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# Learning Curve for Surgical Treatment of Acetabular Fractures: A Retrospective Clinical Study of a Practical and Theoretical Training Course

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**Background:** Surgical treatment of acetabular fracture and the anatomic reconstruction of the hip joint are difficult to achieve due to the complex pelvic anatomy, and surgical training requires a prolonged and steep learning curve. The aim of this study was to evaluate the effects of an applied training course, including cadaveric dissection, for the surgical treatment of acetabular fractures.

**Material/Methods:** This retrospective study included 35 patients who underwent surgical treatment for acetabulum fractures between 2012–2016. Patients were divided into three groups during two training courses, for the first two years and second two years. The surgical treatment was performed through single or combined standard approaches, according to the fracture pattern. The radiological outcome was evaluated using Matta's criteria to grade postoperative reduction and final radiological outcome and the restoration of the hip joint center (HJC). The clinical outcome was evaluated using the modified the Merle d'Aubigné-Postel (DAP) hip score.

**Results:** Both post-course groups had statistically better functional and radiological outcomes compared with the pre-course group. Depending on the learning curve, the mean duration of surgery decreased from 153 minutes to 82.3 minutes. Although there was no statistical difference between groups in the vertical shift of the HJC, there was a statistically significant in the amount of horizontal shift of the HJC in the second two years of training, compared with the other groups.

**Conclusions:** Functional and radiological outcome of surgical treatment of acetabular fracture may be improved with increased training, depending on the learning curve.

**MeSH Keywords:** **Education, Distance • Fractures, Bone • Learning Curve • Pelvic Bones • Treatment Outcome**

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## Background

Acetabular fractures occur primarily in young adults as a result of high-energy trauma, and these fractures are often associated with other life-threatening injuries [1]. Acetabular fractures are rare and occur in approximately 37 per 100,000 of pelvic fractures annually in the USA [2]. Displacement of acetabular fracture fragments may lead to the articular incongruity of the hip joint, and this condition can lead to osteoarthritis [1].

Long-term results of surgically treated acetabular fractures depend on the quality of reduction and level of involvement of weight-bearing joint surface [3,4]. Due to the complex pelvic anatomy, difficulties in the surgical approach to repair of the hip joint complicate the surgical treatment of acetabular fractures [5,6].

Surgical treatment of acetabular fractures requires a prolonged and very steep learning curve [7]. The experience of the surgeon and the approach to the treatment of the fracture also affect the clinical outcome [8]. Following the surgical treatment of these fractures, many complications may occur, such as soft tissue infection, delayed union of bone, screw penetration, neurovascular injury, hernia, thrombosis, hematoma, bleeding, arthritis, and also heterotopic ossification (HO) and avascular necrosis (AVN) of the femoral head. The complication rates following surgical treatment of acetabular fracture differ according to the presence of additional injuries, the mechanism of injury, the timing of surgery, the surgical approach, and the experience of the surgeon [7–11].

Predictable outcomes following surgery for acetabular fractures may be classified as surgeon-dependent variables and surgeon-independent variables [12]. The surgeon cannot control the mechanism of injury, femoral head damage, sciatic nerve damage, dislocation, the pattern of fracture, additional injuries, the age of the patient, and other comorbidities. However, factors such as the timing of the surgery, the quality of the surgical reduction and fixation, and the surgical approach are surgeon-dependent factors that can affect clinical outcome [13–15].

There have been several national and international theoretical and practical training courses that have been organized to increase the success rate of surgical treatment of acetabular fractures, which are associated with complex adjacent anatomic structures and with a steep surgical learning curve.

The aim of this study was to evaluate the effects of an applied training course, including cadaveric dissection, for the surgical treatment of acetabular fracture on the clinical outcome and the surgical learning curve.

## Material and Methods

A retrospective review of the hospital records of 35 patients who underwent open reduction and internal fixation of acetabular fractures between 2012–2016 was undertaken. All patients were given detailed information about the surgery, and approval was obtained from the local Medical Research Ethics Committee (2016/1-19). Patients were divided retrospectively into three groups: surgery performed before the training course; surgery performed within the first two years after the training course; and surgery performed two years after the course, to evaluate the role of training and surgical experience on patient outcome.

All patients had plain pelvic X-radiographs and three-dimensional (3-D) reconstruction computed tomography (CT) scans before surgery (Figure 1A, 1B). The fractures were classified according to Letournel's classification system [13]. All patients had full clinical and neurological examinations, initially as a part of their management protocol. All surgical procedures were performed by the same surgeon, (HBT), under spinal anesthesia.

All patients had defined indications for surgery that included >2 mm displaced acetabular fracture, and Matta's criteria were used to grade postoperative reduction and final radiological outcome and the restoration of the hip joint center (HJC), with a roof-arc angle <45°, and posterior wall fractures with more than 50% of the wall involved, an intra-articular fragment, hip instability, and independent ambulation before acetabular injury and operative intervention [9]. After pre-operative preparation and hemodynamic stabilization, all patients had acetabular surgery as soon as their physiological status permitted. The surgery was performed through single or combined standard approaches, as per the fracture pattern and the pre-operative treatment plan (Figures 2–4).

