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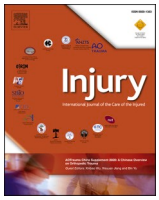

Isolated posterior stabilization of the pelvic ring in type III/IV fragility fractures of the pelvis are beneficial compared to 360° antero-posterior surgical approaches. A dual-center cohort analysis

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ABSTRACT

Background: Fragility fractures of the pelvis (FFP) in elderly patients are an increasing concern due to their association with osteoporosis and the aging population. These fractures significantly affect patients' mobility and quality of life. This study evaluates different surgical techniques in patients suffering from FFP to provide standardized recommendations for treatment strategies. In addition, we compared therapeutic concepts and their outcome between two major trauma centers in Germany.

Methods: We conducted a retrospective analysis of 882 patients aged over 65 years who suffered from FFP between 2003 and 2020 at a level I and level III trauma center in a german metropolis. Fractures were classified according to Rommens and Hofmann. Data collection included patient demographics, fracture type, treatment strategy, and length of hospital stay.

Results: FFP I fractures were predominantly treated conservatively at both centers. Significant variability was noted in the treatment of type II and III fractures, with level III trauma center having a higher surgical intervention rate for FFP II in 27.6 % compared to the level I trauma center in 9.9 % of the cases. The most common procedure at both hospitals was the stabilization of the posterior pelvic ring. Patients who underwent less invasive posterior-only stabilization had shorter length of hospital stay than those who received combined anterior and posterior stabilization.

Conclusions: The study reveals substantial differences in the treatment approaches for FFP between two major trauma centers. Less invasive surgical methods, particularly posterior-only stabilization, are associated with shorter hospital stays and potentially better outcomes for elderly patients with unstable FFP.

Clinical Relevance: This study underscores the importance of minimally invasive surgical techniques in managing FFP in elderly patients, highlighting their potential to reduce the length of hospital stay and improve recovery.

Introduction

Fragility fractures of the pelvis (FFP) represent a significant clinical challenge, particularly in the elderly population due to the high incidence and the complex treatment requirements associated with osteoporotic bone conditions. Due to the increasing life span, structural stability makes these fractures especially debilitating, leading to prolonged recovery times, increased morbidity, and a substantial impact on quality of life. Although the majority of the patients are able to return to their familiar surroundings after the injury and rehabilitation, a major amount of FFP patients don't achieve to regain their index activity level. The high 1-year mortality rate of 30 % for FFP is also striking [1–3].

For classification and treatment of pelvic ring fractures in younger adults, the AO/OTA Fracture and Dislocation Classification is widely used [4]. However, the established classification is inaccurate in pelvic fractures of the elderly due to the different trauma mechanisms and the reduced bone quality with subsequent specific fracture patterns [5]. To take these into account, Rommens and Hofmann developed a new

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classification system in 2013 specifically for FFP after low-energy trauma. The classification is based on morphological characteristics and the degree of instability. Recommendations for the therapeutic approach can be derived from this.

Especially in orthogeriatric patients with a high presence of comorbidities, the quality of health, general and living conditions, in addition to the fracture patterns, should be considered when making treatment decisions [6]. In FFP I and II fracture patterns, conservative treatment is primarily recommended. If the non-operative strategy including treatment with high dosage painkillers and physiotherapy fails after 1–2 weeks, a surgical procedure needs to be discussed [7]. FFP III and IV should be addressed surgically because of the instability of these fractures [8]. Various treatment options for stabilizing the anterior and posterior pelvic ring are described in the literature [4,8,9]. However, treatment recommendations are predominantly based on retrospective studies with small case numbers or expert opinions.

This study evaluates different surgical techniques in patients suffering from FFP with the goal of improving patient outcomes and providing further evidence for treatment recommendations. In addition, we compared therapeutic concepts and their outcome between a standard and maximum care provider in a German metropolis.

Materials and methods

The conduct of this study was approved by the local Ethics Committee under project number 18-518. A total of 882 patients were included in the analysis. Of these 455 patients were treated at a level I trauma center between 2003 and 2019. The remaining 427 were treated at a level III trauma center between 2011 and 2020. The patients included were older than 65 years at the time of diagnosis and had a confirmed pelvic ring fracture. As this is a retrospective analysis, all data were collected from patient records and the corresponding radiological images. The patients' pelvic ring fractures were classified according to Rommens and Hofmann. To avoid excessive fragmentation of the data, only FFP groups and not subtypes were considered. In addition to age, gender, and fracture type, the length of hospital stay was documented.

