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Research Article

Review of the treatment options and results of earthquake-related pelvic injuries after the Türkiye earthquake on 6th February

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ABSTRACT

Objective: The aim of this study was to review the characteristics and classifications of pelvic injuries due to earthquake trauma, to determine the treatment options and outcomes, and to present the experiences of our single trauma center.

Methods: Sixty patients (23 male, 37 female) who underwent surgical treatment for pelvic ring injuries after the earthquake were analyzed in this study. Demographic data, such as age and gender, operations, and fracture details were recorded. Laboratory results and the amount of blood used were included in the analysis. Fractures were classified according to the Young–Burgess classification. Surgical treatment methods, side of injury, accompanying injuries, and treatment results were analyzed using SPSS software.

Results: Left-sided trauma was the most common mechanism of injury, with 36 patients (60%) sustaining left-sided pelvic fractures. Pelvic ring fractures were detected in 78.3% of patients, and combined acetabulum and pelvic ring fractures were identified in 21.7% of patients. Thoracic trauma and extra-pelvic fractures were seen in 12 (20%) and 18 (30%) patients, respectively. Twenty percent of patients underwent emergency abdominal surgery prior to pelvic surgery. Complications were observed in 7 patients (11.6%) in the early period. The average amount of blood used for patients was 2.91 U (min: 0, max: 13 U, SD: 2.66).

Conclusion: This study has shown us that lateral compression injuries are more common, and that low hemoglobin levels, high inflammation parameters, previous abdominal surgery, accompanying fractures, and lung injury are the main characteristics of patients with earthquake-related pelvic injuries. It also demonstrates that for the optimal use of materials and implants, experience in different techniques is required, and shows the significant need for blood transfusions in the treatment of these injuries.

Level of Evidence: Level IV, Therapeutic study.

Introduction

During the 30-year period between 1980 and 2009, 61.5 million people were affected by earthquakes in various ways.[1] Unfortunately, we experienced the latest example of this in our country. On February 6, 2023, Türkiye experienced 2 major earthquakes. The first, measuring 7.7 on the Richter scale, struck the Pazarcik district of Kahramanmaras at 04:17 AM local time. Later that same day, at 01:24 PM, a second earthquake with a magnitude of 7.6 hit the Elbistan district in Kahramanmaras. These seismic events impacted a region spanning 350 km and affected a total of 11 cities.[2] As can be seen, cases during earthquakes go far beyond daily practice. This describes running into multiple emergency patients concurrently.[3] This situation also differs significantly in pelvic ring injuries. The main reason for this is that the mechanism of trauma is different. High-energy fracture patterns are observed in the pelvis that is compressed in multiple directions under collapse. Earthquake-related pelvic injuries differ in terms of accompanying injuries and fracture patterns. While there are numerous studies on non-earthquake pelvic injuries (NEPIs), literature information about earthquake-related pelvic injuries (ERPIs) is scarce.[4] Hence, it is essential to discuss what kind of pelvic injury earthquakes cause, how it is managed, and patient data.

The current study presents the types and severity of pelvic fractures that occurred during the earthquake by reviewing diagnosis and treatment methods. The aim of the study is to review the characteristics and classifications of pelvic injuries related to earthquake trauma and to determine the treatment options and results.

Material and methods

After the Adana City Education and Research Hospital Scientific Research Ethics Committee permission was obtained (decision no.: 2499; date: April 19, 2023), patient data were examined retrospectively. Following the earthquake that occurred in Türkiye on February 6, 2023, all patients who were admitted to our hospital due to pelvic ring injuries and underwent surgical treatment were included in the study. Only surgically treated patients were included in this study because of the possibility of proper recording in the operating room. In a disaster such as an earthquake,

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where there is a high inflow of patients to the emergency department, it was not possible to have an idea about the records and diagnoses of patients who died and patients who were referred. A total of 70 cases were included in the study. Ten patients, for whom sufficient information could not be obtained due to incorrect name registration, transfer to another city, duplicated patient registrations, etc., were excluded from the study. Therefore, a total of 60 patients were included in the study.