All patients were treated postoperatively for 48 hours with prophylactic antibiotics with a first-generation cephalosporin, and for ten days with anticoagulant prophylaxis with low molecular weight (LMWH). Oral indomethacin treatment was given for three months to all patients operated through the posterior and combined approach, as prophylaxis for heterotopic ossification (HO) [16]. Isometric exercises, including ankle pumps, static quadriceps, and gluteal exercises were begun on day one after surgery. Touch down weight-bearing ambulation with support was begun on the fifth day after surgery, and full weight-bearing was permitted three months after surgery. In this study, all patients were followed-up clinically and radiologically at the second and sixth weeks, and at the third, sixth, and twelfth month after surgery, and at the final follow-up visit.

Data from all patients included in the study were analyzed retrospectively, including the radiological images, functional

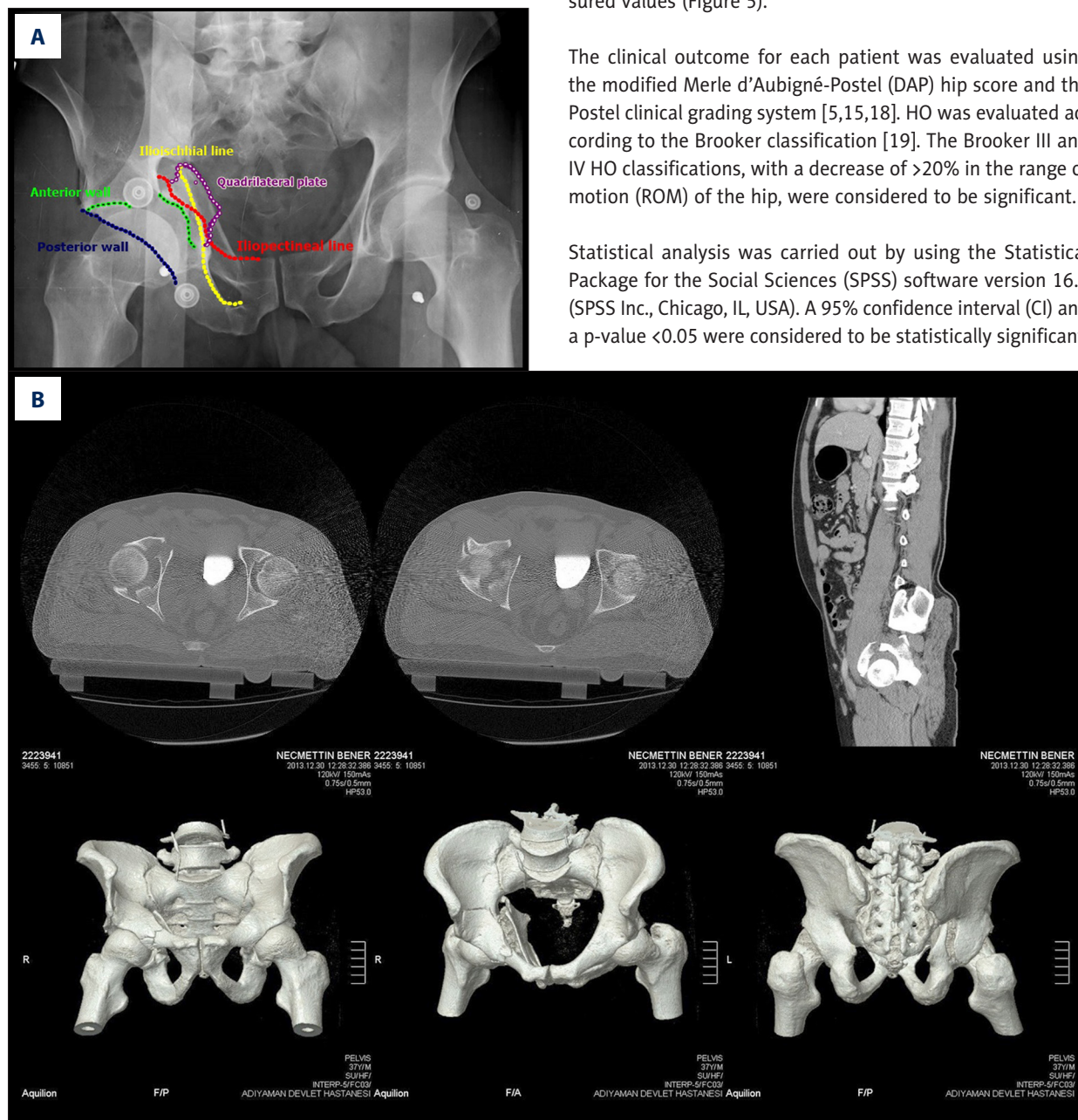
clinical status, and the surgical notes. The radiological outcome was evaluated according to the quality of the reduction of the fracture, as described by Matta, with displacement  $\leq 1$  mm considered to be an anatomic reduction, displacement of 2–3 mm was imperfect, and  $>3$  mm was considered to be a poor outcome [14].

