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ORIGINAL ARTICLE

Could temporary external fixation after reduction of displaced acetabular fractures prevent posttraumatic heterotopic ossification?

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Abstract

OBJECTIVES: To recommend appropriate immobilization after the initial reduction of acetabular displaced fractures in order to minimize the risk of heterotopic ossification formation.
DESIGN: Retrospective study of patients treated in our surgical department during the years 2005-2018.
MATERIALS AND METHODS: There were 94 patients included in statistical analysis. The factors of injury severity, course of surgery and hospitalization and incidence of complications were recorded. The functional and X-ray results were evaluated at least one year after surgery.
RESULTS: The patients were divided into the two groups according to the type of fixation after closed reduction, the external fixation (EF) and the skeletal traction (ST) group. According to the type of fracture there were 33 patients with central displacement and 61 patients with posterior displacement. Ossification grade III. And IV. Occur in 20% of our sample. There was greater incidence of Brooker grade III. And IV. Ossification in the ST group, but statistically insignificant, $p = 0.57$. There was no statistically significant difference in the occurrence of ossifications regarding the severity of the head injury, $p = 0.11$, or to the severity of the injury $p = 0.54$. The combination of posterior displacement and ST results in higher risk for ossifications, specifically in our group at 11.48% compared to the combination of posterior displacement and EF where it is 8.2%.
CONCLUSION: Skeletal traction for posterior displaced acetabular fracture appears to be a more risky procedure for the development of ossifications than external fixation.

Abbreviations:

AIS	- Abbreviated injury score
AO	- Arbeitsgemeinschaft für Osteosynthesefragen
EF	- External fixation
HO	- heterotopic ossification
L / TE	- Levin and Thompson – Epstein classification
ISS	- Injury severity score
NSAID	- non-steroidal anti-inflammatory drugs
ORIF	- open reduction and internal fixation (in our study means plate osteosynthesis)
PAO	- para-articular ossification
ST	- Skeletal traction
XRT	- X-ray therapy

INTRODUCTION

Displaced fractures of the acetabulum occur most often as a result of traffic accidents and falls. They are caused by indirect force through the head of the femur. Dorsal displacement is the most common, the typical mechanism of this injury is the impact of the bent knee in the traffic accident - dashboard injury. Central displacement is caused by a fall or impact from the side. Anterior displacement combined with an acetabular fracture is rare (Melhem *et al.* 2020). Heterotopic ossification is a frequent complication of displaced acetabular fractures. It is formed para-articular around the acetabulum and around the greater trochanter of the femur. Depending on the size they limit mobility in the hip joint up to ankylosis, resulting in pain, and sometimes leading to neurovascular oppression (Pavelka & Houcek, 2009; Firoozabadi *et al.* 2017). The cause of the para-articular ossification formation is not clear, a multifactorial effect is assumed. The main risk factors are insufficient stability or failure of osteosynthesis, an extensive operative approach and severe head injury (Edwards *et al.* 2016). In order to prevent heterotopic ossification, the earliest possible reduction of the displaced femur head and fixation of the limb, indomethacin and X-ray irradiation are recommended (Behery *et al.* 2018; Slawson *et al.* 1989; Eisenstein *et al.* 2018).

Objective of the study: The aim of the study is to recommend appropriate immobilization after the initial reduction of acetabular displaced fractures to minimize the risk of heterotopic ossification formation.

Working hypothesis: Groups of patients treated with external fixation (EF) will have less formation of para-articular ossifications than the group with skeletal traction (ST).

MATERIAL AND METHOD

In the surgical department of our University Hospital and Level I Trauma Center for a region of one million inhabitants, we performed a retrospective study of patients treated during the years 2005-2018.

<u>Selection criteria</u>

The study included patients with dorsal or central displacement of the femoral head requiring acute closed reduction and subsequent skeletal traction (ST) or external fixation (EF). As a displaced fracture of the acetabulum we included fractures complicated by displacement of the femoral head dorsally or centrally. By central luxation, we meant when the acetabular fragments are displaced at least 10 mm medially. We did not treat anterior dislocation combined with an acetabular fracture during this period. A follow-up of at least 1 year (365 days from the injury) was also a criterium for this study.