Patients' demographic information, such as age and sex, fracture type (according to Young–Burgess classification Table 1), associated injuries, type of treatment, preoperative and postoperative lab tests, additional operations, and all the data that were recorded from the files.

Patients who had undergone abdominal surgery before pelvic surgery were noted. The areas where the impact on the pelvic ring caused major damage were recorded.

Information about patients with accompanying injuries in addition to pelvic injury was documented. The day on which patients were operated on and their preoperative and postoperative laboratory results were determined. The amount of blood used and patients' blood groups were identified. Early postoperative complications were observed and recorded. The approaches used during surgery were recorded.

Statistical analysis

To decide on the appropriate tests for the continuous data in the data set, normality testing was performed with the Kolmogorov–Smirnov *Z* test (since n > 50). In the difference analyses of the variables considered significant according to this test, the Mann–Whitney *U*-test was used for the difference of variables with 2 categories, and the Kruskal–Wallis *H* test was used for the difference tests of variables with more than 2 categories. If a difference was found in multi-category tests, the source of the difference was investigated again with the Mann–Whitney *U*-test. In the difference analysis of variables that were not accepted as significant according to the normality test, the independent sample *t*-test was used for the difference of 2-category variables, and the analysis of variance (ANOVA) test was used for the difference tests of variables with more than 2 categories. If there was a significant difference according to the ANOVA test, the source of the difference was examined with Tamhane's T2 test. Similarly, the Pearson correlation test was applied if both variables were under the normal distribution, while in other cases, the relationships between the variables were examined with the Spearman correlation test. The tests were prepared with SPSS ver 21.0 (IBM SPSS Corp.; Armonk, NY, USA) and the results were interpreted at a 95% CI.

Results

Upon reviewing the data of 60 patients included in the study, it was determined that 23 (38.3%) were male, 37 (61.7%) were female, and the mean age was 33.75 years (minimum 8-maximum 75). The distribution of fractures according to the Young–Burgess classification is shown in Table 1. When the distribution of patients according to age groups was analyzed, it was observed that there were 12 (20%) patients over the age of 50, 35 (58.3%) patients between the ages of 18 and 50, and 13 (21.7%) patients under the age of 18.

The main direction of major damage to the pelvic ring was the right side in 15 patients (25%), the left side in 36 patients (60%), and mixed in 9 patients (15%). Patients who had undergone abdominal surgery before pelvic surgery—patients who had undergone emergency abdominal surgery for reasons such as bleeding focus exploration, liver laceration, or bladder or bowel perforation—constituted 12 (20%) of all patients.

The number of patients with pregnancy+intrauterine ex fetus in addition to pelvic ring injury was 5 (8.3%).

Twelve patients (20% of all patients) had thoracic trauma. These injuries include posterior lung hematoma, rib fracture, and pneumothorax. A posterior lung hematoma can be defined as a hematoma located on the entire posterior wall of the lung due to the

HIGHLIGHTS

- This study aimed to review the characteristics, classifications, treatment options, and outcomes of pelvic injuries resulting from earthquake trauma in a single trauma center.
- The results showed that lateral compression injuries were the most common, and many patients required blood transfusions and had accompanying thoracic and extra-pelvic injuries.
- The results from this study indicate a significant need for specialized techniques and materials in treating earthquake-related pelvic injuries, as well as the importance of preparing for substantial blood transfusion requirements.