All patients underwent radiographic analysis of the restoration of the HJC following surgery, by measuring the vertical

(V) and the horizontal (H) shifts of the postoperative center of the femoral head from the estimated center of the femoral head, by referring to the contralateral intact hip [17]. Both restoration of the HJC and the displacement of the fractures were evaluated on standard anteroposterior X-radiographs of the pelvis using the AutoCAD 2015 software program. All the measurements were calibrated with the diameters of the cortical screws measured using digitized radiographic images as a reference. Therefore, actual values indicated the exact measured values (Figure 5).

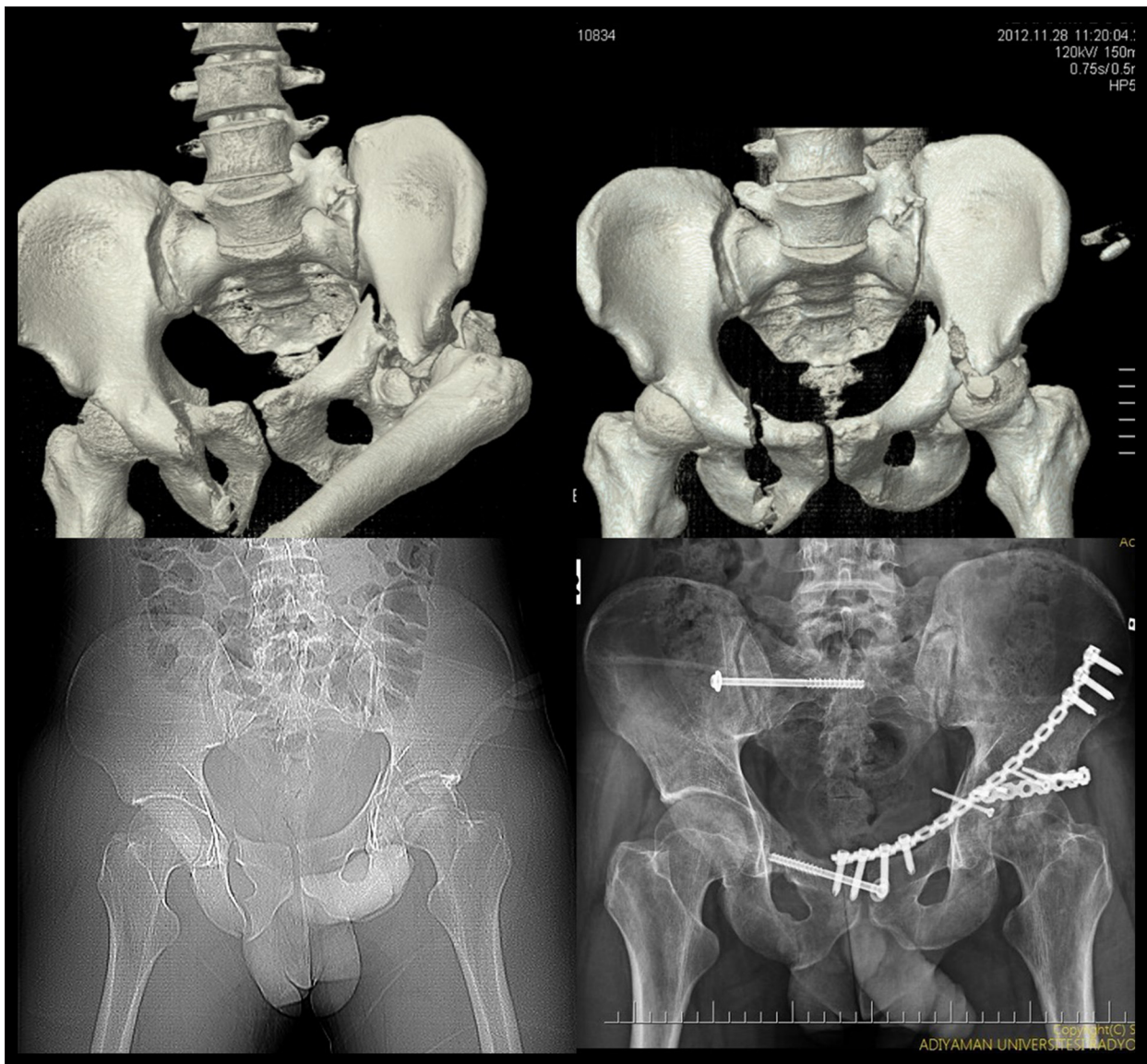
The clinical outcome for each patient was evaluated using the modified Merle d'Aubigné-Postel (DAP) hip score and the Postel clinical grading system [5,15,18]. HO was evaluated according to the Brooker classification [19]. The Brooker III and IV HO classifications, with a decrease of  $>20\%$  in the range of motion (ROM) of the hip, were considered to be significant.

Statistical analysis was carried out by using the Statistical Package for the Social Sciences (SPSS) software version 16.0 (SPSS Inc., Chicago, IL, USA). A 95% confidence interval (CI) and a p-value  $<0.05$  were considered to be statistically significant.