Fig. 1. Patient 1 – unilateral external fixator for displaced acetabular fracture, after close reduction. The construction is reinforced by contralaterally supraacetabular Schanz screw.

Course of treatment

Upon admission, standard X-ray images of the pelvis were taken, followed by a CT scan if necessary before reduction. After the closed reduction of the displaced hip joint, as a part of the primary treatment, immobilization of the limb was necessary. Temporary immobilization was performed, in our workplace, either by ST or EF before the definitive reduction and fixations of the fracture by internal osteosynthesis. Depending on the type of the fracture, external fixation was applied unilaterally or as a cross-over (Fig. 1–5). The choice between ST or EF was determined by the decision of the attending trauma surgeon based on the type of fracture and the stability of the hip joint after acute reduction. The decision was also affected by the workload of the service due to other injuries requiring acute surgical treatment. After successful primary reduction and proper immobilization, a CT scan with 3D reconstruction was performed. Internal osteosynthesis was performed within a week of the injury. These operations were always performed by one of the three surgeons who were experienced in this type of surgery. We used standard operating approaches. Kocher-Langenbeck for the posterior wall and pillar of the acetabulum. For the anterior pillar and ceiling of the acetabulum, we used the Stoppa approach combined with a lateral window in the area of the iliac spine, where it was the proximal part of the ilioinguinal approach (Cutrera *et al.* 2015). We particularly used the combined ilioinguinal and Smith-Petersen approach (Jang *et al.* 2019; Luo *et al.* 2021). After the operation we did an X-ray and if it was necessary also a CT scan with 3D reconstruction. Subsequently, X-rays and possibly CT scans were performed every 4-6 weeks until the fracture healed and the patient was fully mobilized. Patients who were included in our study, were followed-up at least one year after surgery to record the development of arthrosis of the hip joint, necrosis of the femoral head and the

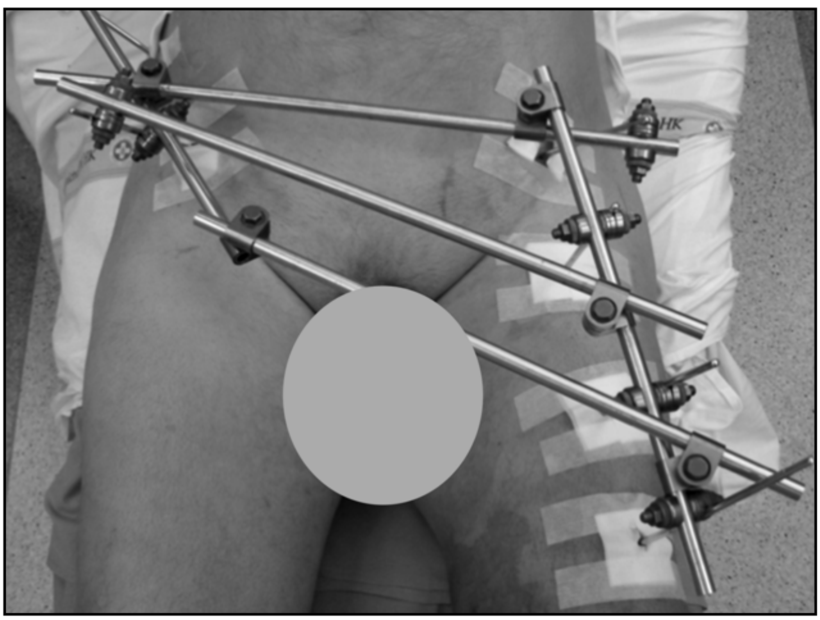

Fig. 2. Patient 2 – crossover external fixator for unstable comminuted acetabular fracture, after close reduction.