Table 1. Patient distribution and characteristics

			N	%
General data	Age groups	>50	12	20.0
		18-50	35	58.3
		<18	13	21.7
	Gender	Male	23	38.3
		Female	37	61.7
	Major trauma side	Right	15	25.0
		Left	36	60.0
		Anteroposterior	7	11.7
		Axial	2	3.3
	Blood types	O+	21	35.0
		O–	1	1.7
		AB+	4	6.7
		AB–	1	1.7
		A+	21	34.9
		A–	6	10.0
		B+	5	8.3
		B–	1	1.7
Non-orthopedic injuries	Previous abdominal surgery	No	48	80.0
		Yes	12	20.0
	Intra-abdominal injury	No	46	76.7
		Yes	9	15.0
		Pregnant	5	8.3
	Lung injury	No	48	80.0
		Yes	12	20.0
Orthopedic injuries	Pelvic fracture type (Young–Burgess classification)	APC 1	2	3.3
		LC-2	4	6.7
		LC-3	31	51.7
		VS	4	6.7
		Combined	2	3.3
		İliac wing	4	6.7
		Acetabulum	13	21.6
	Extra-pelvic fracture	No	42	70.0
		Rib	2	3.3
		Spine	7	11.7
		Humerus	3	5.0
		Femur	2	3.3
		Head	2	3.3
		Tibia	2	3.3

Table 2. Differences between groups according to blood use and laboratory results

			Minimum	Maximum	Mean	SD*	*P***
Erythrocyte suspension	Age groups	<18	1	7	3.69	1.97	.028
		18-50	0	13	3.14	3.03	
		>50	0	5	1.42	1.44	
	Trauma side	Right	0	13	3.73	3.17	.038
		Left	0	11	3.06	2.46	
		Anteropostero	0	5	1	1.91	
		Axial	1	1	1	0	
	Previous abdominal surgery	No	0	7	2.46	2.11	.036
		Yes	0	13	4.75	3.79	
Hemoglobulin level pre-op	Trauma side	Right	6,6	12.1	9.93	1.74	.005
		Left	3	15.6	9.87	2.26	
		Anteropostero	11,4	18.5	13.7	2.58	
		Axial	8,9	11.8	10.35	2.05	
	Gender	Male	3	18.5	11.13	3.36	.04
		Female	6,6	12.1	9.86	1.52	
Hematocrit level preop	Trauma side	Right	19,6	34.9	29.44	5.06	.003
		Left	9,1	46.8	29.31	6.36	
		Anteropostero	33	59.9	41.23	9.22	
		Axial	26,3	36	31.15	6.86	
Aspartate amino transferase	Age groups	<18	28	1341	391.78	490.93	.026
		18-50	17	266	83.06	65.58	
		>50	19	102	46.92	24.6	
	Previous abdominal surgery	No	17	820	89.91	125.85	.034
		Yes	40	1341	457.12	538.87	

*SD, standard deviation.
**$P < .05$.

continuous lying position of patients. Table 1 summarizes the fracture types observed in 60 patients. Combined acetabulum and pelvic ring fractures were observed in 21.6% of patients (Table 1). Extrapelvic fractures were observed in 30% of all patients and are shown in Table 1. Table 2 shows the differences between groups according to blood use and laboratory results. Our results showed that more blood is needed if the trauma direction is right or left compression. In addition, patients with previous abdominal surgery also required more blood. Preoperative hemoglobin was lower in female patients. Aspartate aminotransferase (AST) was higher, especially in patients with abdominal injuries. Details are shown in Table 2. It took an average of 8.1 days for patients to receive definitive treatment after the earthquake (minimum: 1, maximum: 24 days, standard deviation (SD): 5.59) Table 3. Figure 1 shows the distribution of how many patients underwent surgery and on which days after the earthquake.