**Figure 1.** All patients in the study had plain pelvic X-radiographs and three-dimensional (3-D) reconstruction computed tomography (CT) scans before surgery. **(A)** Pre-operative evaluation and definition of acetabular fracture. **(B)** Three-dimensional (3-D) reconstructed computerized tomography (CT) images of the acetabular fracture.





**Figure 2.** Radiological appearance of the patients who underwent surgery in the pre-course group.

All numerical data were represented as median, minimum, and maximum values. Analysis of variance (ANOVA) was used to test differences between two or more means.

## Results

Table 1 shows the pre-operative demographic characteristics of the 35 patients included in the study. Patients were divided retrospectively into three groups: surgery performed before the training course; surgery performed within the first two years after the course; and surgery performed two years after the course, to evaluate the role of training and surgical experience on patient outcome. Three (8.6%) patients underwent acetabular fracture surgery through an ilio-inguinal approach, 21 (60%)

of patients underwent surgery through a Kocher-Langenbeck approach, five (14.3%) patients had surgery through a modified Stoppa approach, and six (17.1%) patients underwent surgery through a combined approach (Table 2). The mechanism of hip joint injury were motor-vehicle accidents in 30 (85.7%), fall from a height in one (2.9%), and motorcycle accidents in four patients (11.4%) with high-energy trauma.

Table 3 shows the findings according to the fracture type, the difference between the quality of reduction of the fracture, the amount of the postoperative shift of the hip joint center (HJC), and the modified Merle d'Aubigné-Postel (DAP) hip score and the Postel clinical grading system. The anatomical reduction was seen more frequently following the training course, than pre-course. Both post-course groups had statistically better



**Figure 3.** Radiological appearance of patient who underwent surgery in the first two years after the training course.

functional outcomes compared with the pre-course group ( $p < 0.001$ ), but there was no statistically significant difference in the first two years after the training course, compared with the second two years after the course groups ( $p > 0.05$ ).

There were no statistically significant differences between the pre-course and post-course groups in the amount of vertical shift of the HJC ( $p > 0.05$ ). However, there was a statistically significant difference in the second two years after the course compared with the first two years after the course in terms of the vertical shift of the HJC ( $p = 0.017$ ). There was a statistically significant difference in the amount of horizontal shift of the HJC in the second two years post-course group compared with the pre-course and first two years post-course groups ( $p = 0.011$  and  $p = 0.005$ , respectively). However, there was no difference between the pre-course and first two years post-course groups ( $p > 0.05$ ).

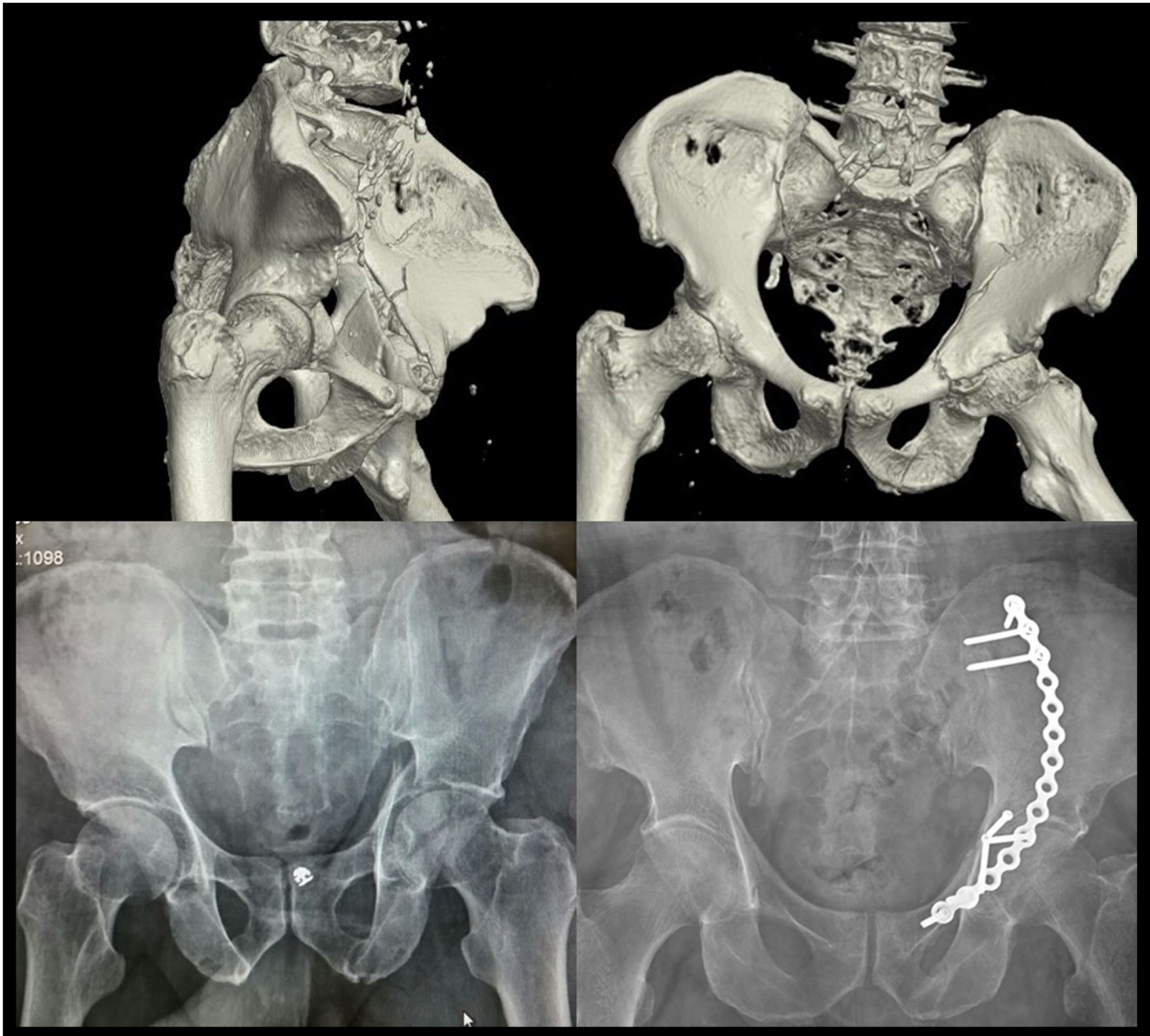
Table 4 shows the comparisons between the groups studied. There was a statistically significant difference between the