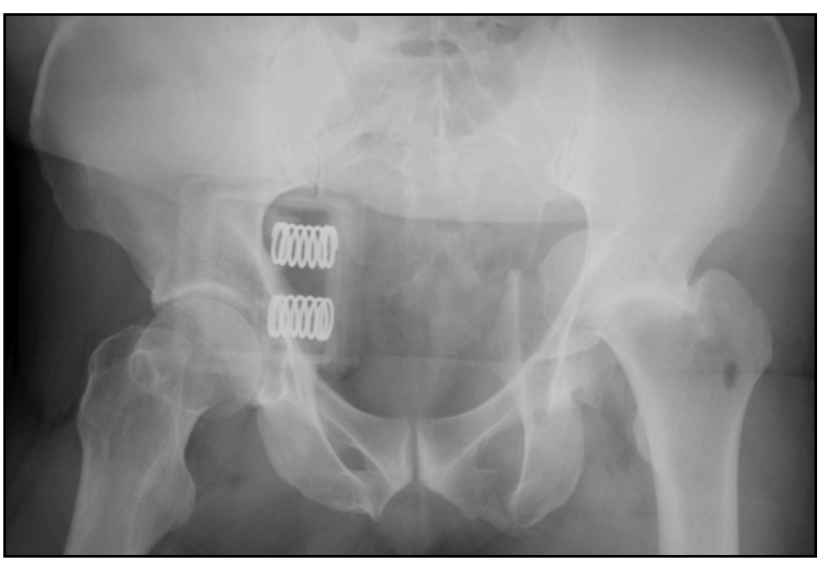

Fig. 3. Patient 2 – X ray after admission.

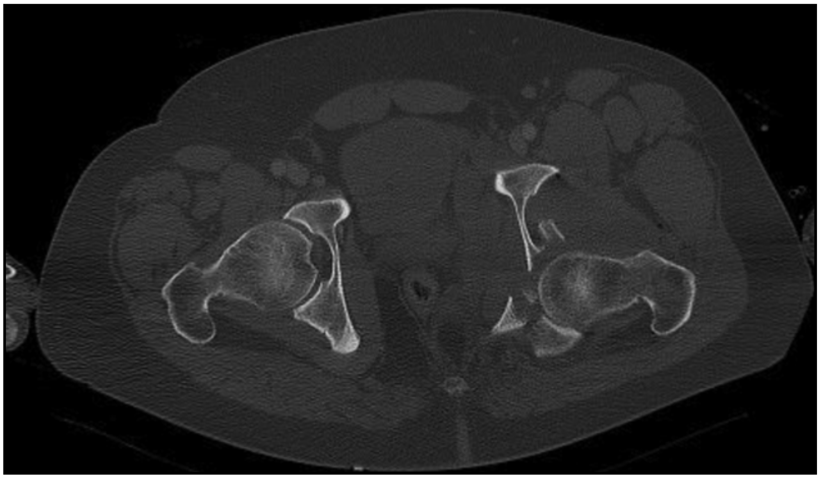

Fig. 4. Patient 2 – CT scan after admission.

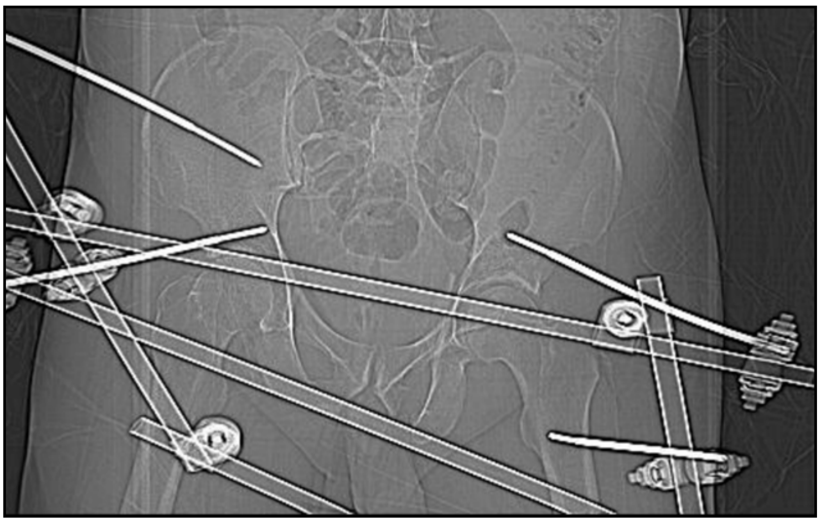

Fig. 5. Patient 2 – X ray after close reduction and crossover external fixations.

development of para-articular ossifications. The X-ray documentation was evaluated for the presence of ossification according to Brooker's classification (Hug *et al.* 2015).

During the primary treatment of displaced acetabular fractures, we did not used indomethacin medication or radiological prevention of the para-articular formation. Indomethacin and radiotherapy were only used after the removal of ossifications, to prevent recurrence.