Table 3. Preoperative and postoperative laboratory results of atients (n=60)

	Minimum	Maximum	Mean	SD
Age	8	75	33.75	16.37
Length of hospital stay (days)	3	22	9.41	4.94
Average permanent treatment days	1	24	8.1	5.59
Erythrocyte suspension used (Unit)	0	13	2.91	2.66
Glucose pre-op (mg/dL)	53	296	125.15	44.95
CRP pre-op (mg/L)	1.3	303.7	110.17	68.41
ALT pre-op (U/L)	6	805	77.22	135.59
AST pre-op (U/L)	17	1341	142.71	263.16
WBC pre-op ($10^3/\mu L$)	3	67.3	13.98	9.74
HGB pre-op (g/dL)	3	18.5	10.35	2.45
HCT pre-op (%)	9.1	59.9	30.79	7.36
PLT pre-op ($10^3/\mu L$)	40	539	265.36	96.69
Post-op WBC ($10^3/\mu L$)	1.5	32.1	10.89	4.66
Post-op HGB (g/dL)	7.6	13.9	9.95	1.26
Post-op HCT (%)	23.3	40.9	29.84	3.64
Post-op PLT ($10^3/\mu L$)	33.9	1037	428.88	210.59

Table 3 contains the preoperative and postoperative laboratory results of patients. The average amount of blood used for patients was 2.91 U (minimum: 0, maximum: 13 U, SD: 2.66). Considering the distribution of patients according to blood groups in Table 1, O+ and A+ were the most common blood groups in patients.

The 10 different approaches used during surgical treatments of patients are as follows: anterior intrapelvic approaches with or without lateral window, Kocher–Langenbeck approaches, posterior oblique incision for transiliac fixation, posterior midline incision, iliosacral screw fixation, anterior and posterior combined approaches, limited approaches and fixator, only fixator, and iliac lateral window approaches.

Complications were observed in 7 of 60 patients (11.6%) in the early period. Among these, wound infection was observed in 3 patients. While 2 of these patients recovered with antibiotics and wound monitoring, one underwent irrigation and debridement surgery. Fixator failure was observed in 1 patient. One patient had sciatic nerve neuropathy. Two patients required postoperative dialysis due to crush syndrome. Additionally, 2 patients died in intensive care after the postoperative period.

Discussion

In this study, patients who suffered pelvic fractures due to the February 6 Türkiye earthquake were presented with their diagnosis and treatment characteristics. This study's presentation of the findings and the experience of a single center with pelvic fractures brought on by earthquakes is its strongest point. It is essential to be able to provide optimal care to many patients who need rapid evaluation and treatment in mass disasters. In disaster environments where patients far more than resources are encountered, precautions can be taken with good planning before the disaster. A good analysis of vital

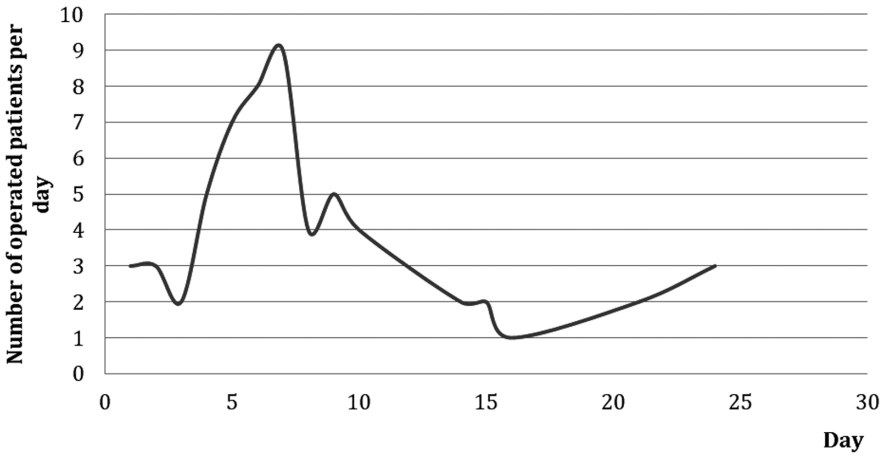

Figure 1. How many days after the earthquake was the patient taken to the main operation?

traumas such as pelvic ring injuries during mass disasters will better prepare us for future disasters.[5]

The study has shown us that injuries following major earthquakes cover a wide spectrum and occur in large numbers, and in a very short time.[6] It is certainly our duty as orthopedic surgeons to transfer such valuable information and experience to scientific.[7] Our study provides valuable information about pelvic ring injuries, one of the major life-threatening injuries. Training courses on disaster medicine may be helpful to provide the most effective healthcare and save as many lives as possible after mass disasters.[8] Therefore, it is important to learn how pelvic fractures are encountered in disaster situations such as earthquakes, in addition to extremity fractures.