The exact type of treatment of the pelvic ring, including the osteosynthesis procedures performed, was recorded. Conservative treatment consists of daily physiotherapy sessions with early mobilization and pain medication as required according to the WHO analgesic ladder. In order to compare the treatment of anterior and posterior pelvic ring fractures, the osteosynthesis procedures were summarized accordingly. In the analysis, not only the anterior and posterior pelvic ring were considered separately, but also the combination of both. In addition, a comparison was made between the treatment strategies and patient outcomes in the level I and level III trauma centers to identify any differences in treatment approaches or outcomes between the two hospitals.

The statistical analysis and creation of the diagrams were carried out using Microsoft Excel® Version 2403 (© Microsoft Corporation, Redmond, WA, USA) and IBM SPSS® Version 29 (© IBM Corporation, Armonk, NY, USA). Frequency data were analyzed along with additional parameters, including mean values and median, standard deviation (SD), and sample size (n). The Kolmogorov–Smirnov and Shapiro–Wilk tests were applied to test for normal distribution. For parametric data, *t*-tests were used for comparing two groups, and ANOVA was applied when comparing more than two groups. If the data were non-normally distributed and the sample size was small, the Kruskal–Wallis test was used to test for significant differences between several independent groups, with the Dunn–Bonferroni test used as a post-hoc test. When comparing two non-parametric groups, the Mann–Whitney *U* test was carried out. The significance level was set at $p \leq 0.05$ and all tests were performed two-tailed.

Results

A total of 882 patients who suffered a FFP were included in our study. Of these, 455 were treated at a level I trauma center and 427 were treated at a level III trauma center in major German city. The mean age of the level I group was 87.2 years, with about 80 % female patients. At the level III trauma center the mean age was 83.4 years, with 86 % women. The most common FFP fracture type in both hospitals were type II fractures (Table 1).

FFP I were predominantly treated conservatively in both clinics, and surgical intervention was only rarely performed. In FFP II and III, most of the patients could be treated without surgery (FFP II: 90.1 % level I and 72.4 % level III; FFP III: 68.5 % level I and 66.7 % level III). However, if the non-operative treatment failed, surgical therapy had to be carried out in a not inconsiderable number of cases. Patients with FFP II were more frequently treated surgically at the level III trauma center than at the level I trauma center (27.6 % vs. 9.9 %). The most common procedure in both hospitals was a stabilization of the posterior pelvic ring in 66.7 % of the surgically treated cases at the level I and 52.7 % at the level III trauma center, respectively. However, at the level III trauma center, every third patient with FFP II who needed surgery was treated with a combination of anterior and posterior pelvic ring stabilization. Whereas other therapeutic options only played a minor role at the maximum care provider. In FFP III, the level III trauma center treated all patients by a combination of stabilizing the anterior and posterior pelvic ring. In contrast at the level I trauma center most of the cases were treated with a stabilization of the posterior pelvic ring only (60.9 %). FFP IV were primarily treated surgically at both clinics (61.9 % level I and 59.0 % level III). Again, stabilization of the posterior pelvic ring only was used in 92.3 % of the cases in the level I trauma center. At the level III trauma center, the surgical procedure for patients with FFP IV varied with either a stabilization of the posterior pelvic ring only in 56.5 % or a combination of the anterior and posterior pelvic ring in 43.5 % of the patients (Table 2). Comparing the surgical approaches for treatment of a fracture of the posterior pelvic ring the majority of the patients suffering FFP II and III were treated by percutaneous sacroiliac screw (SI-screw) in both hospitals. Other treatment options only played a minor role. However, in type IV FFP at the level I trauma center percutaneous SI screw was still the most common procedure in 84.6 %, whereas lumbopelvic stabilization and plate osteosynthesis was carried out in 30.4 % and 19.6 % of the surgically treated patients in the level III trauma center (Table 2).