Statistical analysis

We analyzed the differences between groups by irregular Mann-Whitney and Kolmogov-Smirnov tests. The level of significance was set at $p < 0{,}05$. For the evaluation of particular differences we used the Fisher's exact test or χ^2 test.

RESULTS

From January 2005 to December 2018, we treated 351 acetabular injuries of which 142 were displaced fractures. In this period, we treated 10 acetabular luxation fractures per year on average. In addition to acetabular injuries, we treated 817 pelvic ring injuries during these years. See the number of different types of injury in the graph 1 (Fig. 6). There was an increase of patients after 2008 when patients from our region with this injury were centralized to our workplace.

Of 142 patients with displaced acetabular fracture 94 were included in the statistical analysis. 48 patients were withdrawn: 23 for less than one year follow-up, 22 who were subsequently treated in another hospital, 3 patients died because of severe head injury. Two patients could not be included due to the impossibility of performing a closed reposition and they needed definitive acute surgical treatment. These 2 patients healed without complications.

The patients were divided into the two groups according to the type of fixation after closed reduction, the EF group and the ST group. There were 43 patients in EF group and 51 patients in ST group overall. See the number of patients and type of fixation in each year in the graph 2 (Fig 7). Both groups are comparable in basic demographics data (Table 1). The most common cause of injury was a traffic accident, of which the most often was a car accident (Table 2) the distribution in both groups was comparable, $p = 0.34$. In the EF group there were patients with a higher total injury severity score (ISS), p = 0.000085, see Table 7. Severe head injury according to abbreviated injury scale score (AIS 3 + 4) occurred only in the EF group, p = 0.03 (Table 6). According to the type of fracture there were 33 patients with central displacement and 61 patients with posterior displacement. Posterior displacement was combined with femoral head fracture in 7 cases and with another acetabular injury in 16 cases (Table 5). Fractures with dorsal displacement were classified according to Levin and Thompson-Epstein, with a statistically comparable occurrence of injury types, p = 0.53 (Table 3), (Mandell *et al.* 2017). All fractures were classified according to AO (Table 4). Patients with central displacement occurred more in the EF group, on the contrary, patients with posterior dislocation occurred more in the ST group, p = 0.0027 (Table 5). Average time from injury to the open reduction and plate osteosynthesis (ORIF) was 9.89 days in the EF group, 5.14 days in the ST group, p = 0.000832 (Table 8). Follow-up was on average two and a half years comparable in both groups (Table 9).

Table 10 shows the occurrence of ossification according to the type of primary fixation. Grade of ossification was evaluated according to Brooker (Hug *et al.* 2015). There clearly a greater incidence of Brooker grade III. and IV. ossification in the ST group, but statistically insignificant, p = 0.57. Table 11 provides an overview of other complications, the occurrence of which is comparable in both groups.

The motion of hip joint limitation is clearly shown in Table 12, there was no statistically significant difference.

DISCUSSION

Heterotopic ossification of the acetabulum can be predicted based on the total ISS and therefore the energy of the injury, as well as according to the type