The number of studies revealing pelvic fracture patterns occurring during earthquakes is not at the desired level.[4,9] The mechanism of pelvic ring injury in an earthquake is usually the result of building collapse.[1] After the initial trauma caused by the collapsed building to the pelvic region, continued pressure and crushing cause soft tissue damage and accompanying injuries in addition to fractures.[10] The most common fractures observed in our study were lateral compression-type fractures, at a rate above 50% (Table 1). Furthermore, fractures with the Anteroposterior Compression (APC), Vertical Shear (VS), and combined mechanisms were also observed. It can be understood how APC and Lateral Compression (LC) fractures occur as a result of being crushed under the debris during an earthquake. Therefore, how does VS injury occur? The authors can speculate on this question in light of their experience. Thus, it is useful to think 3-dimensionally about the forces that affect the human body at the time of collapse. The force exerted by the debris vertically on the body in an earthquake may cause vertical shear injury. In another mechanism, the pelvis is pushed upward by the debris while the body trapped under the debris remains stationary. Earthquake-related pelvic injury models can be developed to examine these mechanisms. The patient's position during an earthquake significantly affects the fracture pattern.[4] In the patients we observed in our series, major trauma was on the left side. The authors thought this might have occurred since our patients were lying on the floor and trying to protect themselves in the fetal position. Of our patients, 78.3% had pelvic ring injuries, and 21.7% had combined acetabulum and pelvic ring injuries.

Among all earthquake-related injuries, pelvic fractures vary between 5.7% and 21.5%.[11-13] Earthquake-related pelvic injuries are life-threatening injuries due to both the injury itself and the potential delay in treatment.[14] In our study, it took an average of 8.1 days for patients to receive definitive treatment after the earthquake. It can be possibly caused by the location of the hospital we work in. Our hospital is located in a city affected by the earthquake and is in the closest region to the cities where major impacts occurred. In this study, patients who arrived at our hospital from surrounding provinces were operated on until the 24th day. In the report presented by Dailey et al,[15] the treatment was provided on an average of 7.4 days after the earthquake. The number of patients receiving surgical treatment per day also varies over the days. The reason for this is that the hospital continued to receive transferred patients. On the other hand, the clinical conditions of patients, surgical team availability, and material management can also be considered among the factors affecting the number of daily patient surgeries. In this regard, Table 3 shows the intensity of pelvic surgery by days in a hospital like ours after the earthquake. The experience of the distribution of earthquake-related pelvic fracture surgeries by day in a centralized hospital like ours may be a limited example of what kind of pelvic fracture density would be encountered in a future earthquake disaster.

In mass disasters, the qualities of the treatment center largely determine the quality of treatment to be provided. If there is a limited health infrastructure before the earthquake, this will also affect the course of treatment during the disaster.[16] This is related to early and late intervention in permanent surgical treatment. The fact that our hospital, where the presented cases were treated, is earthquake-resistant and fully equipped has been an opportunity for the treatment and initial care of these patients.

