Injury, Int. J. Care Injured 50 (2019) 337–343

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Inter- and intraobserver reliability and critical analysis of the FFP classification of osteoporotic pelvic ring injuries

Dietmar Krappinger[a], Verena Kaser[b], Christian Kammerlander[c], Carl Neuerburg[c], Anke Merkel[a], Richard A. Lindtner[a,*]

[a] Department of Trauma Surgery, Medical University of Innsbruck, Austria
[b] Department of Radiology, Medical University of Innsbruck, Austria
[c] Department of General, Trauma and Reconstructive Surgery, Ludwig Maximilian University Munich, Germany

ARTICLE INFO

Article history:
Accepted 13 November 2018

Keywords:
Pelvic fracture
Pelvic ring fracture
Pelvic ring injury
Fragility fracture
Osteoporotic fracture
Insufficiency fracture
Osteoporosis
Classification
Intraobserver reliability
Interobserver reliability
Reliability

ABSTRACT

Introduction: The classification and management of osteoporotic pelvic ring injuries (OPRI) remain challenging. The fragility fractures of the pelvis (FFP) classification system proposed by Rommens and Hofmann constitutes the first comprehensive classification system of OPRI and may contribute to a more thorough assessment and grading of these injuries. The reliability of the FFP classification system, however, has not been evaluated yet. The purpose of this study therefore was to determine the inter- and intraobserver reliability of the FFP classification system and to critically analyse its strengths and weaknesses.

Materials and methods: One-hundred pelvic CT scans obtained from a consecutive series of patients aged 70 years and older who sustained a low-energy pelvic ring injury were included in this study. Three orthopaedic traumatologists of varying levels of experience (one experienced pelvic surgeon, one consultant, one resident) and one musculoskeletal radiologist independently classified each OPRI according to the FFP classification in two different sessions. Intra- and interobserver reliability were determined using percentage agreement and Cohen's Kappa coefficients.

Results: The observed relative distribution of FFP fracture types was comparable to that reported in the original study by Rommens and Hofmann. Overall interobserver reliability for all 100 cases was moderate with Kappa values from 0.42 to 0.59 (mean percentage agreement: 61% (54%–68%)), while intraobserver reliability was substantial with Kappa values from 0.68 to 0.72 (mean percentage agreement: 77% (76%–78%)). Subgroup analysis revealed lowest reliability for the classification of Type IIc, IIIc and IVb injuries (32 cases). Within this subgroup of combined anterior and posterior OPRI involving a complete nondisplaced or displaced (uni- or bilateral) sacral fracture, Kappa values for interobserver reliability ranged from 0.10 to 0.52, while those for intraobserver reliability ranged from 0.29 to 0.66.

Conclusion: Overall interobserver reliability of the FFP classification system was moderate, while intraobserver reliability was substantial. Despite the acceptable overall reliability, classification of FFP subtypes involving a complete nondisplaced or displaced sacral fracture showed relatively poor reliability. The latter limits the usefulness of the FFP classification for both clinical and research purposes and needs to be addressed in future studies.

Introduction

The overall incidence of osteoporotic pelvic ring injuries (OPRI) has shown a sharp rise over the last decades [1,2]. Despite their high morbidity and mortality [3–5], these injuries have received considerably less attention in the literature compared to other osteoporotic fractures, such as proximal femoral and humeral fractures or vertebral compression fractures [6–8]. The optimal treatment strategies for OPRI therefore remain largely unclear. This is particularly true with regard to the indications for operative vs. nonoperative treatment. Current treatment recommendations are either expert opinions [9,10] or based on retrospective studies with small sample sizes [11,12] due to the lack of prospective or even randomized studies on OPRI.

Although typically not very popular among surgeons, the classification of fractures represents the essential first step of a

* Corresponding author at: Department of Trauma Surgery, Medical University of Innsbruck, Anichstraße 35, 6020 Innsbruck, Austria.
E-mail addresses: richard.lindtner@i-med.ac.at, r.lindtner@gmx.at (R.A. Lindtner).

https://doi.org/10.1016/j.injury.2018.11.027
0020-1383/

thorough clinical and scientific fracture evaluation. In general, the three major quality criteria for classification systems are validity (extent to which a classification system corresponds accurately to the real world), objectivity (extent to which a classification system works without reference to outside influences and bias) and reliability (extent to which a classification system returns the same results in repeating measurements). While the validity and objectivity of fracture classification systems have to be further proofed during their clinical and scientific application, a high reliability of the classification system is a major prerequisite. Additionally, classification systems need to be comprehensive, simple, related to injury severity and linked with treatment strategies and outcome.