Length of hospital stay increased with the complexity of the fracture, with the longest stay of 19.3 days at level I and 18.9 days at level III hospitals in FFP IV. Comparing the two different trauma centers, the stay was significantly shorter at the level I hospital in FFP II (12.2 days $\pm$ 9.1 vs. 15.5 $\pm$ 10.1 days, $p < 0.001$). In FFP I and III, we could observe a trend towards a shorter length of hospital stay at the maximum care provider without a statistically significant difference (10.8 $\pm$ 7.5 vs. 12.3 $\pm$ 8.1; p 0.263 and 13.9 $\pm$ 8.1 vs. 16.7 $\pm$ 11.3; p 0.271) (Table 3). Conservative treatment leads to shorter stays for all fracture types. Comparing the surgical treatment between the two hospitals, we see a

Table 1
Baseline clinic parameters.

	Level I	Level III
Cases n	455	427
Mean age *y* $\pm$ SD	87.2 $\pm$ 4.5	83.4 $\pm$ 7.0
Sex *n* (%)		
male	93 (20.4)	59 (13.8)
female	362 (79.6)	368 (86.2)
Fracture type *n* (%)		
I a / b	59 (13)	120 (28.1)
	56 / 3	116 / 4
II a / b / c	302 (66.4)	199 (46.6)
	59 / 36 / 207	39 / 81 / 79
III a / b / c	73 (16)	30 (7)
	16 / 23 / 34	3 / 7 / 20
IV a / b / c	21 (4.6)	78 (18.3)
	7 / 6 / 8	37 / 40 / 1

Table 2
Different treatment strategies according to the treating hospital.

FFP type	I		II		III		IV	
	Level I *n* (%)	Level III *n* (%)	Level I *n* (%)	Level III *n* (%)	Level I *n* (%)	Level III *n* (%)	Level I *n* (%)	Level III *n* (%)
Total	59	120	302	199	73	30	21	78
Conservative	58 (98.3)	113 (94.2)	272 (90.1)	144 (72.4)	50 (68.5)	20 (66.7)	8 (38.1)	32 (41.0)
Operative	1 (1.7)	7 (5.8)	30 (9.9)	55 (27.6)	23 (31.5)	10 (33.3)	13 (61.9)	46 (59.0)
n (% of surgically treated)								
Anterior only		6 (85.7)	6 (20.0)	6 (10.9)	5 (21.7)		1 (7.7)	
Posterior only			20 (66.7)	29 (52.7)	14 (60.9)		12 (92.3)	26 (56.5)
Combination	1 (100)	1 (14.3)	4 (13.3)	20 (36.4)	4 (17.4)	10 (100)		20 (43.5)
Treatment strategies of a fracture of the posterior pelvic ring n (% of surgically treated)								
SI-screw unilateral	1 (100)		7 (23.3)	20 (36.4)	11 (47.8)	7 (70.0)	1 (7.7)	
SI-screw bilateral			15 (50.0)	20 (36.4)	5 (21.7)		10 (76.9)	23 (50.0)
Lumbopelvic stabilisation		1 (14.3)	1 (3.3)	6 (10.9)		1 (10.0)	1 (7.7)	14 (30.4)
Plate osteosynthesis			1 (3.3)	1 (1.8)	2 (8.7)			
Internal fixator				2 (3.6)		2 (20.0)		9 (19.6)

SI-screw: Sacroiliac screw.

Table 3
Length of hospital stay based on treatment strategy and treating hospital.

FFP type	I		II		III		IV	
	Level I mean ± SD	Level III mean ± SD	Level I mean ± SD	Level III mean ± SD	Level I mean ± SD	Level III mean ± SD	Level I mean ± SD	Level III mean ± SD
Total	10.8 ± 7.5	12.3 ± 8.1	**12.2 ± 9.1***	**15.5 ± 10.1**	13.9 ± 8.1	16.7 ± 11.3	19.3 ± 16.4	18.9 ± 12.2
Conservative	10.8 ± 7.6	11.8 ± 7.8	11.7 ± 9.2	13.2 ± 8.9	11.5 ± 7.9	14.3 ± 11.6	10.6 ± 4.0	13.1 ± 9.6
Operative			17.4 ± 6.2	21.5 ± 10.5	18.9 ± 6.3	21.6 ± 9.4	24.7 ± 18.9	22.9 ± 12.2
Anterior only		17.5 ± 8.9	16.8 ± 5.6	23.7 ± 10.6	17.8 ± 2.3		70.0 ± 0	
Posterior only			17.5 ± 6.9	18.8 ± 9.3	17.8 ± 6.8		20.9 ± 13.6	20.3 ± 8.5
Combination	9 ± 0	31 ± 0	17.8 ± 3.4	24.7 ± 11.4	24.3 ± 6.0	21.6 ± 9.4		26.4 ± 15.5

