

Article

Functional Outcome and Survival of the Femoral Head After Traumatic Hip Dislocation

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Abstract

Objective: Traumatic dislocation and fracture–dislocation of the hip are rare and severe injuries often associated with high-energy trauma. Early recognition and rapid, stable reduction are essential for successful treatment; otherwise, this type of injury is associated with poor functional outcomes and high rates of complications such as avascular necrosis. This retrospective study aims to describe and analyze long-term outcomes and survival rates after a hip dislocation. **Methods:** Between 2008 and 2021, all patients with traumatic hip dislocation who were treated in a Level I Trauma Center were retrospectively assessed and analyzed. During the follow-up examination, two experienced surgeons carried out a clinical follow-up examination and evaluated the available X-ray images. Anterior and posterior fracture–dislocations and femoral head fractures were classified according to Stewart and Milford’s and Pipkin’s classification system, respectively. All patients were followed up using the Harris Hip Score (HHS) and Lequesne score. **Results:** Forty-four (38 male and 6 female) patients with a mean age of 46.02 (± 19.48) years were included. The average follow-up period was 45.69 (± 45.69) months. Traffic accidents were the main cause of traumatic dislocation in this series, accounting for 75% of all cases. Associated injuries were noted in 28 cases. Twenty-three and 21 patients were treated with closed and open reduction, respectively. Isolated hip dislocations without bony involvement according to Stewart and Milford type 1 occurred in five cases. Type 3 injuries were most common, followed by type 4 injuries. This study found that the type of reduction and the trauma mechanism are not significant factors in long-term prognosis ($p = 0.463$). Thirteen patients had subjective excellent or good results in the HHS and Lequesne score. Late post-traumatic osteoarthritis of the hip developed in 10 patients (22.7%). Patients received a hip replacement at 20.7 months (1–102) months. Thus, after 2 years, implantation of a hip prosthesis due to post-traumatic coxarthrosis was necessary in 22.7% of all cases. The type of hip dislocation classified according to Stewart and Milford had no significant influence on the implantation of a hip prosthesis. **Conclusions:** Excellent or good results in HHS were obtained in patients with early, stable, and accurate reduction by closed or open methods. After 2 years, 22.7% of the patients needed a total hip replacement.

Keywords: hip dislocation; Pipkin; posttraumatic coxarthrosis



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1. Introduction

Traumatic dislocation of the native hip joint is a rare injury that often occurs in the setting of high-impact trauma [1–5]. In the overall view of all hip dislocations, only 5% are traumatic, whereas most dislocations occur in the context of endoprosthetic joint replacement [1,6]. In the case of a traumatic genesis, a distinction must be made between isolated hip dislocation and dislocation or protrusion due to a concomitant acetabular fracture [5–9]. Isolated hip dislocations without an additional acetabular or femoral fracture are rare and occur in only approximately 25% of cases [7]. The most common trauma mechanism is a traffic accident in which an axial force is applied to the 90 ° flexed hip joint [3,10–12]. In the context of demographic change, acetabular fractures with dislocation or protrusion of the femoral head, particularly into the lesser pelvis, are increasingly occurring because of low-energy trauma, such as a fall from a standing position [6,7,13,14].

In addition to hip dislocations, concomitant injuries often occur as the patient population is frequently polytraumatized [15,16]. These concomitant injuries decisively determine the outcome [7,11,17,18]. In Sahin's study, 10 of 24 patients with multiple injuries had a poor outcome [17]. Hip dislocations are most commonly classified according to Stewart and Milfort's classification system, in addition to Pipkin's classification. Typically, a dorsal dislocation occurs in more than 90% of the cases [7]. In these dislocations, a distinction can be made between a posterior superior (luxatio iliaca) and a posterior inferior (luxatio ischiadica) [7]. In anterior luxation, a distinction is made between the anterior superior (luxatio publica) and anterior inferior (luxatio obturatoria) [7]. The femoral head often collides with the posterior acetabulum, which then leads to a dorsal acetabular fracture [3,9,12,17,19]. Anterior dislocation is present in only 10% of all hip dislocations [20]. Regarding the outcome, a good to very good result is described in 82% of the cases relative to the Harris Hip Score (HHS) [17]. However, in more than 25% of the cases, a complication in post-traumatic coxarthrosis or femoral head necrosis occurs in the long-term course [21]. Furthermore, due to the close positional relationship of the sciatic nerve to the dorsal pillar of the acetabulum, the risk of post-traumatic nerve lesions is high. Therefore, prompt reduction of the hip is essential to prevent possible nerve damage [21]. This procedure can be closed or open surgery depending on the type of injury [10,22]. Another complication of hip dislocations can be femoral head necrosis, which occurs because the misalignment creates increased pressure on the femoral head [7,9,23]. Recent reviews have further emphasized that early diagnosis, prompt reduction, and comprehensive CT-based assessment remain the cornerstones of treatment and are the most important determinants of long-term outcomes following traumatic hip dislocation [24].

One consequence is early post-traumatic coxarthrosis. Particularly, post-traumatic coxarthrosis can be accelerated by the retention of free joint bodies [25]. Because the patients are predominantly young, the complications can mean a relevant reduction in quality of life as well as significant economic burdens on the healthcare system [26].