The most widely used classification systems of pelvic ring injuries, i.e. the Tile/AO as well as the Young and Burgess classification, were developed for the classification of pelvic ring injuries in patients sustaining high-energy trauma and thus are often of limited value for the proper assessment and categorisation of OPRI [8,9]. As a consequence, an "A-B" problem [13] as well as a "B-C" problem [8] have been described in the literature when using, for example, the Tile/AO classification for the assessment of OPRI. Rommens and Hofmann [9] therefore published a classification system specifically developed for OPRI (fragility fractures of the pelvis (FFP) classification). The reliability of the FFP classification, however, has not been evaluated yet. The aim of the present study therefore was to assess the inter- and intraobserver reliability of the FFP classification system of OPRI and to critically analyse its strengths and weaknesses.

Materials and methods

The study was approved by the institutional review board. One hundred CT scans obtained from a consecutive series of patients with osteoporotic pelvic ring injuries (OPRI) were analysed. All CT scans were performed during clinical routine with pain in the pelvic region as the indication for all CT scans. Accordingly, the patients were not exposed to any additional radiation for the purpose of this study. Inclusion criteria were (1) OPRI after low-energy trauma or without history of trauma and (2) age > 70 years. Exclusion criteria were (1) pelvic ring injuries after high-energy trauma, (2) age < 70 years, (3) osteolytic pelvic lesions and (4) metal implants in the pelvic ring. Patients with implants in the lumbar spine and the proximal femur not interfering with pelvic CT imaging were not excluded.

The OPRI were classified according to the FFP classification (9) which is summarized in Table 1. Native axial slices as well as coronal and sagittal two-dimensional reconstructions of the pelvic ring were available in a PACS system. Additionally, the observers were able to reconstruct the osseous pelvic ring in any arbitrary plane by using a multiplanar reconstruction tool (IMPAX EE, Agfa Healthcare). The OPRI were independently classified by four observers in order to assess interobserver reliability. The observers had varying levels of clinical experience and different specialities. There was a second-year orthopaedic trauma surgery resident, an orthopaedic trauma surgeon in his first year as a consultant, an orthopaedic trauma surgeon specialised in pelvic surgery with several years of experience and a radiology consultant. The fracture classification of the experienced pelvic surgeon was used for the description of the patients' collective and as a reference for the subgroup analysis. Two months later, the same observers were asked to classify the randomly ordered OPRI cases once more in order to assess intraobserver reliability.

IBM SPSS Version 24.0 (Chicago, IL, USA) was used for the statistical analysis. Metric scaled data are reported as arithmetic mean ± standard deviation. Categorial data are reported as absolute frequencies and relative distribution. A Fisher Exact test was used for the analysis of categorial data. Percentage agreement was used for the description and Cohen's Kappa coefficients were calculated for the analysis of inter- and intrarater reliability. Cohen's Kappa estimates the degree of inter- and intraobserver agreement for categorial data by additionally considering agreement by chance. It uses values between 0 (no agreement beyond random agreement) and 1 (perfect agreement). The grading system of Landis and Koch [14] is widely used for the interpretation of Kappa values. Kappa values between 0.01 and 0.20 are interpreted as "slight agreement", values between 0.21 and 0.40 as "fair agreement", values between 0.41 and 0.60 as "moderate agreement", values between 0.61 and 0.80 as "substantial agreement" and values >0.81 as "(almost) perfect agreement".

Results

There were 86 women and 12 men with a mean age of 83.6 years (range 70.1–97.4 years). Two female patients had a CT scan on the day of trauma and an additional CT scan due to persisting pain after 42 and 77 days, respectively (Fig. 1). Seventy CT scans were performed in the first three days after trauma, 9 CT scans between 4 and 14 days and 14 CT scans later than 14 days after trauma, while 7 patients had no history of trauma. In patients with either no or nondisplaced posterior lesions (i.e. type I and II), 85.9% of all CT scans (73/85) were performed within 14 days after trauma, whereas the rate was 40% (6/15) in patients with displaced posterior lesions (i.e. type III and IV). This difference was statistically significant (Fisher Exact test, p = 0.01).