Length of hospital stay in days.
* Statistically significant difference ($p < 0.001$) is indicated in bold font.

trend towards a shorter length of stay at the level I trauma center regardless of the type of fracture and type of treatment. However, we could not observe a significant difference (Table 3). Focusing on the different treatment strategies, we analyzed all 882 patients from both study centers. 185 patients were treated surgically. The surgical procedures depending on the FFP classification are listed in Table 4. Looking at the variety of different treatment options for stabilizing the posterior pelvic ring only, there was no significant difference in the length of hospital stay (FFP II: $p = 0.35$, FFP III: $p = 0.55$, FFP IV: $p = 0.87$). Our data also showed no difference in outcomes whether SI screws were placed at one or two levels, or whether they were inserted unilaterally or bilaterally (Fig. 1). Looking at the different options for stabilizing the anterior and posterior pelvic ring together, our analysis could not reveal a superior combination as well ($p > 0.05$) (Supp. 1).

When comparing surgical approaches involving only the posterior pelvic ring to those addressing both, the anterior and posterior pelvic ring, the length of hospital stay is shorter when only the posterior pelvic ring is addressed, regardless of the fracture type. In FFP II, treatment of the posterior pelvic ring alone is associated with a significantly shorter stay of 18.3 ± 8.4 days compared to the combination treatment of the anterior and posterior pelvic ring with 23.5 ± 10.8 days ($p = 0.045$). Similar results could be observed in FFP III and FFP IV, with a median stay when treating the posterior pelvic ring of 18.8 ± 6.8 days and 20.5 ± 10.2 days compared to 22.4 ± 8.4 days and 26.4 ± 15.5 when both pelvic rings are addressed (FFP III: $p = 0.069$, FFP IV: $p = 0.077$) (Fig. 2).

Table 4
Number, type, and localization of the operative procedure depending on the FFP classification.

FFP type	I	II	III	IV
Posterior pelvic ring n				
SI-screw unilateral (1 level)		10	9	
SI-screw bilateral (1 level)		17	1	13
SI-screw unilateral (2 levels)	1	17	9	1
SI-screw bilateral (2 levels)		18	4	20
Lumbopelvic stabilisation		7	1	14
Lumbopelvic stabilisation + SI-screw	1			1
Plate osteosynthesis		2	2	
Internal fixator		2	2	8
Internal fixator + SI-screw				1
Anterior pelvic ring n				
IlluminOss	4	13	4	8
Plate osteosynthesis	3	9	8	4
IlluminOss + Plate osteosynthesis	1	7	3	2
External fixator		2	1	5
External fixator + plate osteosynthesis			2	
Creeping screw		3		
Internal fixator		2	1	2
Localization of operative stabilization *n* (%)				
Total n	179	502	103	99
Surgically treated	8 (4.5)	85 (16.9)	33 (32.0)	59 (59.6)
n (% of surgically treated)				
Anterior pelvic ring only	6 (75.0)	12 (14.1)	5 (15.2)	1 (1.7)
Posterior pelvic ring only		49 (57.6)	14 (42.4)	38 (64.4)
Combination of anterior and posterior	2 (25.0)	24 (28.2)	14 (42.4)	20 (33.9)

SI-screw: Sacroiliac screw.