In the literature, good to very good results for the functional outcome are described for the majority of patients [17,18,27,28]. Poor results are also reported in the literature, particularly after a late reduction of more than 6 h [4,13,23]. However, to date, no data have been collected on the time at which endoprosthetic joint replacement becomes necessary after trauma. This study aims to determine the time interval between trauma and the mean survival time of the affected joint. Although recent studies have improved the understanding of patient-reported outcomes after traumatic hip dislocation, data regarding native hip survival and the timing of conversion to total hip arthroplasty remain limited [8]. Furthermore, long-term results on complications, functional outcome, and quality of life will be collected.

2. Material and Methods

A retrospective cohort study included all patients treated for traumatic hip dislocation at the Department of Orthopedics and Trauma Surgery, University Hospital Bonn, Germany, from 1 January 2008 to 1 January 2021. The study was approved by the Institutional Review Board of the University Hospital Bonn, Germany (No. 406/17), and was conducted following the ethical standards of the 1964 Declaration of Helsinki and its subsequent amendments.

For data collection, an analysis of the institute's clinical workplace system (KAS) and the patient file documented here was performed. Using the ICD code for dislocation of the hip S72.00-S72.08, the corresponding patients were identified.

Inclusion criteria included treatment of a traumatic hip dislocation during the period 1 January 2008–1 January 2021.

Exclusion criteria included dislocation of hip replacements, underaged patients < 18 years, and local metastatic disease.

Data on the accident mechanism, concomitant injuries, and complications during the inpatient stay were collected through a retrospective evaluation of the patient record. In addition, two independent orthopedic surgeons with ten or more years of professional experience in traumatology classified the dislocation based on radiographs at admission according to Stewart and Milford's classification system [29]. For closed reduction, this procedure was performed under intravenous analgesia. In the case of open reduction, the surgical approach was selected according to the accompanying fracture. For dorsal acetabular fracture with posterior hip dislocation, a dorsal Kocher–Langenbeck approach was used. Particularly, in the case of preoperative paralysis, a dorsal approach was used for open exposure and neurolysis of the sciatic nerve.

Furthermore, a retrospective evaluation of the examination findings was performed in the clinical follow-up after 6 weeks and 12 months. All patients underwent a physical examination and were evaluated using the Harris Hip Score (HHS) and Lequesne score [16,30]. Both scores record pain, walking performance, and ability to cope with everyday life relative to a hip injury that has occurred. One hundred points can be achieved in the HHS. A score of 80–100 points indicates a good to excellent result, and a score below 70 is a poor result [16]. The Lequesne score devotes 5, 2, and 4 questions to the pain the patient experiences in everyday life, the patient's walking behavior, and general everyday complaints, respectively. Twenty-four points can be scored, with a high score reflecting a poor result [30].

In addition, plain radiographs were performed. In case of a concomitant fracture of the acetabulum or the proximal femur, an accompanying computed tomography (CT) diagnosis was performed afterwards [31].

For further follow-up, an additional telephone contact was made in 27 of 44 cases to evaluate the long-term outcome. The implantation of a hip prosthesis or the creation of a Girdlestone resection was considered a failure of the hip joint. This was shown in a Kaplan–Meier survival curve.

The data of the patients were statistically analyzed with IBM SPSS Statistics 25 (Ehningen, Deutschland). Mean values, standard deviations, 95% confidence intervals (CI: 95%), medians, and second and third quartiles were calculated. The simple *t*-test was used to compare parametric values (before and after the surgery). The Wilcoxon–Mann–Whitney test was used to evaluate comparisons between two groups of non-parametric values. In addition, Cohen's effect size (*d*) was calculated, with values 0.2, 0.5, and 0.8 denoting small, medium, and great effect, respectively. The correlations were determined according to Pearson, including effect size (effect force, according to Evans). Evaluation of the correlation

coefficient r was graded: <0.2 = poor; $0.2 < r < 0.4$ = weak; $0.4 < r < 0.6$ = moderate; $0.6 < r < 0.8$ = strong; and $r > 0.8$ = optimal. The level of significance was set at $p < 0.05$.

3. Results

3.1. Demographics

In the period under consideration, 44 patients who had a traumatic hip dislocation were identified. Of the affected patients, $n = 38$ (86.4%) were male and $n = 6$ (13.6%) were female. The mean age was $46.02 (\pm 19.48)$ years, and the mean follow-up period was $45.69 (\pm 45.69)$ months. The average inpatient length of stay was 31.02 days (2–132 days). The majority of patients suffered trauma because of a traffic accident as a passenger car driver (34.1%) or motorcycle driver (31.8%).

According to the Stewart and Milford classification, 5 patients had an isolated hip dislocation without bony involvement (Type I), 2 patients had a Type II injury with a small acetabular rim fracture, 22 patients sustained a Type III injury with a large acetabular rim fracture, and 15 patients presented with a Type IV fracture–dislocation associated with a Pipkin fracture. (Figure 1). Among the patients who showed a Pipkin fracture, the majority, comprising 9 patients, suffered a Pipkin type 4 fracture with acetabular involvement. Two and three cases had a Pipkin type 1 and type 2 fracture, respectively, and a Pipkin type 3 fracture did not occur. The accident mechanism did not significantly influence the type of dislocation ($p = 0.21$). The type of hip dislocation did not significantly influence the length of stay or the severity of complications ($p > 0.05$).

