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# Demographic changes in pelvic fracture patterns at a Swiss academic trauma center from 2007 to 2017

**Karin Villiger, MD, Malin Kristin Meier, MD, Rebecca Maria Hasler, MD, Johannes Dominik Bastian, MD, Moritz Tannast, MD, Aristomenis Konstantinos Exadaktylos, MD,** *and* **Simon Damian Steppacher, MD***, Bern, Switzerland*

**BACKGROUND:** Increasing life expectancy has led to higher incidence of fragility fractures of the pelvis. These demographic changes may have a direct impact on fracture patterns. The goal of this study was (1) to evaluate demographical trends in patients with pelvic ring injuries at a tertiary Swiss trauma center and (2) to analyze the influence on fracture patterns.

**METHODS:** We performed a retrospective cross-sectional study including 958 patients (mean ± SD age, 57 ± 21 years; 48% women) with a pelvic ring injury between 2007 and 2017. Fractures were classified according to Tile, Young and Burgess or Rommens and Hofmann (fragility fractures) using conventional and computer tomography imaging. Low-energy fractures were defined as fractures resulting from fall from standing height or less. Fracture classifications, age, sex, Injury Severity Score, and trauma mechanism were compared using analysis of variance or $\chi^2$ test. Cluster analysis was performed to identify groups with similarities in fracture patterns and demographic parameters.

**RESULTS:** From 2007 to 2017, the frequency of pelvic ring injuries increased by 115% (increase per decade), and mean age increased by 15% ($p = 0.031$). A trimodal age distribution was found; highest increase for fractures occurred in the older (265%) patient group. Low-energy fracture was the most common trauma mechanism (43% of all fractures, an increase of 249%). Changes in fracture pattern showed a disproportioned increase of lateral compression (LC) fractures (LC type 1 in 64%) or partially stable fracture (B2, with 39%). In patient older than 65 years, the strongest increase was found for nondisplaced posterior fractures with an overall prevalence of 62%. Five clusters were found with the most frequent cluster representing older female patients with low-energy fracture (LC, Tile type B) in 30%.

**CONCLUSION:** The current results corroborate the trend of increasing frequency of fragility fractures in an aging society. The demographic shift has a direct impact on fracture pattern with a disproportionate increase in partially stable compression fracture of the pelvis. (*J Trauma Acute Care Surg.* 2022;92: 862–872. Copyright © 2021 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American Association for the Surgery of Trauma.)

**LEVEL OF EVIDENCE:** Prognostic/Epidemiologic, Level III.

**KEY WORDS:** Pelvic ring injury; fragility fracture; orthogeriatrics; trauma; epidemiological trends.

Increasing life expectancy has led to a higher incidence of fragility fractures of the pelvis in the elderly population.[1,2] These demographic changes may have a direct impact on fracture patterns observed in pelvic ring injuries. Previous studies reported on demographic trends in patients with pelvic ring injuries; however, results were based on selected patient groups (geriatric patients[2–4] or high-energy trauma[5]) or did not include additional evaluation of fracture patterns.[1,3,5] There is a lack of comprehensive reports of demographic trends and associated pelvic fracture patterns with a detailed and year-by-year evaluation. In addition, result of demographic trends and fracture patterns for the recently introduced classification system for pelvic fragility fractures are sparse.[1–4,6–8]

In the past, we experienced an increase in the frequency of pelvic fragility fractures assigned to the Swiss tertiary trauma center at the author's institution. We hypothesized that changes in demographics such as age, sex distribution, or trauma mechanism have a direct impact on the pelvic fracture patterns. Therefore, the objectives of the current study were (1) to evaluate demographical trends of patients with pelvic ring injuries (frequency, age, sex, and trauma mechanism) over a study period from 2007 to 2017 at a tertiary Swiss trauma center and (2) to analyze the association between demographic changes and pelvic fracture patterns (classification of Tile,[9] Young and Burgess[10] and fragility fractures of the pelvis classification according to Rommens and Hofmann[8]).