Discussion

The current study offers a comprehensive analysis of the acute management of fragility fractures of the pelvis (FFP) in elderly patients treated at a level I trauma center and a level III trauma center in Germany. The key finding of this study is the benefit of isolated posterior

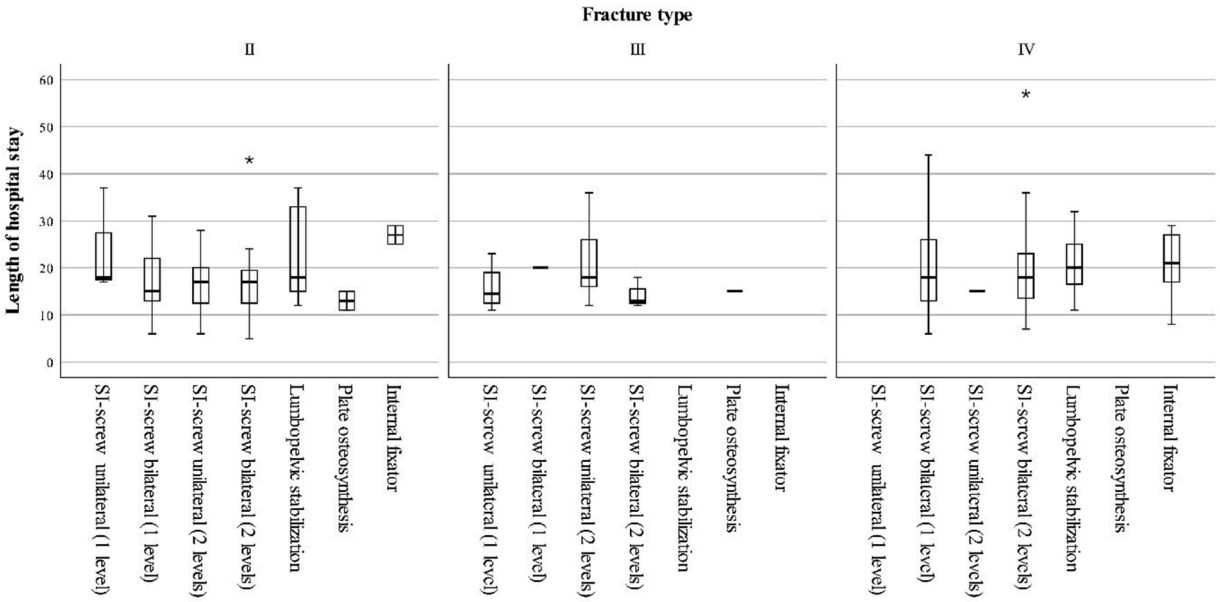

Fig. 1. Treatment options for stabilization of the posterior pelvic ring.
Values are presented as median; the central box represents the interquartile range (IQR); whiskers are used within 1.5 IQR; outliers within 1.5–3.0 IQR are marked with dots. Beyond 3.0 IQR asterisks are used.

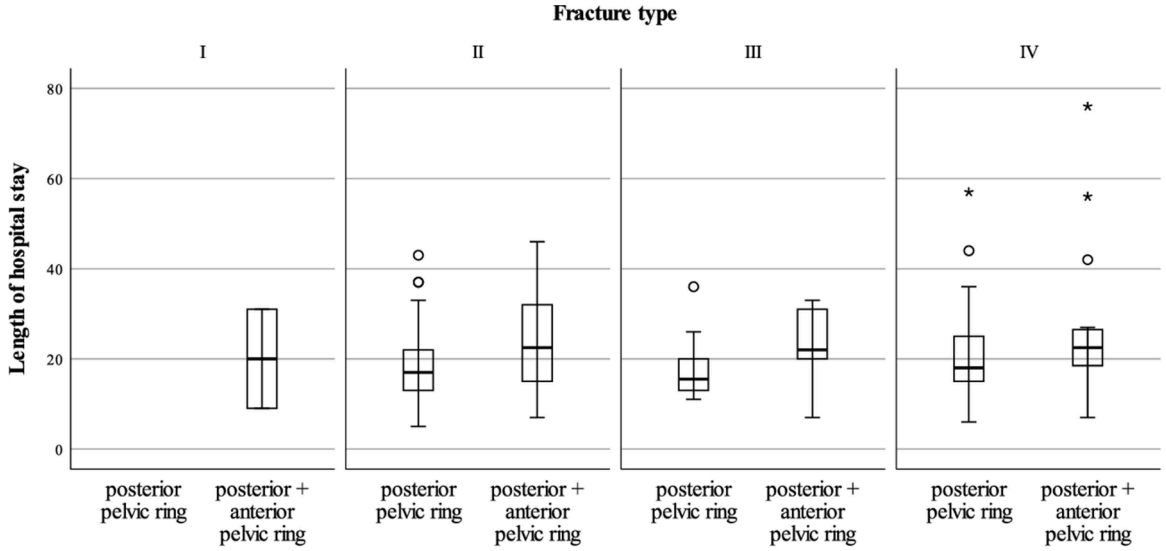

Fig. 2. Impact of treatment of the posterior pelvic ring alone and combination of the anterior and posterior pelvic ring on length of hospital stay.
Values are presented as median; the central box represents the interquartile range (IQR); whiskers are used within 1.5 IQR; outliers within 1.5–3.0 IQR are marked with dots. Beyond 3.0 IQR asterisks are used.