A dorsal dislocation occurred in most cases, that is, in 33 patients (75%). Only 3 cases showed an anterior dislocation. In 7 cases, a protrusion into the intrapelvic direction was observed. One patient was urgently transported to an external hospital and then transferred to us. In these cases, the accident mechanism had no significant influence on the direction of dislocation ($p = 0.0662$).

A closed reduction could be performed under analgesia in 22 cases, whereas an open reduction was performed in 21 cases. No data were available in 1 case as this patient had already been reduced in an external hospital and was transferred further for surgical treatment. Whether a closed or open reduction had to be performed had no significant influence on the length of stay ($p = 0.94$).

3.2. Trauma Mechanism

In the course of the accident, 16 patients suffered a mono-injury of the hip joint. Nine patients suffered minor concomitant injuries, such as abrasions, radius fractures, and metacarpal fractures. Nineteen patients (75%) sustained severe to life-threatening concomitant injuries because of the accident, such as rib series fracture with pneumothorax or intracerebral injuries. Of the 19 patients with severe to life-threatening injuries, 17 sustained them in the context of a car or motorcycle accident. One patient was hit by a car, and nine fell from a height of more than 3 m. Therefore, 18 of the 33 patients who were involved in road traffic accidents also suffered life-threatening concomitant injuries. However, the severity of the concomitant injuries did not significantly influence the length of stay ($p = 0.10$).

3.3. Treatment

Ten of the 44 patients suffered a neurogenic injury in the course of the trauma (22.7%). Nine of these 10 cases showed a weakness of the dorsiflexion, and 1 patient complained of dysesthesias in the ipsilateral foot without motor deficit. Patients with closed reduction had, in 8 cases, a neurological deficit; patients with open reduction had, in 2 cases, a neurological deficit ($p < 0.005$). All patients with a neurological deficit showed dorsal hip dislocation.

Surgical therapy was based on concomitant bony injuries. Plate osteosynthesis for acetabular fractures, additional fixation of free bone fragments using polylactide pins, isolated open refixation of free bone fragments using polypins, closed reduction, and open reduction without osteosynthesis were performed in 22, 3, 6, 6, and 2 cases, respectively. In two cases, free bone fragments had to be removed openly.

In one patient, a Girdlestone resection was created in the case of massive destruction. In the presence of a Pipkin fracture, a K-wire fixation was performed for stabilization in 2 cases, and lag screw osteosynthesis with trochanter flip was performed in 3 cases.

3.4. Functional Outcome

Based on the Lequesne score, three patients reported no limitation in activities of daily living. In contrast, 18, 1, 4, and 1 patient(s) experienced moderate, severe, very severe, and extreme limitations, respectively. Follow-up data regarding limitations in activities of daily living were unavailable for 17 patients. Functional assessment revealed a mean Harris Hip Score (HHS) of 86.9 ± 2.935 , with no significant differences between the Stewart and Milford classification groups ($p > 0.05$) (Figure 2). Patients with isolated hip dislocation without concomitant fracture (Stewart and Milford Type I), those with a concomitant large acetabular fracture (Type IV), and those with an associated Pipkin fracture (Type III) achieved mean HHS values of 98, 84, and 85 points, respectively. The lowest functional outcome was observed in patients with a concomitant small acetabular fracture (Stewart and Milford Type II), who achieved a mean HHS of 76 points.

Overall, ten patients (22.7%) underwent total hip arthroplasty (THA) after a mean interval of 20.7 months (range, 1–102 months) following injury (Figure 1). In nine patients, THA was performed because of secondary post-traumatic osteoarthritis, whereas one patient required arthroplasty due to avascular necrosis of the femoral head. Consequently, approximately one quarter of all patients required THA within the first two years after trauma (Figure 3). Consequently, approximately one quarter of all patients required THA within the first two years after trauma. Neither the Stewart and Milford classification ($p = 0.152$) nor the mechanism of injury ($p = 0.93$) had a significant influence on the subsequent need for THA. Kaplan–Meier survival analysis demonstrated an overall hip joint survival rate of 77.3% at the end of the follow-up period (153 months) (Figure 4). The cumulative hip survival declined progressively from 97.7% after 1 month to 93.2% after 5 months, 88.7% after 8 months, 86.4% after 9 months, 84.1% after 20 months, 81.8% after 24 months, and 79.6% after 25 months, reaching 77.3% after 102 months. No further arthroplasties occurred thereafter, and hip joint survival remained stable until the end of follow-up.

With regard to the timing of reduction, 22 patients underwent reduction within the first hour after injury, 19 between 1 and 6 h, two between 6 and 24 h, and one after more than 24 h. Patients treated within the first hour and those reduced between 1 and 6 h demonstrated comparable functional outcomes, with mean HHS values of 85.9 and 89.7, respectively, as well as similar rates of subsequent THA (22.7% vs. 21.1%). Although patients who underwent reduction between 6 and 24 h after injury showed markedly poorer functional outcomes (mean HHS 43) and a higher THA rate (50%), this subgroup consisted of only two patients. No statistically significant association was found between reduction time and the subsequent need for THA ($p = 0.760$). An univariable Cox proportional hazards regression analysis demonstrated no significant association between the reduction time and the risk of subsequent total hip arthroplasty (hazard ratio 1.20, 95% CI 0.38–3.83, $p = 0.759$).