Table 1
FFP classification system [9].

FFP type		Anterior pelvic ring	Posterior pelvic ring	
I	a	Unilateral	No Injury	
	b	Bilateral		
II	a	No injury	Nondisplaced unilateral posterior injury	Unilateral sacrum fracture
	b	Uni- or bilateral	Nondisplaced uni- or bilateral posterior injury	Crush zone of the ventral sacral ala/Bone bruise in the sacral ala (MRI)
	c	Uni- or bilateral	Nondisplaced uni- or bilateral posterior injury	Nondisplaced sacral (complete), iliosacral or ilium fracture
III	a	Uni- or bilateral	Displaced unilateral posterior injury	Iliac fracture
	b			Iliosacral disruption
	c			Sacral fracture
IV	a	Uni- or bilateral	Displaced bilateral posterior injury	Bilateral iliac fracture or Bilateral iliosacral disruption
	b			Bilateral sacral alar fracture/Spinopelvic dissociation
	c			Combination of different displaced posterior injuries

FFP: fragility fractures of the pelvis.

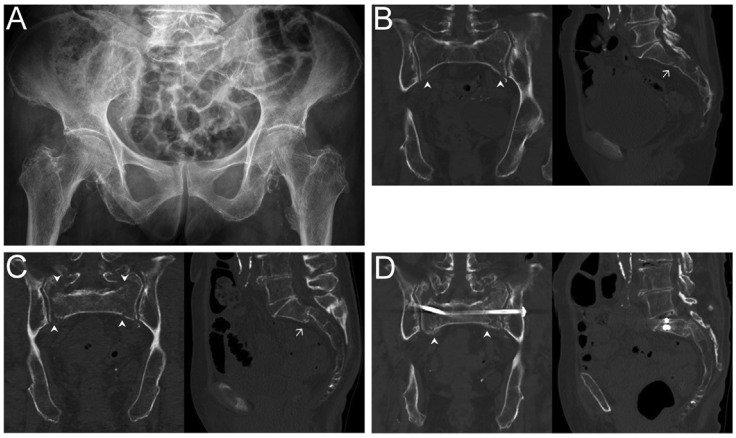

Fig. 1. Eighty-six-year-old female after a simple fall in a nursing home.
(A) Anteroposterior pelvic radiograph after trauma: No injury of the anterior pelvic ring (confirmed by CT). (B) CT scan after trauma (inlet and midline sagittal reconstruction): Bilateral crush zone of the ventral sacral ala (*white arrowheads*). Crush zone of the anterior cortex of S2 in the sagittal midline (*white arrow*) indicating a transverse sacral fracture component. No involvement of the posterior sacral cortex, no displacement or widening of the fracture gap. This fracture was classified as Type IIa, IIb, IIc and IVb by the four observers, respectively. (C) CT scan after 6 weeks of nonoperative treatment: complete bilateral alar fracture with widening of the fracture gaps (*white arrowheads*) and bilateral fractures of the transverse process L5. No neurological deficit. This fracture was classified as Type IVb by all four observers. (D) CT scan 6 weeks after bilateral percutaneous SI screw fixation: bilateral callus formation bridging the anterior cortex (*white arrowheads*).

The relative distribution of FFP fracture types is shown in Fig. 2 and was comparable to that reported in the original study by Rommens and Hofmann. The fracture types Ia, IIb, IIc, and IVb were the most frequent types in both studies. In 79 of 100 CT scans, at least one posterior lesion was detected, whereas no posterior lesion was found in 21 CT scans. Overall, there were 101 posterior lesions (57 unilateral posterior lesions and 22 bilateral posterior lesions) and the vast majority (93/101) were fractures of the sacral ala.

The overall intra- and interobserver reliability for all 100 cases is shown in Table 2. There was substantial intraobserver agreement with Kappa values between 0.68 and 0.72 and mean percentage agreement of 77% (76%–78%). The interobserver reliability was markedly lower with a mean percentage agreement of 61% (54%–68%) and Kappa values between 0.42 and 0.59 indicating moderate agreement. There was no significant correlation between the inter- and intraobserver reliability and the observer's experience in pelvic surgery.