stabilization for FFP. Compared to a antero-posterior approach, posterior-only stabilization was associated with a shorter hospital stay and favorable patient outcomes. This approach highlights the potential of less invasive techniques, particularly in elderly patients who often face increased surgical risks due to frailty and comorbidities.

Despite the widespread use of the Rommens and Hofmann classification system to standardize treatment decisions for the different types of FFP, a key finding of this study is the marked difference in treatment strategies between the two major trauma centers. FFP I were predominantly treated conservatively at both hospitals, which aligns with the consensus in the literature that non-operative management is often sufficient for these less severe fractures [4]. However, significant variability was observed in the treatment of FFP II and III. At the level III trauma center, a higher rate of surgical intervention was noted for FFP II (27.6 % vs. 9.9 %). The most common surgical approach in both hospitals was the stabilization of the posterior pelvic ring in type II fractures. Rommens et al. treated 21.8 % of the patients suffering from FFP II surgically [10]. The decision between conservative and operative management of fractures remains a subject of ongoing debate. According to current recommendations, conservative therapy should be attempted for 5–7 days, with surgical intervention being reconsidered if immobility persists or pain remains prolonged [11]. Conservative treatment typically includes adequate pain management and physical therapy, with early mobilization under full weight-bearing as tolerated [8]. Previous studies showed that elderly patients are not able to maintain weight-bearing restrictions [12]. This approach is often preferred for less severe fractures (FFP I and II) or for patients with significant comorbidities that increase surgical risks [13,14]. This could

also explain the significantly lower number of surgically treated patients at the level I trauma center, as patients with severe comorbidities are often referred to a maximum care provider for further treatment. However, recent analyses from national registers have found no correlation between hospital volume or level of care and the severity of pre-existing conditions [15,16].

Operative treatment, on the other hand, aims to provide immediate stabilization, reduce pain more effectively, and potentially shorten recovery time, although it comes with increased surgical risks [13]. Operative treatment of FFP is associated with low mortality rates. However, the length of hospital was longer, and at discharge, the non-operative group was even more mobile and independent [10]. The decision to opt for surgical intervention should be based on a thorough assessment of the patient's overall health, bone quality, and functional status by an interdisciplinary team of geriatricians, physiotherapists, and orthopedic surgeons [3]. This aligns with the current study's findings, underscoring the importance of considering patient-specific factors in treatment planning.

Looking at the length of hospital stay, patients at the level I trauma center were discharged after 12.2 days, whereas patients in the level III trauma centers stayed 15.5 days. The trend towards shorter periods at the level I hospital was seen across all fracture types and treatment approaches. Rommens et al. described for their patients with FFP II a significantly shorter length of hospital stay of 10 days [10]. The length of hospital stay varied in the literature. Walker et al. for example observed no significant difference in the length of stay between patients treated operatively and non-operatively, with an average of 3.6 days and 4.2 days, respectively [17]. We reported a significantly longer length of stay for patients treated operatively, though this included an average of 5–7 days spent on attempting conservative management prior to surgery. Similar results are described by Höch et al. with 18 vs. 9 days [18].

Furthermore, we observed a variety of different treatment approaches to address the posterior and anterior pelvic ring. This reflects the existing literature in which numerous different surgical procedures for FFP are described [10,19]. For fractures of the posterior pelvic ring, SI screw fixation, transiliac bridging osteosynthesis, transsacral bar osteosynthesis, and lumbopelvic fixation are possible treatment options. As there are no randomized studies, the choice of procedure depends on fracture morphology and the surgeon's assessment. Less invasive procedures, like SI screw fixation, were superior to the open procedure with lumbopelvic fixation in terms of length of hospital stay. Previous studies underline that minimally invasive techniques reduce surgical trauma, are associated with lower complication rates, and facilitate faster postoperative recovery [20]. These benefits are particularly important in the elderly population, where comorbidities and frailty can significantly impact surgical outcomes [21]. Nevertheless, we couldn`t identify a superior method for stabilization of the posterior pelvic ring.

