment that used a plate with a polyaxial screw locking: *a* AP view; *b* cranial view

The radiographic study confirmed that the pelvic ring was stable; the implant was removed.

Case 2

Patient, 50 years old, 9 months after the injury due to a road accident. External fixation of fractures of the

pelvic ring was performed at the site of injury. Ten days after stabilization of the condition, the final bone fixation with two plates was performed. The patient complained of pain in the anterior part of the pelvic ring and had a feeling of instability. X-rays revealed failure of fixation with two plates. He was hospitalized in CITO with a diagnosis of unstable post-traumatic deformity of the pelvic ring; chronic multiple fractures of the pelvic bones; condition after metalodesis of the pubic articulation with plates and the left ilium with plates (Fig. 5).

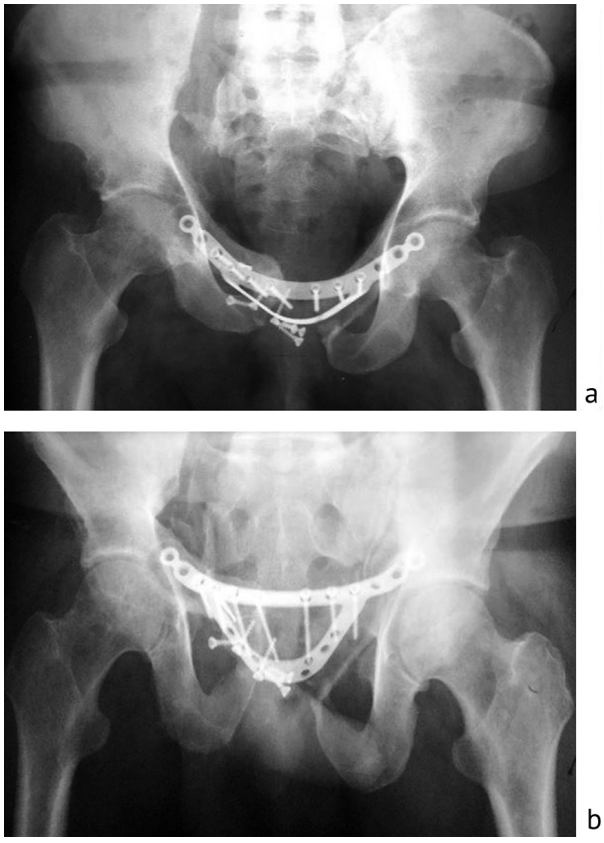

Fig. 5 Radiographs of the pelvis of group 2 patient at admission: *a* AP view; *b* cranial projection

It was decided to perform re-osteosynthesis with one plate after thorough examination (Fig. 6)

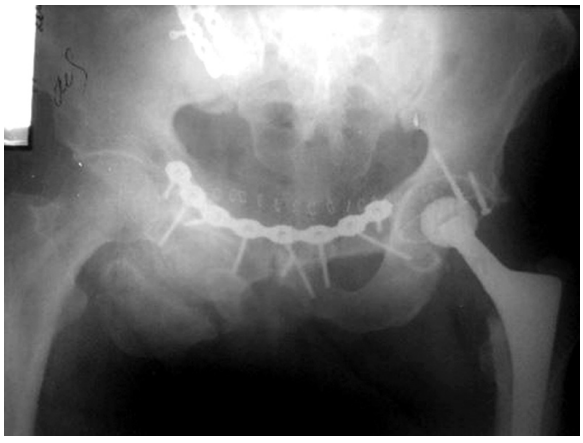

Fig. 6 AP radiograph of the pelvis of group 2 patient upon re-osteosynthesis of the anterior pelvic ring

On the 7th day after the operation, when the patient was activated, the patient began to complain of pain in the area of the left sacroiliac joint, in connection with which the left SIJ was fixed with a cannulated screw (Fig. 7).

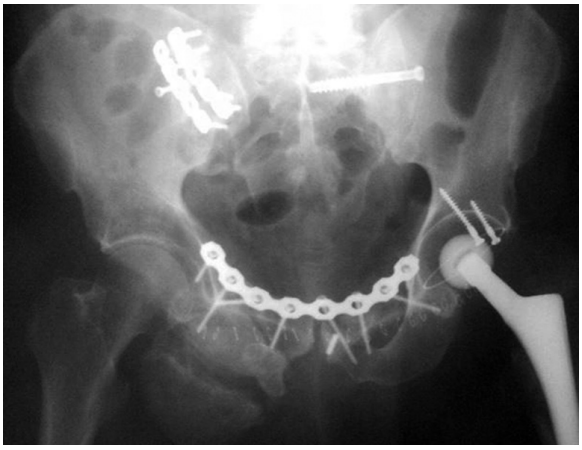

Fig. 7 AP X-ray of the pelvis of the patient from group 2 after fixation of the left sacroiliac joint with a cannulated screw

Fourteen days after the surgical intervention, immediately after discharge from the hospital, the patient complained of pain in the anterior part of the pelvic ring; migration of the screws was revealed on the radiographs. The patient was prescribed outpatient treatment with dynamic monitoring in CITO. After 7 months, the patient was hospitalized with an increased pain due to destabilization of the implant (Fig. 8).