groups in terms of the mean duration of surgery ( $p = 0.007$ ). The mean duration of surgery in the second two years after the training course were statistically significant decreased compared to pre-course ( $p = 0.005$ ). Depending on the learning curve, the mean duration of surgery decreased from 153 minutes to 82.3 minutes.

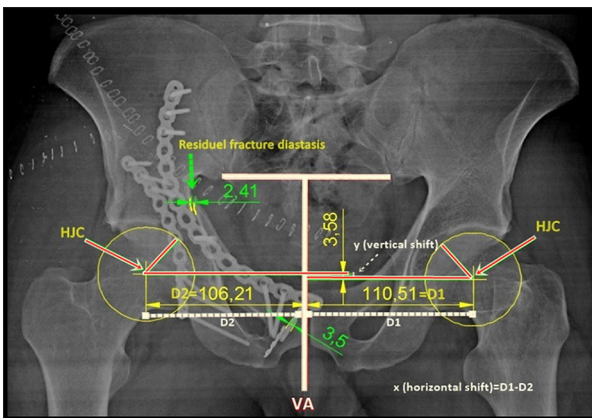
There was a statistically significant difference between groups in terms of surgical approach ( $p < 0.05$ ). Particularly, during the second two years after the training course when compared with other groups, when the modified Stoppa technique began to be frequently used. There was a significant difference between the groups in terms of surgical plate preference ( $p = 0.001$ ); 4.5 mm thick plates were used in pre-course group, and 3.5 mm thick plates were preferred in post-course groups.

In this study, there were no cases of iatrogenic nerve injury postoperatively. Three cases of nerve palsy occurred, which were associated with posterior femoral head injury pre-operatively, but were resolved during the follow-up period. In





**Figure 4.** Radiological appearance of patient who underwent surgery in the second two years after the training course.



**Figure 5.** Radiographic measurement of the shift of hip joint center (HJC) and the quality of the reduction of the acetabular fractures.

5 patients (14.2%) HO developed despite indomethacin prophylaxis; one of the cases was Brooker type I (2.8%), two of the cases were Brooker type II (5.7%) and two were Brooker type III (5.7%). One patient with acetabular protrusion had avascular necrosis (AVN) of the femoral head, and total hip arthroplasty (THA) was performed five months after acetabular surgery. Two patients (2.8%) who developed wound infection during follow up were treated with intravenous antibiotics (imipenem and cilastatin sodium) for infection with for *Pseudomonas aeruginosa*. There was no iatrogenic vascular injury or clinically evident deep venous thrombosis in the patients in the study groups.

**Table 1.** Demographic characteristics of the patients before surgery.

		Pre-course	First 2 years after course	Second 2 years after course	Total
Number of the patients	n (%)	5 (14.3)	19 (54.3)	11 (31.4)	35 (100)
Age	mean (range)	45 (22–56)	43 (15–71)	39 (16–70)	42 (15–71)
Sex (Male)	n (%)	5 (14.3)	17 (48.6)	8 (22.8)	30 (85.7)
Affected hip (Right)	n (%)	3 (8.6)	12 (34.3)	4 (11.4)	19 (54.3)
The mechanism of injury					
Motor-vehicle accidents	n (%)	5 (14.3)	15 (42.8)	10 (28.6)	30 (85.7)
Motorcycle accidents	n (%)	–	4 (11.4)	–	4 (11.4)
Fall from high	n (%)	–	–	1 (2.9)	1 (2.9)
Fracture type					
Elementary	n (%)	2 (5.7)	14 (40)	6 (17.1)	22 (62.8)
Associated	n (%)	3 (8.6)	5 (14.3)	5 (14.3)	13 (37.2)
Fragmentation of the articular surface	n (%)	2 (5.7)	6 (17.1)	5 (14.3)	13 (37.1)
Displacement of the quadrilateral plate	n (%)	–	5 (14.3)	4 (11.4)	9 (25.7)
Posterior femoral head dislocation	n (%)	2 (5.7)	7 (20)	3 (8.6)	12 (34.3)
Acetabular protrusion	n (%)	1 (2.8)	–	1 (2.8)	2 (5.7)
Nerve injury	n (%)	–	2 (5.7) <sup>a</sup>	1 (2.8) <sup>b</sup>	3 (8.6)
Accompanying injuries	n (%)	3 (8.6) <sup>c</sup>	9 (25.7) <sup>x</sup>	1 (2.8) <sup>y</sup>	13 (37.2)