Table 3 shows intra- and interobserver reliability for the 61 cases, which were classified as Type IIb (uni- or bilateral crush zone of the anterior sacral ala) or Type IIc (nondisplaced uni- or bilateral complete sacral fracture) by the pelvic surgeon. Accordingly, this subgroup analysis aimed to assess the reliability of the FFP classification for anterior pelvic ring disruptions with either incomplete or complete nondisplaced posterior sacral lesions, respectively. The intraobserver reliability was comparable to the intraobserver reliability of the entire study group with a mean percentage agreement of 75.5% (74%–77%) and Kappa values between 0.62 and 0.67 indicating substantial agreement. The interobserver reliability was marginally lower than the interobserver reliability for the entire study group with a mean percentage agreement of 57% (50%–67%).

Table 4 shows intra- and interobserver reliability for the 32 cases, which were classified as Type IIc (nondisplaced uni- or bilateral complete sacral fracture), Type IIIc (unilateral displaced sacral fracture) and Type IVb (bilateral displaced sacral fracture) by the pelvic surgeon. Accordingly, this subgroup analysis aimed to assess the reliability of the classification for anterior pelvic ring disruptions with either nondisplaced or displaced complete posterior sacral lesions, respectively. The intraobserver reliability was markedly lower compared to the intraobserver reliability for the entire study group as well as for the combined Type IIb/Type IIc group with a mean percentage agreement of 66.25% (56%–78%) and Kappa values between 0.28 and 0.66. Similarly, the interobserver reliability was markedly lower than the interobserver reliability for the entire study group as well as for the combined Type IIb/Type IIc group with a mean percentage agreement of 49.5% (39%–68%) and Kappa values between 0.10 and 0.52.

Discussion

There is widespread agreement that the established classification systems for pelvic ring injuries, which were initially developed for patients sustaining high-energy trauma, are not suitable for the classification of OPRI in the elderly [8,9,13]. For example, disruptions of the symphysis and the SI joint are frequent in patients sustaining high-energy pelvic ring injuries, whereas these structures are rarely involved in OPRI. Accordingly, classification systems specifically developed for OPRI are mandatory. Linstrom et al. [15] published a classification system of sacral insufficiency fractures based on biomechanical criteria in a finite element analysis. Recently, Bakker et al. [16] described a morphological classification system of sacral insufficiency fractures based on the risk of cement leakage during sacroplasty. Both classifications, however, solely focus on sacral insufficiency fractures and are therefore not comprehensive for OPRI.

A much more comprehensive classification system of OPRI was published in 2013 by Rommens and Hofmann (FFP classification) [9] and is summarized in Table 1. Type I injuries are uni- or bilateral injuries of the anterior pelvic ring without involvement of the posterior pelvic ring. Type II injuries comprise nondisplaced injuries of the posterior pelvic ring. Unilateral displaced posterior injuries are defined as Type III injuries and bilateral displaced posterior injuries as Type IV injuries. Subgroups within each type are distinguished based on morphological criteria such as the involvement of the anterior pelvic ring (no involvement in Type IIa), anterior sacral crush (Type IIb) or complete fracture (involving the anterior and posterior sacral cortex; Type IIc) and the localisation of posterior pelvic ring injury (ilium vs. iliosacral joint vs. sacrum in Type III and Type IV injuries).

The FFP classification represents the first comprehensive classification for a medical problem that is still massively underrepresented in the literature. This classification system has received considerable attention since its publication with more