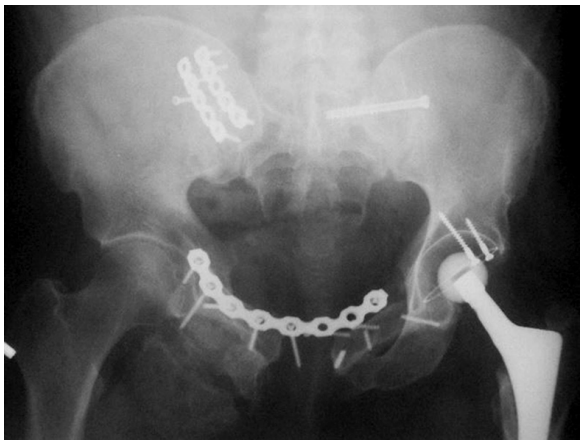

Fig. 8 AP X-ray of the pelvis of the patient from group 2 seven months after surgical treatment

The patient underwent surgical treatment using a polyaxial plate (Fig. 9).

A year later, the patient re-applied for a consultation at CITO, and the metal structure was removed due to its instability. In connection with the persistent deformation of the pelvic ring, the patient was prescribed outpatient aftercare.

During follow-up examinations in group 2, patients aged 18 to 35 complained of dyspareunia.

A statistical analysis of long-term results of treatment was carried out using the Majeed rating scale. When analyzing the results using the IBM SPSS Statistics 26 software, statistically significant differences were obtained with the Mann-Whitney U-test at p = 0.05 (Tables 1, 2, 3, 4).

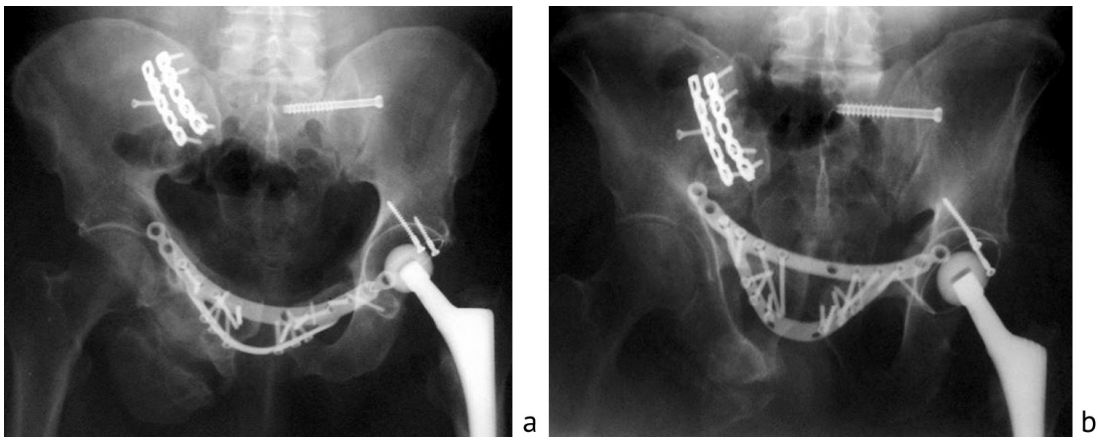

Fig. 9 Radiographs of the pelvis of a patient from group 2 after re-osteosynthesis of the anterior pelvic ring using a plate with polyaxial locking: *a* AP view; *b* cranial projection

Table 1

Statistical data of the groups

Group	Fixation method	n	Mean	Standard deviation	Standard error
1	Two plates	36	72.06	7.243	1.207
2	Polyaxial plate	30	74.93	6.346	1.159

Table 2

Summary on the validation of the hypothesis

	Null hypothesis	Criterion	Value	Solution
1	The results of the treatment of group 1 are similar to group 2	Mann-Whitney U test for independent samples	0.026	Null hypothesis is rejected
2	The distribution of group 1 is the same for group 2	Kolmogorov-Smirnov criterion for independent samples	0.075	Null hypothesis is accepted

The asymptotic significances are derived. Significance level p = 0.05.

Table 3

Summary of the Mann-Whitney U-test for independent samples

Total	66
Mann-Whitney U-test	712.500
Statistics of the test	712.500
Standard error	77.305
Standard statistics of the test	2.231
Asymptotic Significance (2-tailed test)	0.026

Table 4

Summary of the Kolmogorov-Smirnov test for independent samples

Total		66
Greatest extreme discrepancies	Absolute	0.317
	Positive	0.317
	Negative	0.000
Statistics of the criterion		1.281
Asymptotic Significance (2-tailed test)		0.075

The Majeed rating in the study group 1 showed the average score of treatment outcomes was 72, which corresponds to good results; in group 2, the average score was 74, which is a good result. However, taking into account the mean score differences, fewer destabilizations of metal implants, the treatment with a polyaxial plate showed the best results in compared groups (Table 5).