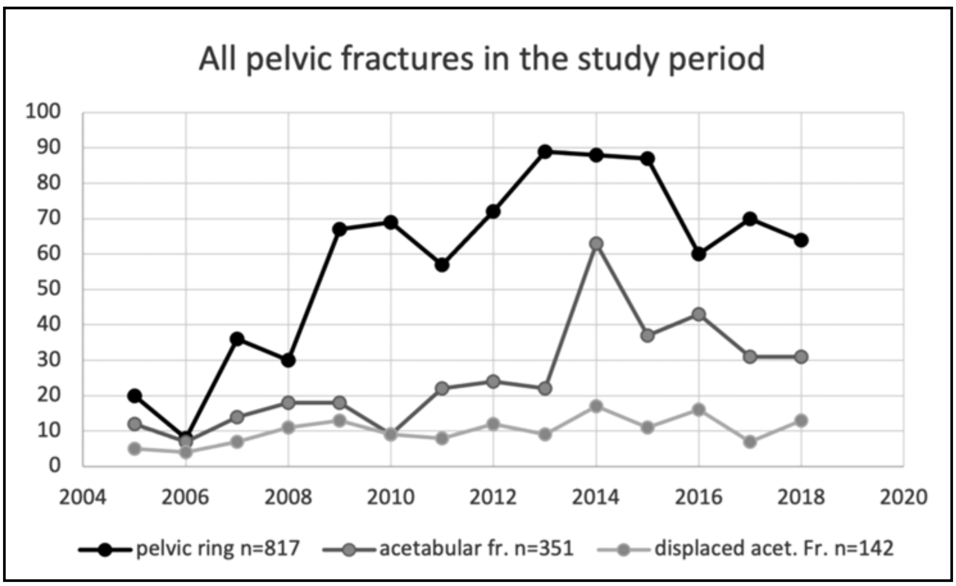

Fig. 6. Graph 1 shows number of all pelvic fractures in the study period.

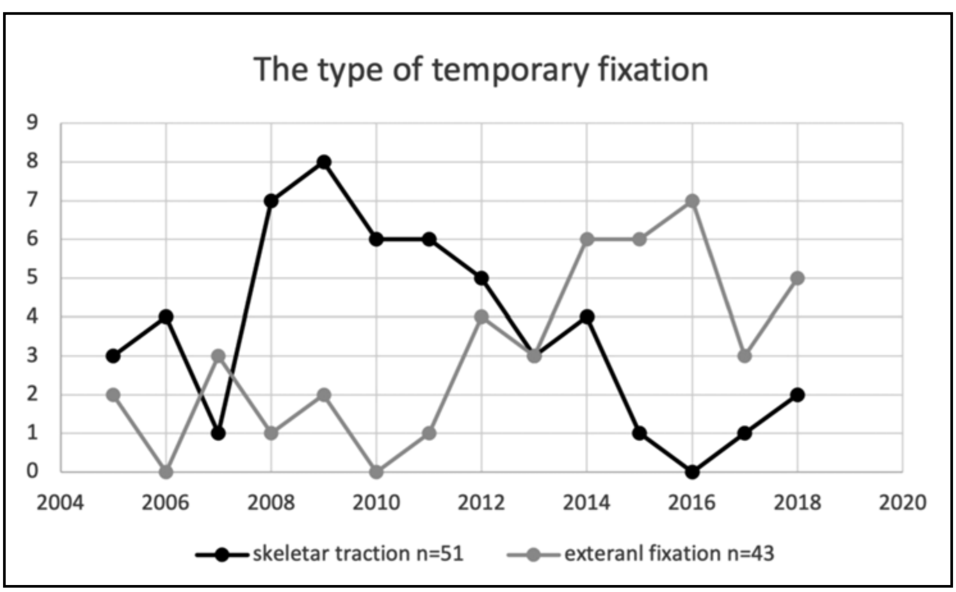

Fig. 7. Graph 2 shows number of temporary fixation type during study period.

Tab. 1. Basic characteristics of groups

Basic characteristics	patients	male	female	age - mean	age -median
EF	43	37	6	47.02	48.87
ST	51	44	7	43.32	42.06

EF-external fixation, ST-skeletal traction

Tab. 2. Mechanism of injury

Mechanism of injury	EF	ST	Total
Car accident	22	35	57
Bicycle accident	1	1	2
Pedestrian hit by car	2	0	2
Motorcycle accident	6	3	9
Falls	11	10	21
Others	1	2	3
Total	43	51	94

EF-external fixation, ST-skeletal traction

Tab. 3. Levin and Thompson – Epstein (L/TE) classification of dorsal displacement

L/TE_klas_	EF	ST	Total
L-4/TE-2	8	12	20
L-4/TE-3	9	17	26
L-4/TE-4	1	7	8
L-5/TE-5	3	4	7
Total	21	40	61

Tab. 4. AO classification of acetabular fractures

AO_class._	EF	ST	Total
31-C1.2	0	2	2
31-C1.3	3	2	5
62-A1.1	1	9	10
62-A1.2	10	17	27
62-A2.3	3	1	4
62-B1.1	2	0	2
62-B1.2	2	1	3
62-B1.3	1	2	3
62-B2.3	0	2	2
62-B3.1	1	0	1
62-C1.1	1	0	1
62-C1.2	1	0	1
62-C1.3	0	1	1
62-C2.2	6	4	10
62-C2.3	2	0	2
62-C3.1	1	1	2
62-C3.2	5	9	14
62-C3.3	4	0	4
Total	43	51	94