Up to what time should late cases be treated? In our series, the last earthquake-related pelvic ring injury operation was performed on the 24th day. The optimal time for definitive treatment is not clearly defined in the literature. Although there is a tendency toward early fixation, the definition of "early" refers to the time varying between the first 8 hours and the first 7 days in the literature.[17] The main disadvantages of early fixation are the risk of bleeding and the risk of a second hit to the patient not fully resuscitated. On the other hand, the main disadvantages of late fixation can be listed as infection, thromboembolism, decubitus ulcer, and failure to achieve anatomical reduction.[18] It has been emphasized that the most important factors affecting the timing issue are the hemodynamic status and response to resuscitation, fracture pattern, accompanying injuries, and the patient's inflammatory status.[19] In our study, the patients' preoperative and postoperative hemodynamic status and traumatic

inflammatory state were recorded as much as possible in the disaster environment. The ability to document laboratory data in ERPI patients is one of the aspects that makes our study come to the fore. The preoperative white blood cell (WBC) and C-reactive protein (CRP) levels of patients were high, as seen in Table 3. The mean preoperative hemoglobin (HGB) level of our patient series was 10.35. Patients with low hemoglobin levels were operated on. Our study showed that the direction of trauma was associated with preop low hemoglobin level. This was probably because high-energy fractures such as lateral compression type were more common in earthquakes. On the other hand, hemoglobin levels were significantly lower preop in females as shown in Table 2.

In disaster situations with large numbers of patients, it may not be appropriate to comply with the optimal waiting time for surgical treatment. This is one of the differences between NEPI and ERPI. Damage control orthopedic strategies should also be considered in pelvic ring injuries, and it is essential to plan definitive treatment after the fourth day.[18] Although there were patients admitted early, the definitive treatment in our study was provided 8.1 days on average after the earthquake.

In our case series, an average of 2.91 units of blood was used, which is consistent with publications in the literature reporting similar and greater use of blood. However, this may vary depending on factors such as the stability of the fracture and accompanying injuries.[20] Considering the distribution of patients according to blood groups, it was observed that O+ and A+ were the most common blood groups (Table 1). This point comes to the fore as an important highlight of our study. The current research presented the blood group distribution and the amount of blood used in ERPI patients for the first time in the known literature. Previous studies have shown that blood groups in society vary depending on the region.[21,22] Earthquakes cause more injuries than any other disaster. Logistic and organizational changes must be made in hospital operations to maximize capabilities. Especially when preparing for mass events such as disasters, knowing the blood group distribution in each region and the average blood needs in similar cases is crucial for effective preparation.[23]

It is challenging to evaluate outcome studies following the fixation of pelvic injuries due to inadequate follow-up, injury pattern heterogeneity, related visceral and neurologic injury, and the absence of a valid outcome measure for pelvic ring injuries.[24] Moreover, specifying the profile and characteristics of our patients is of great importance in terms of shedding light on future studies. Accompanying fractures outside the pelvic region were observed in 30% of the patients. Of the patients, 20% had thoracic trauma, and 20% had undergone abdominal surgery prior to pelvic surgery. Of the patients, 8.3% had a pelvic fracture together with the termination of pregnancy. Early postoperative complications were observed in 15% of the patients. The aforesaid data demonstrate the difficulty of the patient group in question. As in many disasters, logistics and resource provision are important in earthquakes. Resource management plays an essential role in the course of treatment. The basic treatment principles of general pelvic ring injuries were also applied to earthquake-related injuries.[25] As soon as possible, particular attention was paid to the stable fixation of the pelvic ring in our cases. The implants and materials obtained could be applied as a fixation method in this disaster environment, as shown in the case examples (Figures 2 and 3). The authors experienced the fact that it is important for the teams that will perform ERPI surgical treatment to have mastery of different surgical methods and surgical approaches. Many different surgical approaches were used, taking into account implant and material logistics, surgical experience, and patient injury characteristics. In our case series, many different approaches were used as emphasized in the results. These include modified Stoppa, Kocher Lagenbach, sacral approaches, percutaneous screw techniques as well as spinopelvic fusion.