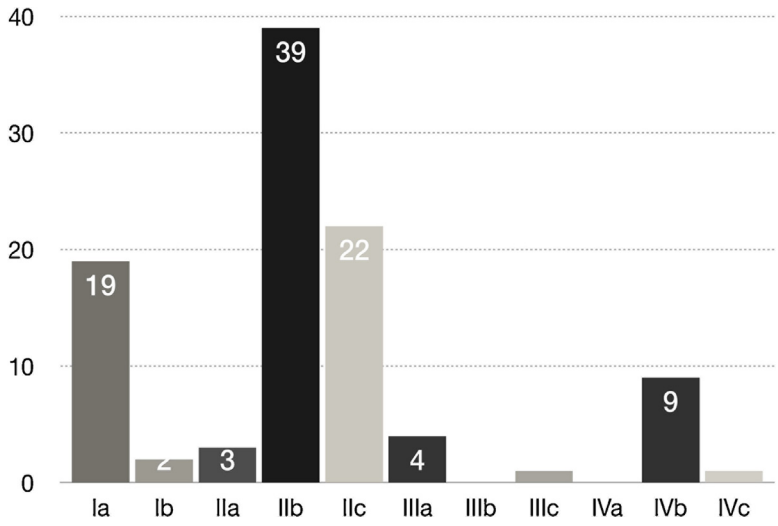

Fig. 2. Relative distribution of fracture types according to the FFP classification (as classified by the pelvic surgeon).

Table 2
Overall inter- and intraobserver *(grey)* reliability (n = 100 cases) (percentage agreement and Kappa coefficients). Values of both sessions were used for the assessment of interobserver reliability.

	Pelvic Surgeon		Consultant		Resident		Radiologist	
Pelvic Surgeon	76%	0.68	62%	0.50	57%	0.45	64%	0.51
Consultant	62%	0.50	77%	0.70	68%	0.59	61%	0.49
Resident	57%	0.45	68%	0.59	78%	0.72	54%	0.42
Radiologist	64%	0.51	61%	0.49	54%	0.42	77%	0.70

Table 3
Inter- and intraobserver *(grey)* reliability for FFP IIb and FFP IIc injuries (n = 61 cases) (percentage agreement and Kappa coefficients). Values of both sessions were used for the assessment of interobserver reliability.

	Pelvic Surgeon		Consultant		Resident		Radiologist	
Pelvic Surgeon	77%	0.66	55%	0.26	50%	0.20	67%	0.35
Consultant	55%	0.26	74%	0.62	61%	0.44	59%	0.35
Resident	50%	0.20	61%	0.44	74%	0.62	50%	0.25
Radiologist	67%	0.35	59%	0.35	50%	0.25	77%	0.67

than 40 citations in less than 5 years (Web of Science, all databases, June 2018). One major strength of the FFP classification is its focus on the posterior pelvic ring. Fractures of the anterior pelvic ring are usually easily diagnosable on X-rays. The diagnosis and interpretation of posterior pelvic ring injuries, however, are much more difficult, which may lead to misinterpretations of OPRI [8,13]. Special attention is given to the sacral ala, where most – and most challenging – OPRI are located [15]. In our study, for example, 92% of all posterior lesions occurred in the sacral ala. Accordingly, the differentiation between Type IIb (nondisplaced anterior sacral ala crush zone) und Type IIc (nondisplaced complete sacral ala fracture involving the anterior as well as the posterior sacral

Table 4
Inter- and intraobserver *(grey)* reliability for FFP IIc, IIIc and IVb injuries (n = 32 cases) (percentage agreement and Kappa coefficients). Values of both sessions were used for the assessment of interobserver reliability.

	Pelvic Surgeon		Consultant		Resident		Radiologist	
Pelvic Surgeon	59%	0.29	51%	0.25	53%	0.26	39%	0.10
Consultant	51%	0.25	78%	0.66	68%	0.52	39%	0.13
Resident	53%	0.26	68%	0.52	72%	0.58	47%	0.19
Radiologist	39%	0.10	39%	0.13	47%	0.19	56%	0.28

cortex) may be subtle at first glance, but is of high clinical relevance according to our own experience.

Rommens and Hofmann additionally described an interesting finding that an osteoporotic pelvic ring injury may progress from a fracture type with a lower degree of instability to a fracture type with a higher degree of instability due to inadequate treatment [9]. This observation may be called “FFP transition”. It was noted that particularly Type III and IV fractures were found in patients with a history of pain for several weeks (Fig. 1). It is thus reasonable to assume that these fractures initially were Type II injuries with subsequent transition to Type III and IV injuries. The results of our study support this interpretation. We found the majority of type III and IV fractures (60%) in patients with either no history of trauma or with a time span of more than 14 days between trauma and CT imaging. In contrast, this rate was only 14.1% in patients with Type I and II injuries (Fisher-Exact test, $p = 0.01$). The transition of a fracture type in the course of time might be unfamiliar for surgeons, but is of great importance in terms of indications for nonoperative vs. surgical treatment of OPRI.