<sup>a</sup> Sciatic nerve palsy; <sup>b</sup> sciatic neuropathy, <sup>c</sup> contralateral sacroiliac joint (SIJ) separation and os pubis frc; ipsilateral SIJ separation; bladder rupture and symphysis pubis separation; <sup>x</sup> epidural hematoma/left distal radius frc; contralateral os pubis frc; ipsilateral SIJ and symphysis pubis separation; cerebral contusion and right femur shaft frc/kontralateral femur shaft frc/ipsilateral femur intertrochanteric frc; kontralateral os pubis frc/cerebral contusion, <sup>y</sup> bilateral humerus frc, calcaneus frc and pulmonary contusion

## Discussion

The goals of surgical treatment of acetabular fractures are to achieve a stable, functional, and painless hip with full anatomic configuration while avoiding surgical complications [5,13,20]. Surgical experience is necessary to avoid complications and to achieve anatomical reduction [7]. El-khadrawe et al. [7] reported that relatively low anatomical reduction rates (32.7%) might be related to a long learning curve in complex acetabular fractures, and suggested that reducing the amount of displacement in multi-fragmentary acetabular fractures to <1 mm was a difficult surgical procedure with a steep learning curve.

Meena et al. [9] reported on the main factors that significantly affected the clinical outcome of acetabular fracture surgery. The first group of factors determining clinical outcome were related to surgery and included timing of the surgery and success of the reduction; the second factor was trauma; patient-related factors associated with outcome included dislocation,

displacement of the fracture, and additional musculoskeletal injuries [9].

Mardani-Kivi et al. divided patients with acetabular fracture treated with surgery into two groups according to the experience of the surgeon, with training periods representing a learning curve of the first two years and the second two years [10]. As the duration of surgical experience decreased, the surgical outcome, as determined by clinical and radiological results, depended on the learning curve, and surgical experience played an important role in the reduction of surgical complications.

Gupta et al. reported that outcomes significantly improved in follow-up surgery depending on the learning curve [21]. Kinet et al. compared the results from the first year with the results from the following two years and noted an anatomic reduction rate of 66% compared with 75% [22]. This previous study reported poor surgical reductions in most of the fractures in both cohorts and attributed this to surgery performed by the

**Table 2.** Fracture type and surgical approach.

Fracture type	n (%)	Surgical approach (n)				
		I&I	K-L	S	K-L+I&I	K-L+S
<b>Elementary (n=22)</b>						
Anterior wall (AW)	–	–	–	–	–	–
Anterior column (AC)	5 (14.3)	2	–	3	–	–
Posterior wall (PW)	15 (42.8)	–	15	–	–	–
Posterior column (PC)	–	–	–	–	–	–
Transverse (TR)	2 (5.7)	1	1	–	–	–
<b>Associated (n=13)</b>						
Posterior column+ wall (PC+D)	1 (2.9)	–	1	–	–	–
Transverse+posterior wall (TR+PW)	5 (14.3)	–	3	–	1	1
T-type (T-t)	1 (2.9)	–	–	–	–	1
Anterior wall/column+posterior Hemitransverse (AW/C+PH)	5 (14.3)	–	1	2	2	–
Both column	1 (2.9)	–	–	–	1	–
<b>Comparison of surgical approach</b>						
Pre-course	5 (14.3)	1	2	1	1	–
<b>Post-course</b>						
First 2 years	19 (54.3)	2	15	–	2	–
Second 2 years	11 (31.4)	–	4	4	–	3
<b>Total</b>	<b>35 (100)</b>	<b>3 (8.6)</b>	<b>21 (60)</b>	<b>5 (14.3)</b>	<b>4 (11.4)</b>	<b>2 (5.7)</b>

I&I – ilioinguinal; K-L – Kocher-Langenback; S – modified stoppa; K-L+I&I – combined ilioinguinal and Kocher-Langenback; K-L+S – Kocher-Langenback and modified stoppa.