Tab. 5. Type of acetabular fracture displacement. Dorsal displaced fractures are divided in tree subgroups

Type of displacement	EF	ST	Total
Central	22 (51.16%)	11 (21.57%)	33 (35.11%)
Dorsal	21 (48.84%)	40 (78.43%)	61 (64.89%)
posterior wall	*12*	*26*	*38*
posterior pillar	*6*	*10*	*16*
Pipkin fracture	*3*	*4*	*7*
Total	43 / 100.00%	51 / 100.00%	94 / 100.00%

EF-external fixation, ST-skeletal traction

Tab. 6. Abbreviated injury scale (AIS) of head

AIS head	EF	ST	Total
0	27	32	59
	62.79%	62.75%	62.77%
1	3	8	11
	6.98%	15.69%	11.70%
2	7	11	18
	16.28%	21.57%	19.15%
3+4	6	0	6
	13.95%	0.00%	6.38%
Total	43	51	94
	100.00%	100.00%	100.00%

EF-external fixation, ST-skeletal traction

of fracture and the corresponding soft tissue damage and fragment displacement. Another known factor is severe head injury (Behery *et al.* 2018; Eisenstein *et al.* 2018; Edwards *et al.* 2016; Firoozabadi *et al.* 2017).

In our work, we would argue that greater stabilization until definitive treatment, logically leads to less secondary traumatization of the soft tissue as one of the factors in the development of HO.

Ossification grade III. and IV. occur in 20% of our sample. If we also included 23 patients who were without problems and were therefore followed for less than one year, the incidence of HO would drop to 16%. Furthermore, in our group we worked only with displaced fractures and not with all acetabular fractures.

Overall, there was no statistically significant difference in the occurrence of ossifications regarding the severity of the head injury, $p = 0.11$, or to the overall severity of the injury (ISS) $p = 0.54$. In a deeper analysis of the possible proportion of head injury to the incidence of HO, it is evident that in the ST group the maximum head injury was AIS 2, and at the same time the incidence of HO Brooker 3 and 4 was higher. On the contrary, in the group with EF there were 6 patients with AIS head (3–4), but with a minimal occurrence of ossification, namely Brooker 0. (1x; 2.3%), Brooker I. (3x; 18.8%), Brooker III. (2x; 14.3%). For the EF group, the relationship between head injury and the incidence of HO was significant, $p = 0.0351$, which was due to the higher incidence of Brooker 3 and 1 in the head AIS 3+4 group. For the ST group, this relationship was insignificant, $p = 0.306$. If we focus on type of injury, a posterior dislocation was associated with HO Brooker III. (13x) and Brooker IV. (1x), but the ST group predominates 9:5 to the EF group. In the case of central dislocation, PAO Brooker III. (2x), Brooker IV. (4x), ST vs EF ratio is 50%. From the above, the combination of posterior displacement and ST results in a higher risk for PAO, specifically in our group at 11.48% compared to the combination of posterior displacement and FE where it was 8.2%.

According to the other complications, sciatic nerve palsy occurred the most frequently, a total of 15 times, which was 10 times associated with posterior displacement. Coxarthrosis and necrosis of the femoral head occurred 6 times, these complications were also more often associated with posterior displacement in a ratio of 10:2 to central dislocation. Pipkin fractures occurred a total of 7 times, of which 5 times in combination with posterior displacement. Only one patient with this fracture had no complications, one was with the sciatic nerve palsy, one with the femoral head necrosis and four with coxarthrosis. It is clear that even for the occurrence of other complications, posterior dislocation is a risk factor.

In our study we discovered a significantly longer ($p = 0.000832$) average time from injury to ORIF in the EF group (9.89 days) in comparison with the ST group (5.14 days). According to mean ISS (20.95) in EF group the patients suffered more serious trauma with multiple injuries in opposite the mean ISS in ST group (11.49) suggested monotrauma only. Timing of ORIF in EF group was affected by structure and severity of associated injuries. Another factor could be greater stability of external fixator construction which allows longer interval to ORIF compared with skeletal traction.