Rommens and Hofmann stated in the original manuscript that a classification system of musculoskeletal injuries must be “comprehensive, simple, inter- and intraoberserver reliable, related to the severity of the injury and connected with treatment strategies and outcome” [9]. These five aspects of the FFP classification will therefore be further discussed and critically analysed in the following section.

Comprehensiveness

A fracture classification is comprehensive if all possible fracture patterns are covered by the classification scheme. The FFP classification covers the vast majority of OPRI and obviously more injury patterns than the abovementioned classification systems of Linstrom et al. and Bakker et al. [15,16]. There are, however, distinct fracture types that are not clearly classifiable using the FFP classification. Fig. 1B, for example, shows CT images of a 86-year-old female, which were obtained a few hours after she had sustained a simple fall. A bilateral crush zone of the ventral sacral ala in the axial CT reconstructions as well as a crush zone of the anterior cortex of S2 in the sagittal reconstructions (indicating a transverse sacral fracture component) were found. There was no involvement of the posterior cortex, no displacement or widening of the fracture gaps and no involvement of the anterior pelvic ring. This fracture was classified as Type IIa, IIb, IIc and IVb by the four observers, respectively, who obviously weighed the different aspects of this injury differently. Type IIa fractures, however, are described as unilateral sacral fractures by Rommens and Hofmann, Type IIb and IIc fractures require an involvement of the anterior pelvic ring and Type III and IV fractures are defined as displaced posterior pelvic lesions. Incomplete bilateral sacral ala fractures without involvement of the anterior pelvic ring are therefore not clearly covered by the FFP classification.

Simplicity

Leonardo da Vinci stated in the 16th century that simplicity is the ultimate sophistication. This is still true 500 years later and applies for fracture classification systems as well. Additionally, simplicity is a prerequisite for reliability. The definition and distinction of the four main injury types of the FFP classification scheme is clear and simple. This is also true for the distinction of subgroups in Type I, III and IV injuries (Table 1). It may be less intuitive, however, for Type II injuries, even though these represent the majority of osteoporotic pelvic ring injuries. Type IIa fractures compromise different types of unilateral nondisplaced sacral fractures without involvement of the anterior pelvic ring, while nondisplaced iliac fractures and sacroiliac disruptions without anterior involvement are not covered in this subgroup. The involvement of the anterior pelvic ring is a prerequisite for Type IIb and IIc injuries. Type IIb injuries on the one hand cover sacral fractures only, while Type IIc injuries additionally include nondisplaced iliac fractures and sacroiliac disruptions for the purpose of comprehensiveness. This might be a bit confusing at first glance. However, we are aware that it is difficult to develop a comprehensive classification that is perfectly simple with an acceptable number of types and subgroups and at the same time does not oversimplify.

Inter- and intraobserver reliability

Higher intra- than interobserver reliability is a common finding in reliability studies [14,17,18]. A theoretically infinite number of different fracture patterns are clustered into a small number of fracture types during the classification process. Although the majority of fractures may be clearly allocated to a defined fracture type, there may be a lack of clarity for fractures in the “grey area” between two fracture types. The allocation of these fractures therefore require some sort of individual interpretation by the observer resulting in higher intra- than interobserver reliability. Although this is not a specific shortcoming of the FFP classification scheme, it emphasizes the need for clear definitions of the distinctive features of each fracture type. The differentiation between Type IIb (ventral sacral ala crush zone) and Type IIc (nondisplaced complete sacral ala fracture), for example, can be

challenging on CT scans in some cases, but at least it is clearly defined (anterior sacral cortex involvement only vs. anterior and posterior sacral cortex involvement). The latter may explain the finding that the inter- and intraoberver reliability for the assessment of Type IIb and Type IIc injuries was comparable to those of the entire study group. In contrast, the proposed criterion for differentiation of Type III and IV injuries from Type II injuries is displacement of the posterior lesion. However, the definition of displacement, in our opinion, remains relatively vague as displacement was defined as "deformation of anatomical landmarks". "Widening and gap formation between fracture fragments" in Type IIIc fractures was described as an additional feature of displacement. Unsurprisingly, the inter- and intraoberver reliability for the assessment of nondisplaced (Type IIc) and displaced (Type IIIc and IVb) posterior sacral lesions was therefore markedly lower in our study. The authors may have been aware of this vagueness as they used the term "complete" instead of "displaced" several times within their manuscript. Focusing on "complete" instead of "displaced" and including the time span between trauma and CT imaging may thus be a viable option to be considered for potential future revisions of the FFP classification.