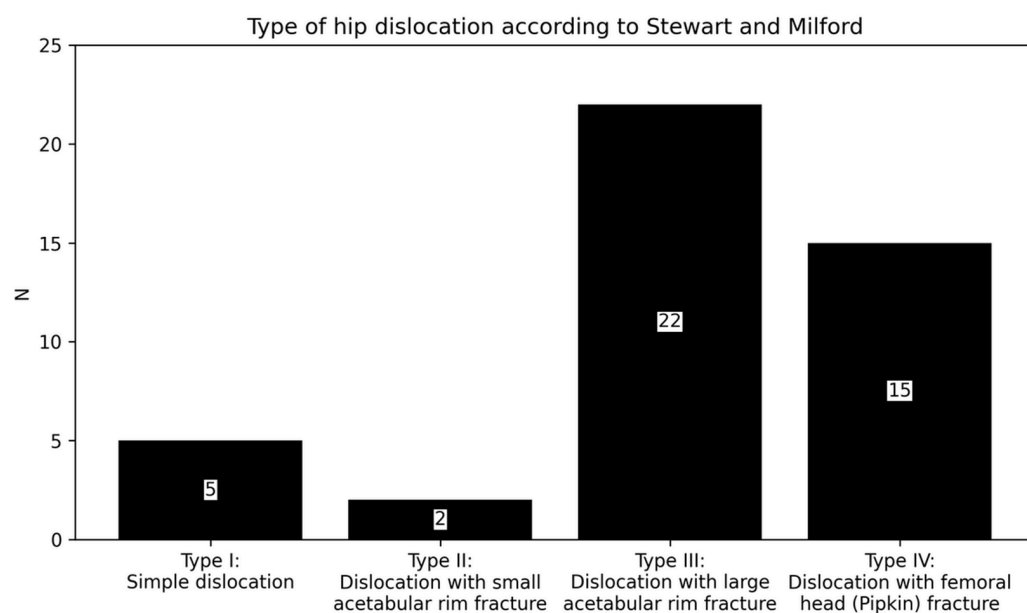


Figure 1. Classification of hip dislocation according to Stewart and Milford. The majority of hip dislocations are concomitant with an acetabular or Pipkin fracture.

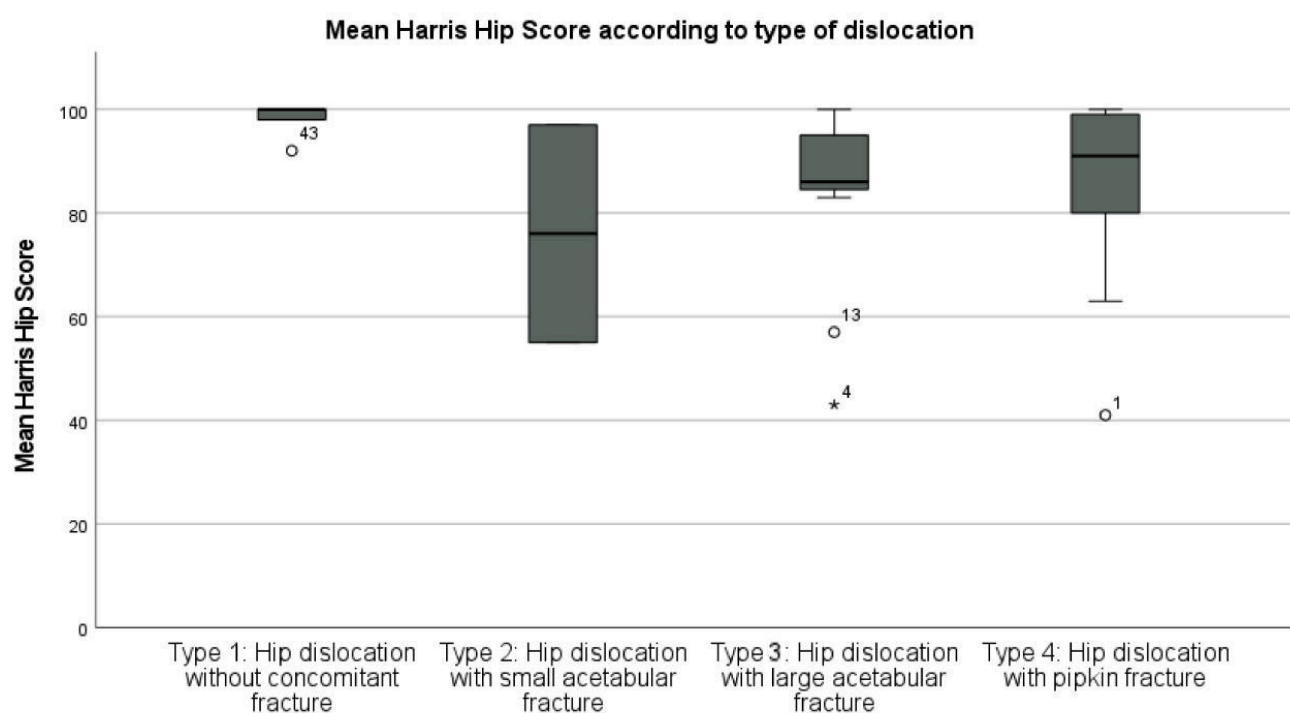


Figure 2. The box plot results of the Harris Hip Score in relation to the type of dislocation according to Stewart and Milford.