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From the Department of Anesthesiology and Pain Therapy (K.V.), Inselspital, Bern University Hospital, University of Bern, Bern; Department of Orthopaedic Surgery and Traumatology (M.K.M., J.D.B., S.D.S.), Inselspital, Bern University Hospital, University of Bern, Bern; Department of Traumatology (R.M.H.), Zürich University Hospital, Zürich; Department of Orthopaedic Surgery and Traumatology (M.T.), Fribourg Cantonal Hospital, University of Fribourg, Fribourg; and Department of Emergency Medicine (A.K.E.), Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland.

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Address for reprints: Simon Damian Steppacher, MD, Department of Orthopaedic Surgery and Traumatology, Inselspital, Bern University Hospital, Freiburgstrasse 8, 3010 Bern, Switzerland; email: Simon.Steppacher@insel.ch.



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# PATIENTS AND METHODS

## Patient Selection

After institutional review board approval, we performed a retrospective cross-sectional study evaluating demographic trends and fracture patterns in patients with pelvic ring injuries assigned to the trauma center of the Inselspital, Bern University Hospital, between 2007 and 2017. It is a tertiary trauma center with 45,000 emergency consultations per year in an area of about 2 million habitants.[11] Patients younger than 16 years were not included in the current study since they are referred to the pediatric emergency department in the hospital. Two different clinical reporting systems of the emergency department were used during the study period with cases recorded in Qualicare (Qualicare AG, Trimbach, Switzerland) up to May 2012 and subsequently in E-Care (E-Care BVBA, Turnhout, Belgium). Inclusion criterion was a documented pelvic fracture in the clinical reporting systems with a total of 1,051 patients from February 2007 to December 2017. Exclusion criteria were missing or incomplete imaging of the pelvis (n = 52 patients; 4.9%), isolated acetabulum fracture rather than the documented pelvic ring fracture (n = 34 patients; 3.2%), and a pathological fracture of the pelvis due to a tumor (n = 7 patients; 0.7%). This left a total of 958 patients with pelvic ring injuries for evaluation (Fig. 1). In 887 patients (93%), imaging included conventional radiographs and computer tomography (CT) of the pelvis, and in 71 patients (7%), conventional imaging only existed. Additional data from the Trauma Audit and Research Network were available for 556 of the 892 patients (62%) from April 2009 to December 2017. Of those 556 patients, the mean Injury Severity Score was 27 ± 15 (4–75), the 30-day mortality rate was 6% (34 of 556 patients), and 309 patients (56%) were assigned to the resuscitation room at admission.

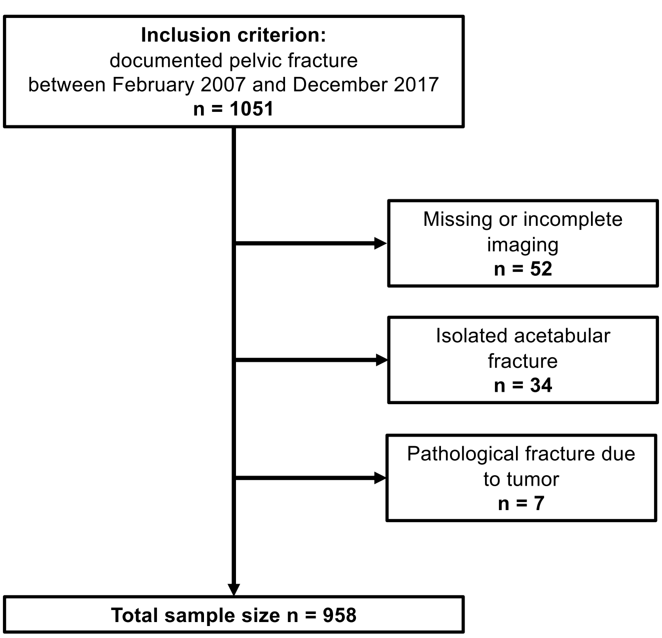


**Figure 1.** Flow diagram showing inclusion and exclusion of patients. After excluding 52 patients because of incomplete imaging, 34 patients because of isolated acetabular fracture, and 7 patients because of fracture caused by tumor, the final sample size was 958.