**Table 3.** Evaluation of radiological and functional outcomes.

The modified Postel-d'Aubigne clinical score n (%)				Matta score according to the quality of the reduction n (%)				The vertical (V) and horizontal (H) shifts of the HJC mean (mm)		
Results	Pre-course	Post-course		Results	Pre-course	Post-course		Pre-course (V/H)	Post-course (V/H)	
		First 2 years	Second 2 years			First 2 years	Second 2 years		First 2 years	Second 2 years
Excellent	–	9 (47.4)	9 (81.8)	Anatomical	1 (20)	14 (73.7)	10 (90.9)	3.4/3.7	3.1/3.1	0.9/0.6
Good	2 (40)	7 (36.8)	2 (18.2)	Imperfect	1 (20)	4 (21.1)	1 (9.1)			
Fair	2 (20)	2 (10.5)	–	Poor	3 (60)	1 (5.2)	–			
Poor	1 (40)	1 (5.3)	–							
<b>Total</b>	<b>18 (51.4)</b>	<b>Excellent, 11 (31.4)</b> <b>Good, 3 (8.6)</b>	<b>Fair, 3 (8.7)</b> <b>Poor</b>	<b>25 (71.4)</b>	<b>Anatomical, 6 (17.1)</b> <b>Imperfect, 4 (11.4)</b>	<b>Poor</b>			<b>2.4/2.4 (V/H)</b>	



**Table 4.** Comparison of the pre-course and post-course outcomes in this study.

		Pre-course	Post-course		Total
			First 2 years	Second 2 years	
Number of patients	n	5	19	11	35
Operation duration (min.)					
Kocher-Langenback		117.5 (105–130)	93.57 (60–125)	67.5 (65–70)	
Ilioinguinal	Mean (range)	190	125 (115–135)	–	106 (50–130)
Modified Stoppa		100	–	67.5 (50–90)	
Combined		240	190 (170–210)	125 (120–130)	
Total		153 (100–240)	107 (60–210)	82.3 (50–130)	
Timing of surgery (day)	Mean (range)	6 (5–8)	8 (3–50)	7 (4–18)	8 (3–50)
Follow-up period (month)	Mean (range)	44 (40–51)	28 (19–37)	14 (4–14)	24 (4–51)
Postoperative complications					
AVN		1 (2.8)		–	1 (2.8)
HO	n (%)	–	4 (11.4)	1 (2.8)	5 (14.2)
Failure of the implant		1 (2.8)	–	–	1 (2.8)
Wound infection		–	1 (2.8)	1 (2.8)	2 (5.7)

surgeon during first two years of the learning curve [22]. In the findings of the present study, improved radiological and functional results depended on the learning curve, and improved following education by senior surgeons during practical courses. Also, both clinical and radiological outcomes improved with increased experience and the learning curve in the second two-year period following the training course (Table 4).

The appropriate surgical approach is important in acetabular fracture treatment to avoid complications and achieve successful joint reduction [20,23]. The approach to complex acetabular fractures requires a graded learning curve, with surgical decisions and clinical outcomes improving during the increasing duration of the learning curve and improving with increased experience [20].

Planning of the treatment for acetabular fracture and choice of surgical approach frequently depends on the pattern of displacement and the type of the fracture [13,24,25]. Computed tomographic (CT) evaluations help inexperienced surgeons to make correct classifications [20,24]. Kinok et al. have highlighted that the correct definition of the fracture type, appropriate surgical selection, understanding acetabular anatomy, good fracture reduction, and surgical experience were important for good long-term outcomes in the surgical treatment of

the displaced acetabulum [25]. From the findings of this study, we also believe that the correct definition of the fracture type is very important for treatment planning in acetabulum fracture because fracture type may be complex, misdiagnosed, and an incorrect surgical approach may lead to difficulties in achieving adequate reduction during surgery. In our surgical practice, we have started to use the modified Stoppa technique as an anterior approach in the second two years following the training course due to the recognized learning curve and the known requirement for increased surgical experience. We believe that this anterior approach is better than the ilio-inguinal method, both regarding fracture reduction and fracture fixation.

The operation time in hip surgery becomes shorter with experience [26]. In our study, the mean duration of surgery was 153 minutes before the training course and 82.3 minutes after the training course. Depending on the learning curve, the mean duration of surgery in second two years after the training course were significantly decreased compared with the duration of surgery performed pre-course.

In previously reported studies, both radiological and functional outcomes and complication rates differ depending on the intervention performed during acetabular surgery (Table 5) [5,7,9–11,16,20–23,25–35]. Surgical experience leads to lower