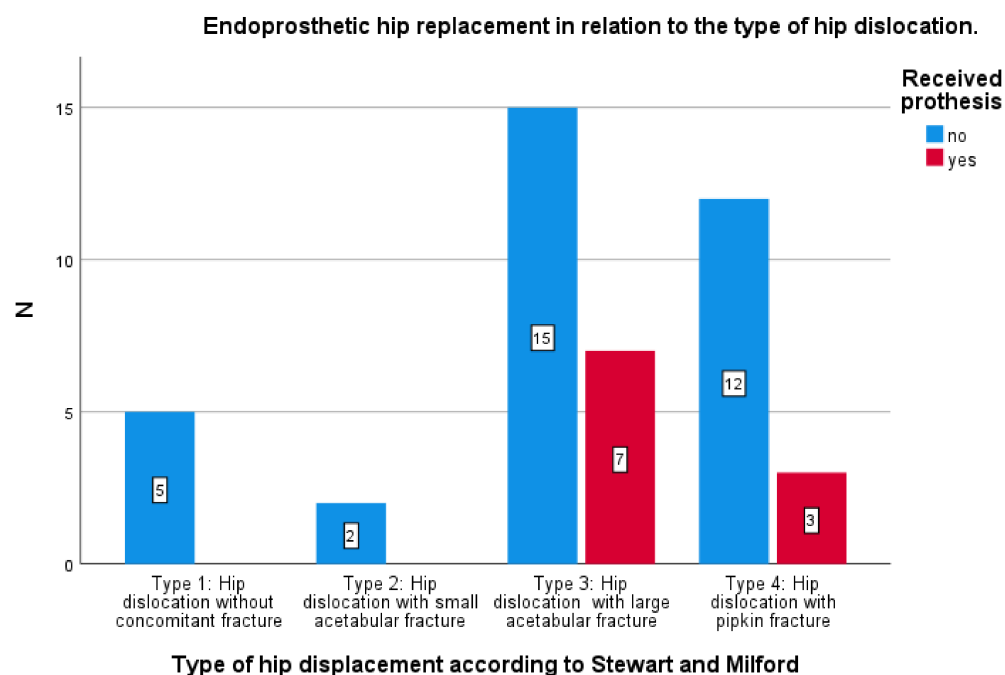


Figure 3. Number of patients who received a hip joint prosthesis after hip dislocation depending on the type of dislocation according to Stewart and Milford. The majority of patients received a hip joint prosthesis after suffering a large acetabular fracture or Pipkin fracture during hip dislocation.

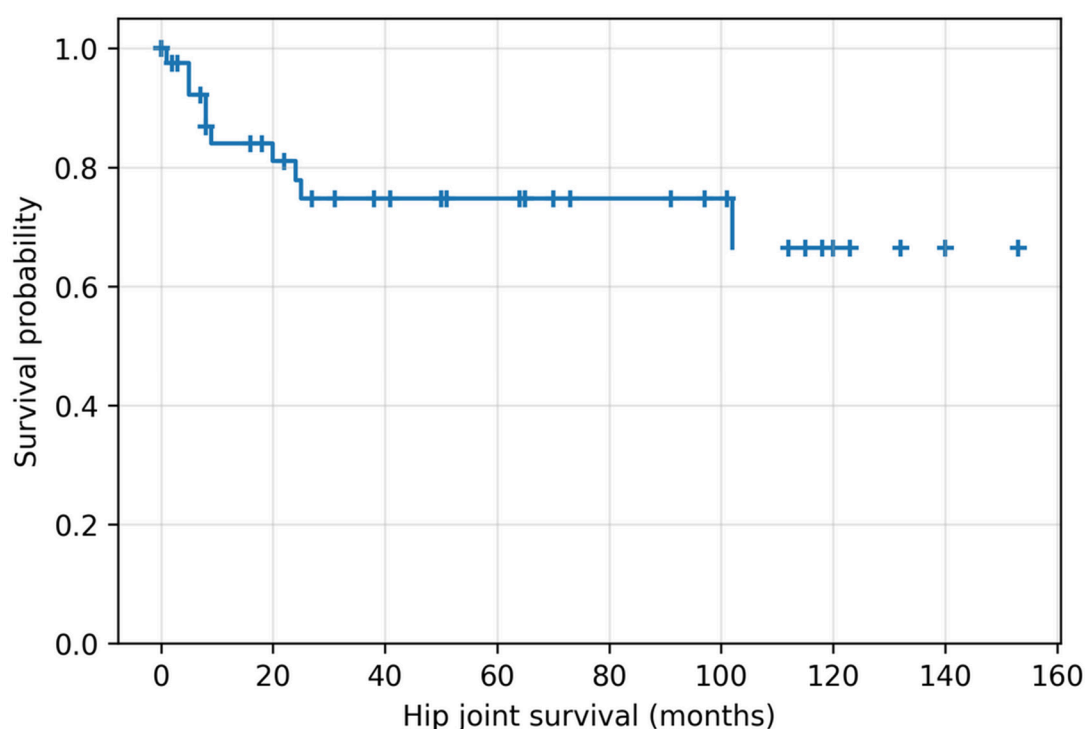


Figure 4. Survival time of the native hip joint in months until hip joint replacement. After 2 years, 25% of patients received a hip joint replacement.