## Fracture Classification

The fracture pattern of pelvic ring injuries was classified using the conventional images and CT scans according to the classification systems of Tile[9] or Young and Burgess.[10] In patients older than 65 years, fractures were additionally classified according to Rommens and Hofmann[8] for fragility fractures of the pelvis. The classifications were performed by two of the authors: one (K.V.) being a resident specifically trained in classifying pelvic ring injuries and one (S.D.S.) being an experienced orthopedic and trauma surgeon reviewing the cases. The classification systems have previously been evaluated for interobserver and intraobserver reliability and showed a moderate to substantial agreement.[12,13] However, differences in agreement were reported among observers with a different degree of experience regarding the treatment of pelvic trauma.[12,13] For specialized pelvis surgeons, a level of agreement with a $\kappa$ of 0.52/0.50 (interobserver/intraobserver agreement) for the Tile[9] classification, 0.60/0.55 for the Young and Burgess[10] classification, and 0.47/0.49 for the Rommens and Hofmann[8] for fragility fractures of the pelvis has been reported.[12,13]

## Fracture Classification According to Tile

Classification according to Tile[9] was performed depending on the stability of the posterior arch of the pelvis including stable (type A), partially stable (type B), and instable (type C). Each fracture type included three subtypes resulting in a total of nine fracture types according to Tile[9] (Supplementary Table 1, http://links.lww.com/TA/C191). The Tile classification[9] could be applied to 944 of 958 pelvic injuries (99%; Supplementary Table 1, http://links.lww.com/TA/C191) with exclusions of 14 patients (1%) with isolated spinopelvic dissociation with an intact anterior arch of the pelvis.

## Fracture Classification According to Young and Burgess

Classifications according to Young and Burgess[10] were performed according to the fractures mechanism including anteroposterior compression (APC; three subtypes), lateral compression (LC; three subtypes), and vertical shear (VS) injuries with a total seven subtypes. The Young and Burgess classification[10] could be applied in 772 fractures (81%) with exclusion of 172 fractures with an intact posterior arch of the pelvis (Tile type A; 18%) and 14 isolated spinopelvic dissociation (1%). Ambiguities with the classification systems were handled as follows: in cases with bilateral fractures (e.g., B3 or C3 according to Tile[9]), the more severe pelvic fracture was considered for classification according to Young and Burgess.[10] Since symphyseal widening is reduced on images with a pelvic binder, the distinction between Young and Burgess[10] APC1 (<2.5-cm widening) and APC2 (>2.5-cm widening) was performed according to lesion of the posterior arch: a visible opening of the anterior part of the sacroiliac joint fractures was classified as APC2; without widening, as APC1. Anteroposterior compression fractures with symphyseal rupture and a fracture of the posterior ileum were classified as APC3 according to Young and Burgess[10] (defined as symphyses widening with a fracture running through the sacroiliac

**TABLE 1.** Demographic Data Including Mechanisms of Trauma and ISS of the Patients' Series With Pelvic Injuries According the Grading Systems of Tile[9] and Young and Burgess[10] or Age Groups