Relation to the severity of the injury

The FFP classification was developed based on the degree of instability. There are, however, no biomechanical studies assessing the stability of osteoporotic pelvic injuries in the literature yet. Nevertheless, it is reasonable to assume that injuries with involvement of the posterior pelvic ring (Type II–IV) are more unstable than injuries without a posterior component (Type I). Moreover, displaced posterior lesions (Type III and IV) are more unstable than nondisplaced posterior lesions (Type II) and bilateral lesions (Type IV) are more unstable than unilateral lesions (Type III). One drawback of the FFP classification, in our opinion, is the summarization of fractures with different degrees of instability into the same fracture type. This is in particular true for Type IIb and IIc injuries, which may include uni- or bilateral involvement of the anterior and posterior pelvic ring. Accordingly, these injuries consist of a minimum of two and a maximum of four fractures of the pelvic ring. This obviously makes a difference in terms of stability. Furthermore, although Type III injuries are defined as unilateral displaced posterior lesions, Type III injuries with a contralateral nondisplaced posterior lesion are allocated to the same fracture group. Additionally, a transverse sacral fracture component is not considered as a criterion of instability in the FFP classification at all.

Connection with treatment strategies and outcome

Rommens and Hofmann stated that morphological criteria are the most important criteria for the decision between nonoperative and operative treatment as well as for the decision on type and extent of surgery for patients with OPRI [9]. We disagree with this statement. In general, decision-making in ortho-geriatric patients is much more complex than in nongeriatric adult patients. In patients with OPRI, indications for nonoperative or surgical treatment must not solely be based on morphological criteria or distinct fracture types, but requires a comprehensive geriatric assessment, which includes multi-disciplinary assessment tools for the physical, mental and functional state of the geriatric patient [19,20]. Parameters such as preexisting co-morbidities, ambulatory status and social dependency, required pain medication and functional demand need to be considered during the assessment of the "personality of the fractures". Mobility, pain level and function, in our opinion, are more important than the fracture form in geriatric patients and may justify a conservative treatment attempt. In addition, the surgical treatment strategies recommended by Rommens and Hofmann appear to be very aggressive, which also may reflect characteristics of the local health care system. For example, it is recommended to "always combine an anterior fixation with posterior fixation" in FFP Type III lesions and for Type IVb lesions "an iliolumbar fixation will be needed". Fig. 1D, for example, shows a Type IVb injury successfully treated with bilateral percutaneous SI screw fixation. Definite treatment recommendations, in our opinion, should be evidence-based and founded on prospective or even randomized studies. The FFP classification, however, may be a first valuable classification tool to perform high-quality studies comparing different treatment strategies for OPRI.

Some limitations of our study have to be noted. First, 100 CT scans were used in this study. Increasing the number of CT scans would have increased the power of the statistical analysis. This is in particular true for the subgroup analysis. Second, only CT scans were used for the reliability assessment. While fracture lines may be more clearly recognisable in MRI in some cases, the use of CT reflects the clinical routine the FFP classification was mainly developed for. Third, the inclusion of clinical data was beyond the scope of this study. Last, the FFP types as classified by the experienced pelvic surgeon were used as a reference for the description of the patients collective as well as for the selection of cases for the subgroup analysis.

In conclusion, the FFP classification represents a solid basis for the further clinical and scientific assessment of OPRI. Our study revealed moderate overall interobserver reliability and substantial intraobserver reliability of the FFP classification system, but also pointed out several significant limitations. This first comprehensive classification scheme for OPRI was used by the authors for several hundred cases since its publication and served as a valuable tool. The frequent application during clinical routine has allowed us to identify the strengths and limitations of the FFP classification in detail. This may be helpful for surgeons, who have less experience in the treatment of OPRI and in the application of this classification system.

Conflict of interest statement

The authors do not have any conflicts of interest with this study and no funds were received in support of this work.