4. Discussion

The most common trauma mechanism here is high-impact trauma in the context of a traffic accident [1,3,12,17,21,22,32,33]. In our collective, 80% of hip dislocations occurred because of a traffic accident. This finding is consistent with the collective of Sahin et al. (83.9%) [3,17]. This observation is also consistent with the recent review by Benedick et al.,

who identified high-energy motor vehicle accidents as the predominant mechanism of traumatic hip dislocation in adults [24]. The majority of the patients here are male and young [3,27]. Due to the accident mechanism in the form of a dashboard injury, a dorsal dislocation with accompanying acetabular fracture frequently occurs, as was also seen in our patient collective with 34 (77%) patients. Anterior dislocation or medial dislocation is much less common and is described in the literature in 2% of cases [17,28] (Figure 5).

In our patient population, 34 of the 44 patients had an acetabular fracture as an associated injury. In the literature, almost 60% of hip dislocations occur in combination with an acetabular fracture [32,34] (Figures 6–8). Isolated hip dislocations without associated fractures occur less frequently [32,34]. Chigblo et al. describe predominantly good results (91%) after hip dislocations, whereas the results of the present work show that in the course of the trauma, an artificial joint replacement is necessary after 2 years in 22.7% of the patients [35] (Figure 9).

In addition to the hip dislocation, other injuries occur because of the high-force application. Thus, 43% (almost half) of the patients in our collective were polytraumatized. This finding is consistent with Sahin et al., who also describe multiple injuries in 38% of the cases [17]. A high proportion of the patients in this study also showed head injuries, often necessitating damage control and interdisciplinary treatment with neurosurgery [17,20]. The literature also describes a high proportion of concomitant injuries. Jaskulka et al. describe further injuries in 96% of cases, with Jaskulka et al. [36] indicating a high-risk patient population. Here, particular attention should be paid to complete imaging. Particularly, due to the multiple injuries described in the literature, a complete CT diagnosis is necessary [7,20,31,36]. If the acetabulum is involved, CT imaging is obligatory for further surgical planning in our opinion. Our collective revealed that the mechanism of the accident did not influence the severity of hip dislocation or the direction of dislocation. This finding agrees with the results of Upadhyay et al. [33]. This study shows that after simple dislocations, poor clinical as well as radiological outcomes occur in 25% of the cases within 15 years.

In addition to hip-specific complications, such as post-traumatic coxarthrosis (16.1%) and femoral head necrosis (9.6%), patients must also expect a high rate of complications due to concomitant injuries [17,19,20]. This finding is also reflected in the average length of stay of 31 days of our patient collective. However, comparable studies on the average length of stay in the literature are not available.

As a rule, a prompt reduction is sought in dislocated joints to prevent subsequent damage to the joint [17,23,35]. Certain authors describe and recommend a prompt reduction in the emergency center [3,12]. Other authors recommend it under 6 h as a critical value [7,33]. We hold that increased muscular preload often occurs, preventing reduction under analgesia without muscle relaxation. In addition, anesthesia is necessary for the treatment of concomitant injuries, particularly in polytraumatized patients. When the acetabulum is involved, stabilization of the hip joint is often not sufficiently feasible without surgical stabilization of the acetabulum. Of the patients we cared for, none underwent a reduction in the prehospital setting, though 50% and 47.73% of them underwent closed and open reduction, respectively. One patient was urgently transported to an external hospital and then transferred to us. Similarly, in Sahin's study, 80% of the patients could be reduced closed [17]. The finding is due to the frequent concomitant acetabular fracture or free joint bodies. Sahin et al. state that the presence of free joint bodies is an obligatory indication for an open reduction [17]. However, in our collective, a closed approach was not shown to be superior to an open approach, as also observed by Sahin et al. [17].

After closed reduction, 7 of 22 patients showed nerve damage. These seven patients had an associated fracture. Cornwall et al. also describe a nerve lesion in 10% of cases [15]. According to the authors, this condition occurs because of nerve compression or nerve

injury due to fracture fragments [15]. These fracture fragments can only be insufficiently reduced when closed.

For a long time, extension played an important role in the postoperative protocol, and patients were immobilized for 6–8 weeks. Today, this treatment is only performed in exceptional cases. However, new studies recommend early mobilization of patients [7,21,36].

Another relevant complication is post-traumatic coxarthrosis [7]; it occurs particularly in the presence of femoral head necrosis [7,27]. In the literature, a connection with the time of reduction is often described [37]. Brav et al. observed 17.6% of femoral head necrosis with a reduction less than 12 h and up to 56.9% with a reduction longer than 12 h after dislocation [1,38].