**Table 5.** Comparison of the published studies with current study.

Studies	Fracture Type (n)		Surgical approach (n)	Timing of surgery (day)	Operation duration (min)	Quality of the reduction (Matta) (%)			Wound infection (n)	AVN (n)	Osteo-arthritis (n)	HO (n)	Iatrogenic nerve injury (%)	Vascular injury (n)	Functional results (Excellent-good) (%)
	Elementary	Associated				Anatomic	Imperfect	Poor							
Current study	22	13	3 I&I + 21 K-L + 5 S + 6 C	8	106	71.4	17.1	11.4	2	1	–	5	–	–	82.8
Li [5]	57		57 K-L	7.2	60	79	17.5	3.5		2	–	6	–	–	93
El-khadrawe [7]	4	51	30 I&I + 15 K-L + 10 C	6	?	32.7	29.1	38.2	1	–	14	2	14	1	69.1
Meena [9]	54	64	9 I&I + 70 K-L + 33 IF + 6 C	?	?	67.1	16.9	16.1	7	14	34	10	3	–	66.95
Mardini-Kivi [10]	50	54	?	5.55	82.92	74	23.1	2.9	3	27	–	24	10	–	86.42
Elmadag [11]	28	8	19 I&I + 17 S	3.7	?	58.3	33.3	8.3	4	–	–		3	–	88.8
Bhat [16]	39	11	50 (I&I + K-L + IF)	?	160.25	70	20	10	4		18		2	–	70
Arazi [20]	6	14	?	<21	?	40	40	20	1		3	1	2	–	80
Gupta [21]	15	48	14 I&I + 30 K-L + 2 IF + 6T + 11 C	?	210.7	76.2		23.8	5	2	–	5	2	–	76.4
Kinik [22]		25	25 T	?	280	68	8	24	2	2	2	4	–	–	80
Hammad [23]	10	44	33 I&I + 21 (S+IW)	8.85	201.2	46.3	3.7	50	1	–	–		2	2	62.5
Kinik25	15	24	2 I&I + 18 K-L + 2 IF + 12 T	9	240	64.1	23	12.8	3	3	6	9	–	–	76.9
Shazar [26]	78	147	122 I&I + 103 S [35 S + 57 (S+IW) + 11 (S+IF)]	?	262.4	75.1	22.6	2.2	17	–	–	2	9	3	?
Elmali [27]	10	11	12 K-L + 4 IF + 5 T	4.8	?	76.2	14.3	9.5	3	2	4	3	–	–	71.4
Sarlak [28]	23	15	38 S	?	150	74	21	5	2	–	–		–	–	74
Ma [29]	12	38	30 I&I + 30 S	?	219.5	48.3	36.7	15	2		10	4	2	5	76.5
Rocca [30]	22	54	42 I&I +, 34 (S+IW)	?	?	55.3	36.8	7.9		1	–	1	2	–	52.63
Borg [31]	40	61	59 I&I + 40 K-L + 1S + 1 IF	6.2	?	76		24	4	6	15	5	–	–	77
Alexa [32]	23	19	42 K-L	6	?	59.5	26.2	14.3	1	2	2	7	3	1	84.2
Isaacson [33]	6	30	10 S + 23 (S+IW) + 3 (S+K-L)	4.5	320.2	75	17	8	3		19		1	–	63
Matta [34]	33	86	119 I&I	8	222	74	16	10		–	2		2	–	84
Aşık [35]	163	77	216 (I&I + K-L + IF + T) + 24 C	9	186	70	20	7	10	9	31	52	10	–	80

I&I – ilioinguinal; K-L – Kocher-Langenback; S – modified stoppa or anterior intrapelvic; T – triradiate; IF – iliofemoral; IW – iliac window; C – combined (anterior and posterior approaches).

complication rates and a higher chance of excellent reduction [10,36]. Suzuki et al. reported that adequate pre-operative imaging, correct surgical planning, appropriate surgical approach and treatment duration, good quality intraoperative fluoroscopic imaging and a good understanding of pelvic and acetabular anatomy were necessary to achieve safe surgical management, and satisfying outcome, and to prevent potentially fatal complications [36]. In our study, significant improvements were observed in both functional and radiological results due to surgical experience and having taken the training course. The increase in experience helped us to decide how to manage the acetabular fractures better. As a result, the findings of this study compared favorably with those of previous studies, regarding clinical outcome and postoperative complications.

The hip joint center (HJC) is the center of hip rotation, and malposition of the HJC causes poor balance and impairs walking [17,37]. Shi et al. reported that there was a significant relationship between HJC restoration and reduction quality [17]. This previously reported study showed a correlation between the horizontal shift and fracture type and reported that the loading changes in the hip require evaluation with advanced biomechanical studies [17]. Delp et al. reported that a 2 cm proximal shift in HJC caused a 27% decrease in flexion power and a 44% decrease in abduction power; a 2 cm medial shift caused a 26% decrease in adduction power [37]. In our study, HJC shift values were similar to those reported by Shi et al. in a previous study, but there was no relation between vertical and horizontal shift values of the HJC and reduction quality, fracture type, and clinical outcomes in both groups [17]. We believe that even if all measurements are calibrated with computer analysis, millimetric postural disturbances in seemingly normal anteroposterior pelvic X-rays may lead to serious

measurement errors. Therefore, an acceptable standard deviation range should be determined.

Although there were problems related to the measurement of the vertical and horizontal shift value, the HJC in our study was lower than the 2 cm scale reported in the study of Delp et al. [37]. Therefore, the potential contribution to muscle instability and walking changes are likely to be insignificant. However, future computer modeling studies or experimental studies should be performed to provide evidence for this hypothesis. Limitations of this study included the retrospective study design, the small study size, and the short duration of the postoperative follow-up. However, this study was conducted at a single center, with all cases operated by the same surgeon, and all analysis was performed by the same surgeon. This study was one of the first to evaluate the effects of an applied training course for the learning curve of surgical treatment of acetabular fracture before and after a training course.

## Conclusions

The contribution of a national and international surgical treatment management and practice course for acetabular fracture treatment has important implications for the improvement of the diagnosis, planning, selection of appropriate surgical approach, improvement of the clinical outcome of surgical reduction-fixation methods, and the reduction of postoperative complications as experience increases, depending on the surgical learning curve.

## Conflicts of Interest

None.

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