References

[1] Boufous S., Finch C, Lord S, Close J. The increasing burden of pelvic fractures in older people, New South Wales, Australia. Injury 2005;36:1323–9.
[2] Kannus P, Parkkari J, Niemi S, Sievanen H. Low-trauma pelvic fractures in elderly Finns in 1970-2013. Calcif Tissue Int 2015;97:577–80.
[3] O'Brien DP, Luchette FA, Pereira SJ, Lim E, Seeskin CS, James L, et al. Pelvic fracture in the elderly is associated with increased mortality. Surgery 2002;132:710–4 discussion 714–5.
[4] Breuil V, Roux CH, Testa J, Albert C, Chassang M, Brocq O, et al. Outcome of osteoporotic pelvic fractures: an underestimated severity. Survey of 60 cases. Joint Bone Spine 2008;75:585–8.
[5] Krappinger D, Struve P, Schmid R, Kroesslhuber J, Blauth M. Fractures of the pubic rami: a retrospective review of 534 cases. Arch Orthop Trauma Surg 2009;129:1685–90.
[6] Hill RM, Robinson CM, Keating JF. Fractures of the pubic rami. Epidemiology and five-year survival. J Bone Joint Surg Br 2001;83:1141–4.
[7] Krappinger D, Kammerlander C, Hak DJ, Blauth M. Low-energy osteoporotic pelvic fractures. Arch Orthop Trauma Surg 2010;130:1167–75.
[8] Stuby FM, Schäffler A, Haas T, König B, Stöckle U, Freude T. Insufficiency fractures of the pelvic ring. Unfallchirurg 2013;116:351–64.
[9] Rommens P, Hofmann A. Comprehensive classification of fragility fractures of the pelvic ring: recommendations for surgical treatment. Injury 2013;44:1733–44.
[10] Rommens P, Ossendorf C, Pairon P, Dietz S-O, Wagner D, Hofmann A. Clinical pathways for fragility fractures of the pelvic ring: personal experience and review of the literature. J Orthop Sci 2015;20:1–11.
[11] Mehling I, Hessmann M, Rommens P. Stabilization of fatigue fractures of the dorsal pelvis with a trans-sacral bar. Operative technique and outcome. Injury 2012;43:446–51.

[12] Eckardt H, Egger A, Hasler RM, Zech CJ, Vach W, Suhm N, et al. Good functional outcome in patients suffering fragility fractures of the pelvis treated with percutaneous screw stabilisation: assessment of complications and factors influencing failure. Injury 2017;48:2717–23.
[13] Tosounidis G, Wirbel R, Culemann U, Pohlemann T. Misinterpretation of anterior pelvic ring fractures in the elderly. Unfallchirurg 2006;109:678–80.
[14] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
[15] Linstrom NJ, Heiserman JE, Kortman KE, Crawford NR, Baek S, Anderson RL, et al. Anatomical and biomechanical analyses of the unique and consistent locations of sacral insufficiency fractures. Spine 2009;34:309–15.
[16] Bakker G, Hattingen J, Stuetzer H, Isenberg J. Sacral insufficiency fractures: how to classify? J Korean Neurosurg Soc 2018;61:258–66.
[17] Malek IA, Machani B, Mevcha AM, Hyder NH. Inter-observer reliability and intra-observer reproducibility of the Weber classification of ankle fractures. J Bone Joint Surg Br 2006;88:1204–6.
[18] Imerci A, Aydogan NH, Tosun K. Evaluation of inter- and intra-observer reliability of current classification systems for subtrochanteric femoral fractures. Eur J Orthop Surg Traumatol 2018;28:499–502.
[19] Kammerlander C, Roth T, Friedman SM, Suhm N, Luger TJ, Kammerlander-Knauer U, et al. Ortho-geriatric service–a literature review comparing different models. Osteoporos Int 2010;21:S637–46.
[20] Ellis G, Gardner M, Tsiachristas A, Langhorne P, Burke O, Harwood RH, et al. Comprehensive geriatric assessment for older adults admitted to hospital. Cochrane Database Syst Rev 2017;9: CD006211.>Comprehensive geriatric assessment for older adults admitted to hospitalCochrane Database Syst Rev9: CD006211.