However, in addition to femoral head necrosis, an acetabular fracture can also be the cause of subsequent post-traumatic coxarthrosis [1,19,38]. This fracture affected almost every fourth patient in our collective.

The literature describes that post-traumatic coxarthrosis occurs on average 5 years after trauma [7]. After 2 years, 13 of 44 patients had undergone a Girdlestone resection or received a hip prosthesis. Three of these 13 patients did not receive a hip prosthesis at their own request but retained a Girdlestone resection; 10 of these 13 patients received a hip prosthesis. In total, 9 of these 10 patients required the hip prosthesis because of post-traumatic coxarthrosis. Only one patient underwent total hip arthroplasty after an initial Girdlestone procedure had been performed because of a contaminated wound resulting from polytrauma. Hougaard et al. observed that 80% of cases with post-traumatic femoral head necrosis had a type 3 or 4 hip dislocation [7]. However, neither the timing of reduction, the open or closed procedure, nor the type of hip dislocation influences the subsequent failure of the patient's hip joint. This finding is also described by Sahin et al. [17].

The combination of frequently occurring complications due to hip dislocation as well as complications occurring in the context of concomitant injuries results in just over 10% of the patients having no everyday restrictions. This result is based on the Lequesne score after the surgical treatment. Just 20% of the patients complained about severe to extreme limitations of daily living in the Lequesne score at the time of data collection. This finding is predominantly due to persistent neurological deficit or the presence of a Girdlestone resection. Thus, more than half of the patients showed limitations in lifestyle compared with the time before hip dislocation. Furthermore, the literature described the long-term outcome as moderate to poor in almost 75% of cases [32]. The current literature describes the increased risk of receiving a hip prosthesis over the course of life. [8]. However, how long patients retain their native hip joint has not been answered in the literature thus far. Accordingly, our study provides this information, and we can show in a Kaplan–Meier Curve that a quarter of patients no longer have their own native hip joint after 24 months. Recent evidence further supports an individualized treatment strategy based on fracture morphology and associated intra-articular injuries rather than the dislocation pattern alone [39].

In summary, only a quarter of patients had subjective excellent or good to fair results in the HHS and Lequesne score. However, 25% of all cases received a hip replacement 2 years after trauma, due to post-traumatic coxarthrosis. The type of hip dislocation classified according to Stewart and Milford had no significant influence on the implantation of a hip prosthesis.



Figure 5. AP pelvic overview X-ray of a right hip dislocation with accompanying Pipkin fracture.

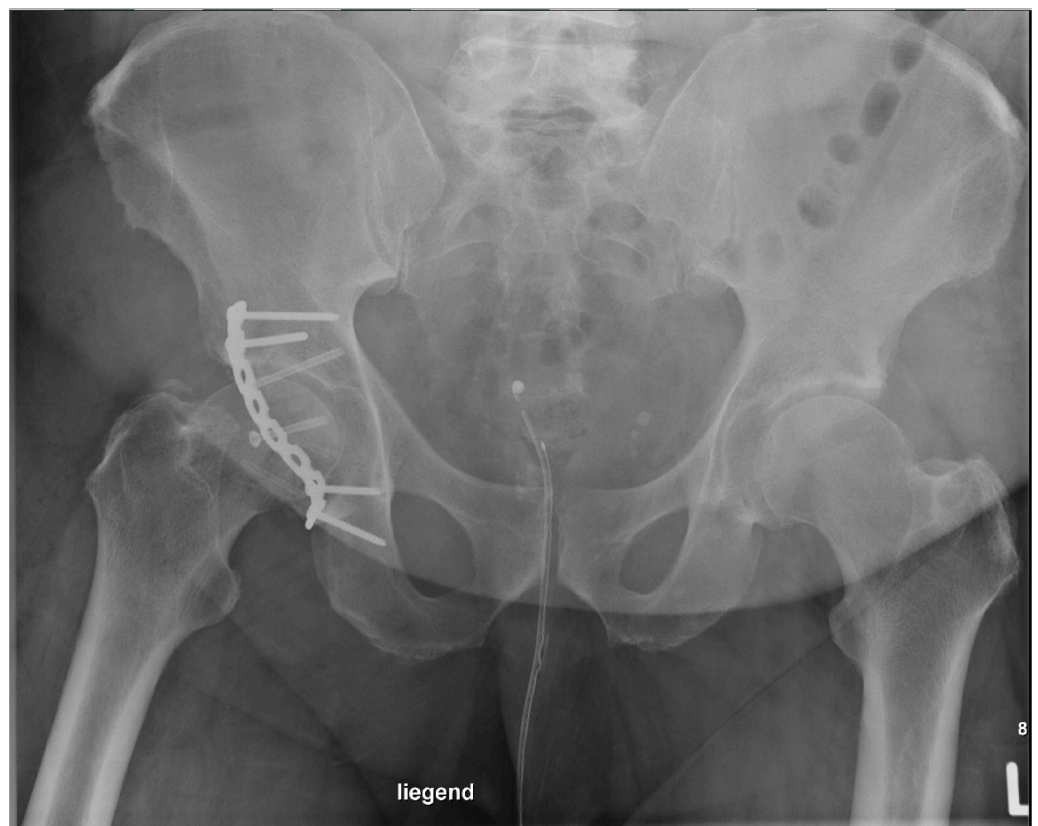


Figure 6. AP pelvic overview X-ray of a right hip dislocation on postoperative day 1 after surgical treatment of a dorsal acetabular fracture. A secondary screw dislocation of the middle screw occurred.