Interestingly, in our study, the combination of anterior and posterior pelvic ring stabilization was associated with longer hospital stays compared to posterior stabilization alone in FFP II, III and IV. This finding suggests that less invasive procedures, especially in geriatric trauma patients, lead to more favorable outcomes. In the operative treatment of FFP, anatomical reduction does not appear to be the focus, but rather achieving sufficient stability for early mobilization. In highly unstable FFP III and IV, a combination of fixation of the fractures of the anterior and posterior pelvic ring is recommended [4]. Therefore, techniques like plate osteosynthesis, external or internal fixators, and anterior internal fixation for example by retrograde transpubic screw fixation or the IlluminOss system are available for anterior pelvic ring fractures. It is discussed whether additional stabilization of the anterior pelvic ring offers further advantages, with a focus on early mobilization and effective pain reduction. A biomechanical analysis showed that stabilization of an additional anterior fracture component improves stability and prevents failure of dorsal stabilization or further progression of the fracture [22]. On the other hand, additional anterior fixation prolongs operation time and comes with additional surgical risks [23–25].

This study is one of the largest on surgically treated FFP, encompassing 882 patients, 185 of whom received surgical intervention. It is the first to offer a comparative analysis of surgical approaches and detailed insights into the management of these fractures across different trauma centers in Germany. Despite the valuable insights, this study has several limitations. As a retrospective analysis, it is subject to biases in data collection and interpretation. The different time frames for data collection at the two hospitals (Level I: 2003–2019, Level III: 2011–2020) could introduce temporal biases, as treatment protocols and standards may have evolved over time. It should be mentioned that patients suffering FFP are also treated on geriatric wards at the level III hospital as part of geriatric early rehabilitative complex treatment. However, this results in longer hospital stays. As only 5 % of patients received this treatment, there was no significant effect on the overall length of hospital stay and therefore was not listed separately. Perioperative parameters like surgical and non-surgical complications, inpatient mortality or mobility at discharge is missing. Additionally, the study did not assess long-term outcomes, such as functional recovery and quality of life, which are crucial for evaluating the overall effectiveness of different treatment strategies. Most treatment recommendations in this field are based on expert opinion or small retrospective studies, highlighting the need for more robust evidence.

Conclusion

The management of fragility fractures of the pelvis in elderly patients remains a challenging and evolving field. This study provides valuable insights into the real-world treatment practices for FFP underscored by the variety of surgical approaches employed across trauma centers despite the existence of standardized treatment recommendations. Importantly, our findings suggest that less invasive surgical approaches, particularly posterior-only stabilization, offer significant advantages for elderly patients. These methods are associated with shorter hospital stays, an essential factor for the frail, high-risk geriatric population. Given these benefits, minimally invasive techniques appear to be a preferable strategy for enhancing patient outcomes in this vulnerable group.

Ethical statement

Author responsibilities, integrity, ethics.

Human and animal rights

The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association revised in 2013 for experiments involving humans as well as in accordance with the EU Directive 2010/63/EU for animal experiments.

Informed consent and patient details

The authors declare that this report does not contain any personal information that could lead to the identification of the patients.

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CRediT authorship contribution statement

Christopher Lampert: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **Florian Pachmann:** Data curation, Formal analysis, Methodology, Writing – original draft. **Johannes Rieger:** Data curation, Formal analysis. **Yunjie Zhang:** Data

curation, Formal analysis, Methodology, Validation. **Johannes Gleich:** Data curation, Formal analysis, Validation. **Markus Stumpf:** Conceptualization, Supervision, Writing – original draft. **Johannes Beckmann:** Supervision, Validation, Writing – original draft. **Wolfgang Böcker:** Conceptualization, Supervision, Validation. **Carl Neuerburg:** Conceptualization, Supervision, Validation, Writing – original draft. **Christoph Linhart:** Conceptualization, Supervision, Validation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2024.112043.

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