Johnson in his work from 1994 reports up to 59% incidence of HO with up to 26% grade III.-IV. in patients without prophylaxis with indomethacin or radiotherapy. When using indomethacin, the incidence of HO was 43% or 16% of grades III.-IV. He describes a significant occurrence of HO especially with the extended iliofemoral approach (up to 62%), in contrast to the Kocher-Langenbeck approach (only 16%), and this without a statistically significant difference compared to prevention with indomethacin (Johnson *et al.* 1994). Burd disagrees with NSAID prophylaxis as well and concludes that patients with concurrent fractures of the acetabulum and long bones (who receive indomethacin) have a significantly greater risk of nonunion of the fractures of the long bones when compared with those who receive XRT or no prophylaxis (Burd *et al.* 2003).

Also, other authors have published negative opinions according to indomethacin prophylaxis based on insignificant changes of HO rates but they emphasize careful surgical technique, (Edwards *et al.* 2016; Collopy *et al.* 2015; Baschera *et al.* 2015; Griffin *et al.* 2013).

In her 2019 descriptive study, Carolyn Meyers reports that NSAID prophylaxis is associated with a risk of fracture failure, use of X-rays with the possibility of joint capsule scarring, and the possibility of malignancy. She

Tab. 7. Injury severity score (ISS)

ISS	Count	Mean	Median	25th percentile	75th percentile
EF	43	20.95	19	10	29
ST	51	11.49	11	9	14

EF-external fixation, ST-skeletal traction

Tab. 8. Time from injury to osteosynthesis (ORIF) in days

Time to ORIF	Count	Mean	Median	25th percentile	75th percentile
EF	43	9.89	7.55	7.56	12.75
ST	51	5.14	4.89	3.00	6.63

EF-external fixation, ST-skeletal traction

Tab. 9. Time from injury to follow up (FW) in days

Time to FW	Count	Mean	Median	25th percentile	75th percentile
EF	43	901	701	427	1276
ST	51	886	608	389	974

EF-external fixation, ST-skeletal traction

Tab. 10. Incidence of ossifications according to Brooker classification

Brooker class.	EF	ST	Total
0.	22 (23.4%)	27 (28.7%)	48 (51.1%)
I.	9 (9.5%)	7 (7.4%)	16 (17%)
II.	5 (5.3%)	5 (5.3%)	10 (10.6%)
III.	4 (4.3%)	**10 (10.6%)**	14 (14.9%)
IV.	3 (3.2%)	**2 (2.1%)**	5 (5.3%)
Total	43 / 100%	51 / 100%	94 / 100%

EF-external fixation, ST-skeletal traction

Tab. 11. Further complications within ossifications

Complications (within ossifications)	EF	ST	Total
No complications	26	32	55
Sciatic nerve palsy	7	8	15
Other neurological problems	0	4	4
Coxarthrosis	4	2	6
Femur head necrosis	4	2	6
Infection	0	1	1
Others	2	3	5
Total	43	51	94

EF-external fixation, ST-skeletal traction

Tab. 12. Hip joint motion restriction

Range of motion	EF	ST	Total
Full	20	24	44
Small limitation	10	11	21
Medium limitation	9	11	20
Serious limitation	4	5	9
Total	42	51	93

EF-external fixation, ST-skeletal traction

cites polytrauma and an extensive surgical approach as a significant risk factor for HO (Meyers *et al.* 2019).

Personally, I believe in the studies that recommend gentle surgical techniques, an individualized prevention protocol, and emphasize the need for a deeper understanding, and influence of the ossification process at the cellular level (Firoozabadi *et al.* 2017; Barfield *et al.* 2017).

CONCLUSION

Our series shows a tendency in our workplace to apply skeletal traction as temporary fixations (a) to patients with posterior displacement if the hip joint appears stable after primary reduction and (b) to patients without other associated injuries. Nevertheless, it is just skeletal traction for posterior displaced acetabular fracture that appears to be a riskier procedure for the development of HO and other complications.

After the evaluation of the occurrence of HO in the previous period, the increase in favor of external fixation has been taking place over the last ten years (Fig. 7). We also prefer external fixation due to better patient comfort and easier nursing care. Considering the total percentage of occurrence of ossification in our group (49%, of which 20% grade III. and IV.), this study is an indicator for more frequent use of an external fixator (especially for dorsal displaced fractures) and for discussion of an individual protocol of primary HO prevention in corresponding workplace.

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