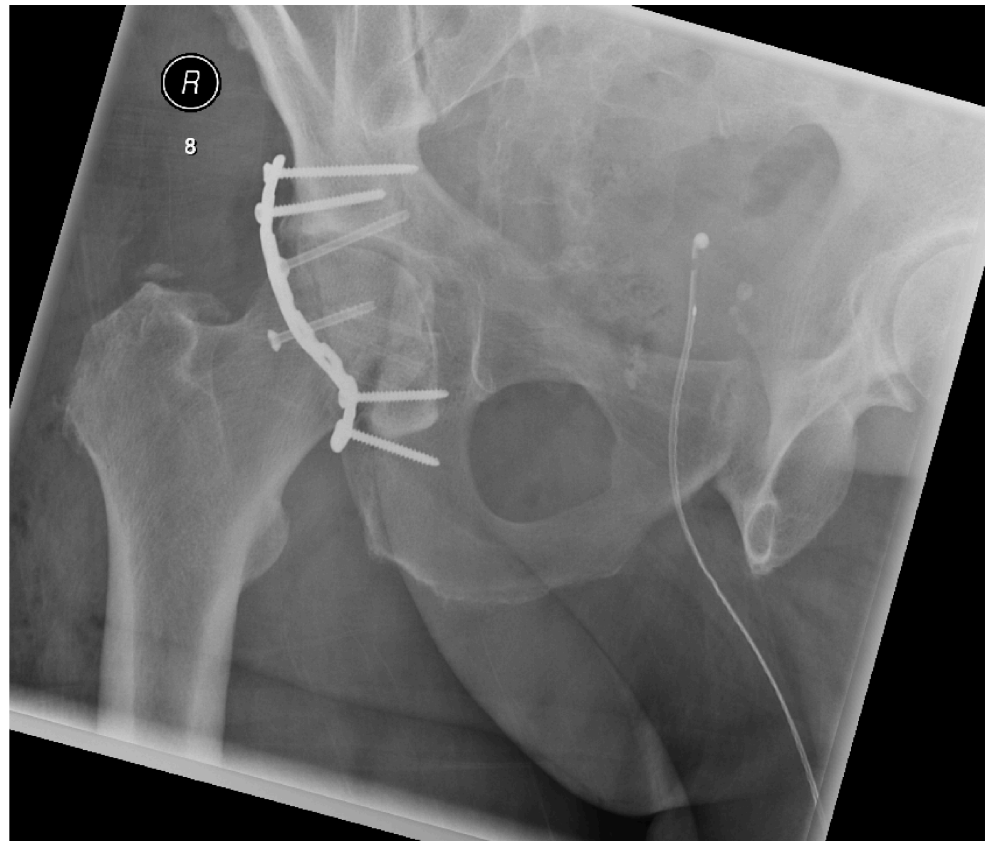


Figure 7. AP pelvic overview X-ray of a right hip dislocation 6 weeks postoperatively after surgical treatment of a dorsal acetabular fracture. A secondary screw dislocation of the middle screw occurred.



Figure 8. AP pelvic overview X-ray of a right hip dislocation three months after surgical treatment of a dorsal acetabular fracture. A post-traumatic coxarthrosis on the right side is recognizable.



Figure 9. AP pelvic overview X-ray after endoprosthetic treatment of post-traumatic coxarthrosis following a right hip dislocation treated with a non-cemented hip stem and screw cup.

Author Contributions: Conceptualization, C.P. and K.W.; methodology, C.P., T.L. and K.W.; validation, C.P., T.L. and K.W.; formal analysis, C.P. and J.R.; investigation, C.P., T.L., J.R., J.K., J.T., L.R. and A.A.Z.; resources, K.W.; data curation, C.P., T.L. and J.R.; writing—original draft preparation, C.P.; writing—review and editing, C.P., T.L., J.R., J.K., J.T., L.R., A.A.Z. and K.W.; visualization, C.P.; supervision, K.W.; project administration, C.P. and K.W.; funding acquisition, C.P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The Ethics Committee for Clinical Trials on Humans and Epidemiological Research with Personal Data of the Medical Faculty of the Rhenish Friedrich Wilhelms University of Bonn was consulted regarding this study. Based on its decision (Ref. No. 406/17, issued on 20 December 2017), the Committee determined that, for this retrospective analysis of routine clinical data, no additional ethics committee approval or renewed informed consent was required.

Informed Consent Statement: Patient informed consent was waived because this study was a retrospective analysis of anonymized/pseudonymized data obtained during routine clinical diagnostics. According to the decision of the Ethics Committee (Ref. No. 406/17), no additional explicit ethics committee approval was required for this type of study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical restrictions, as the dataset contains information that could potentially allow the identification of individual participants.

Conflicts of Interest: The authors declare no conflict of interest.

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