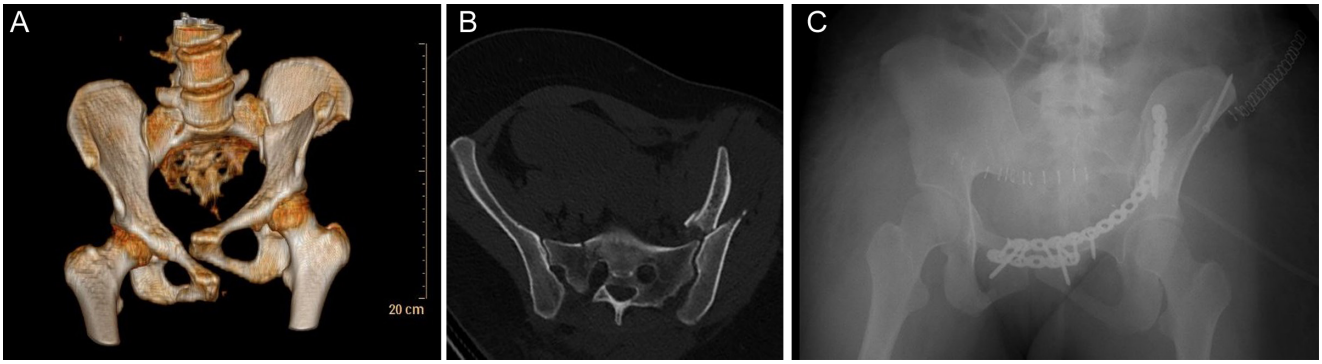

Figure 2. A 32-year-old female patient. (A) Preoperative 3D pelvis CT image, (B) preoperative axial CT image, (C) postoperative AP pelvis X-ray image.

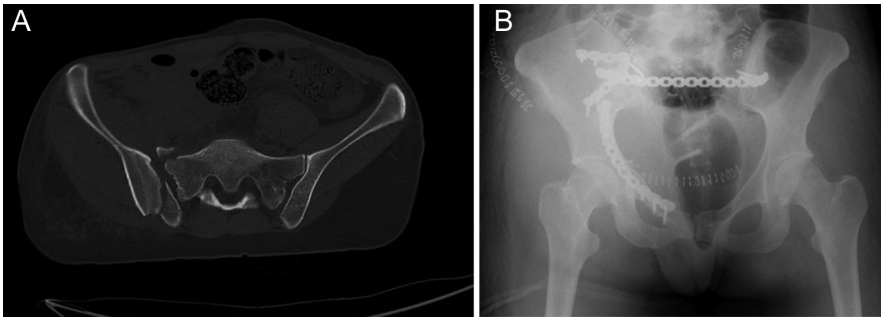

Figure 3. A 26-year-old female patient. (A) Axial CT image shows sacroiliac joint injury. (B) Postoperative AP pelvis X-ray image.

The authors are aware of some limitations of the current study. First, if postmortem pelvic injuries could be analyzed, it would give us more information about ERPIs. On the other hand, the long-term treatment outcomes of patients could not be presented. It should be known that all these are difficulties caused by the disaster environment. While the authors were trying to treat patients, it was important for them to try to keep as many records as they could in order to pass on information to subsequent researchers.

Earthquake-related pelvic ring injuries are high-energy fractures. In light of experience, it was observed that most earthquake-related pelvic fractures were unstable. Lateral compression injuries are more common. Low HGB levels, high inflammation parameters, previous abdominal surgery, accompanying fractures, and lung injury are the main characteristics of patients with earthquake-related pelvic injury. The rate of complications is higher in the early period. For optimal use of materials and implants, experience in different techniques is required. Our study also emphasizes that the need for blood is significant in the treatment of earthquake-related pelvic ring injuries. In conclusion, the present study provides critical information to better prepare for future disasters and highlights points to focus on in treating pelvic injuries. The data from this study will be utilized as a resource in future algorithms developed for earthquake-related injuries.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Adana City Education and Research Hospital Scientific Research Ethics Committee (approval no: 2499; date: 19.04.2023).

Informed Consent: N/A.

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