Table 5

Estimation of the treatment results with Majeed rating system

Result of surgical treatment	Group 1		Group 2	
	Two plates		Polyaxial plate	
	No	%	No	%
Excellent	9	25	17	56.6
Good	17	47.2	8	26.7
Fair	6	16.7	4	13.4
Poor	4	16.7	1	3.3
Total	36	100	30	100
Inc. destabilization	4	16.7	2	6.6

DISCUSSION

The role of surgery as a treatment choice has increased for pelvic injuries [1-17]. Refusal from conservative treatment of pelvic injuries raises an important issue for operating surgeons, both about determining the tactics of surgical treatment and choosing a fixator. The authors mark the advantages of performing early osteosynthesis of the pelvic bones [24-26]. The developed methods of minimally invasive treatment of pelvic ring injuries enable to expand the indications for early osteosynthesis [27-30]. However, the condition of the patient and difficulties in the provision at hospitals do not always allow early final stabilization of the pelvic ring. Fixation of the anterior pelvic ring with one or two plates shows good results in acute pelvic trauma. However, in chronic injuries, metal implants tend to destabilize due to pelvic ring rigidity [4, 8, 9, 14]. One of the important aspects of pelvic ring surgery, according to the authors, is accurate reduction of bone fragments and joints during the osteosynthesis procedure [31–33]. Thus, in the case of chronic injuries, the use of minimally invasive techniques for surgical treatment seems to be ineffective. A number of researchers prefer instrumental treatment of chronic pelvic ring injuries, describing various variants of external fixation apparatus (EFA) arrangement for deformity correction [10, 11, 34, 35]. The authors emphasize the advantages of the apparatus-based treatment such as low trauma compared to internal osteosynthesis, speed, and gradual correction of pelvic deformity in the postoperative period. Unfortunately, this approach is inconvenient for the patient. Bulky EFAs, the need for a constant care of the wires and half-pins, the duration of fixation in the EFA can bother the patient. These and other factors create discomfort for the patient. Moreover, the authors themselves report episodes of purulent inflammatory complications at the outpatient stage of treatment, even if the care is proper.

Having analyzed the positive and negative aspects of the presented methods, we made a choice in favor of internal osteosynthesis with plates. Taking into account cases of destabilization of fixation using one or two plates, an original metal implant structure was developed and applied for providing stronger fixation.

The analysis of the results obtained in the course of our showed that the use of an original metal structure with polyaxial locking for the treatment of chronic injuries of the pelvic ring is more effective than fixation with two standard plates.

However, the use of this plate is associated with technical difficulties in fixing the anterior part of the pelvic ring, associated with the elasticity of the plate and the complexity of the plate for laying on the pubic bones. The use of additive technologies, which are rapidly developing in the modern world, will create individual metal structures with polyaxial locking and solve the problem of plate designs. The good factor about this solution is that patients with chronic pelvic ring injuries are not emergency patients. There is a possibility of a longer preparation for surgical treatment, CT scanning with 3D-modeling of the pelvis to create an individual design, taking into account the anatomical features of the pelvis of each patient.

Patients' complaints about dysparurenia in the cases with the polyaxial plate led to a rethinking of the approach to surgical treatment based on gender differences in the structure of the pelvic ring in men and women. It was decided to develop a female version of the plate in order to exclude a decrease in the quality of life after surgical treatment associated with dyspareunia.

The standard approach to stabilizing such injuries, as in fresh injuries, does not create conditions for stable fixation. Fibrous cicatricial process occurring in traumatic foci promotes a rigid deformity of the pelvic ring when restoring the anatomical integrity of the pelvic ring. The use of two reconstructive plates involves the use of a large number of screws to fix the pubic bone, which leads to a decrease in the strength

of the bone itself due to bone loss. Both plates bear multidirectional loads experienced by the pubic joint, which led to destabilization of the metal structure. The plate experiences stronger loads in chronic injury than in an acute one, which may cause a fatigue fracture of metal structures. Changing the standard approaches to the treatment of chronic injuries of the anterior pelvic ring (3 weeks old or more) using the original plate enabled to create conditions for stable fixation, despite the rigidity of the pelvic ring in chronic injuries.

CONCLUSION

1. The use of the developed original plates based on polyaxial locking for fixation of chronic injuries of the anterior pelvic ring has improved the results of surgical treatment.

2. The phenomenon of dysparenia in women with an established original design requires a change in the approach to the treatment of pelvic injuries, taking into account the gender characteristics of the pelvic ring and the location of the pelvic organs, as well as the creation of a female version of the polyaxial plate.

3. The properties of the implant itself do not allow to accurately shaping the plate for the anatomical features of the pelvic structure of patients, which complicates its implantation. The use of additive technologies at the stage of preparing a patient for surgical treatment and individual designs would solve the problem.

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