| | Patients, n (%) | Age, y | Sex (Female), n (%) | Mechanism of Trauma (Patients), n (%) | | | | | | ISS** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Low Energy | MVA | Fall from Height | Sport Accident | Crush Accident | Others | |
| Overall | 958 | 57 ± 21 (16–98) | 48 | 410 (43) | 242 (25) | 123 (13) | 97 (10) | 50 (5) | 36 (4) | 27 ± 15 (4–75) |
| Tile A | 172 (18) | 57 ± 22 (16–96) | 88 (51) | 94 (55) | 33 (19) | 23 (13) | 11 (6) | 9 (5) | 2 (1) | 21 ± 14 (4–57) |
| Tile B | 507 (54) | 58 ± 20 (16–94) | 268 (53) | 225 (44) | 136 (27) | 44 (9) | 63 (12) | 22 (4) | 19 (4) | 23 ± 13 (4–66) |
| Tile C | 265 (28) | 53 ± 20 (19–98) | 99 (37) | 81 (31) | 73 (28) | 53 (20) | 23 (9) | 18 (7) | 17 (6) | 34 ± 14 (4–75) |
| *p* Value* | | 0.002 B vs. C | <0.001 A/B vs. C | <0.001 A vs. B vs. C | 0.098 | <0.001 A/B vs. C | 0.048 A vs. B | 0.325 | 0.022 A vs. C | <0.001 A/B vs. C |
| Y&B APC | 126 (16) | 53 ± 15 (17–84) | 16 (13) | 19 (15) | 38 (30) | 18 (14) | 33 (26) | 15 (12) | 3 (2) | 25 ± 14 (4–75) |
| Y&B LC | 559 (72) | 58 ± 21 (16–98) | 323 (58) | 267 (48) | 146 (26) | 55 (10) | 46 (8) | 21 (4) | 26 (5) | 29 ± 14 (4–59) |
| Y&B VS | 87 (11) | 49 ± 18 (19–88) | 28 (32) | 20 (23) | 25 (29) | 24 (28) | 7 (8) | 4 (5) | 7 (8) | 36 ± 15 (4–66) |
| *p* Value* | | <0.001 APC/ VS. vs. LC | <0.001 APC vs. LC vs. VS | <0.001 APC/ VS. vs. LC | 0.610 | <0.001 APC/ LC vs. VS | <0.001 LC/ VS. vs. APC | <0.001 LC vs. APC | 0.156 | <0.001 APC/ LC vs. VS |
| Young patient group | 187 (20) | 26 ± 5 (16–38) | 63 (34) | 42 (22) | 73 (39) | 37 (20) | 21 (11) | 11 (6) | 4 (2) | 29 ± 16 (4–66) |
| Middle-aged group | 305 (32) | 48 ± 6 (36–62) | 116 (38) | 90 (30) | 80 (26) | 60 (20) | 41 (13) | 21 (7) | 13 (4) | 27 ± 14 (4–75) |
| Older patient group | 466 (49) | 74 ± 10 (58–98) | 282 (61) | 278 (60) | 89 (19) | 26 (6) | 35 (8) | 18 (4) | 21 (5) | 25 ± 15 (4–66) |
| *p* Value* | | <0.001 1 vs. 2 vs. 3 | <0.001 1/2 vs. 3 | <0.001 1/2 vs. 3 | <0.001 1 vs. 2 vs. 3 | <0.001 1/2 vs. 3 | 0.024 1/2 vs. 3 | 0.164 | 0.356 | 0.028 1 vs. 3 |

Continuous data are presented as mean ± SD with range in parenthesis. From the total of 958 pelvic injuries, 944 (99%) were classified according to Tile,[9] and 772 (81%) were classified according to Young and Burgess.[10]
**p* Value for comparisons of all three groups with significant pairwise comparisons listed.
**Scores were available from 556 of 892 patients (62%) from April 2009 to December 2017.
ISS, Injury Severity Score; Y&B, Young and Burgess.

joint). Isolated sacral compression fractures without an anterior ring fracture (as in fragility fractures type II according Rommens and Hofmann[8]) were classified as B2 according to Tile[9] or as LC 1 according to Young and Burgess.[10]

## Fracture Classification According to Rommens and Hofmann

Of the 365 patients older than 65 years, 320 fractures (88%) were classified according to Rommens and Hofmann[8] for fragility fractures of the pelvis. Fractures were classified as anterior injury only (type I), nondisplaced posterior injury (type II), displaced unilateral posterior injury (type III), or displaced bilateral posterior injury (type IV). Exclusions included 27 patients with avulsion fractures or isolated iliac wing fractures (Tile[9] A 1/2) and 18 pelvic injuries with a symphyseal rupture (Young and Burgess[10] APC 1/2, Tile[9] B 1/3).

## Outcome Measures

(1) For the first study objective, outcome measures to describe demographic trends included frequency, patient age at the time of pelvic fracture, sex, and mechanism of trauma. Mechanism of trauma included low-energy fracture with fall from standing height or less, motor vehicle accident (MVA) including accidents of pedestrians, fall from height, sport accident, and crush injury. The patients were separated into age groups using cluster analysis (see Statistical Analysis). An increase/decrease was quantified with the correlation coefficient of the linear correlation model. In addition, the percentage of increase/decrease over the study period from 2007 to 2017 was calculated based on the linear regression model. (2) For the second study objective, outcome measures to describe fracture patterns included the previously described classification systems of Tile,[9] Young and Burgess,[10] or Rommens and Hofmann.[8] The frequency of each

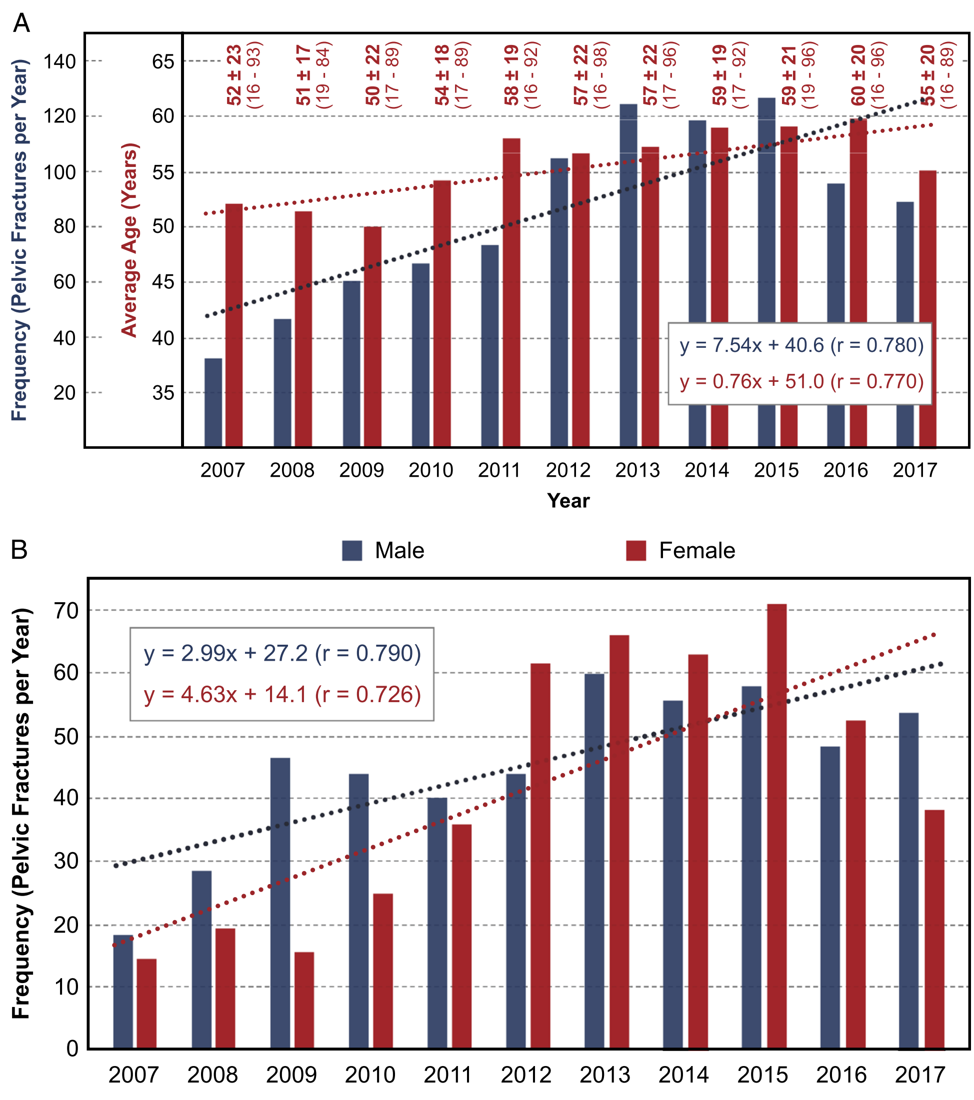


**Figure 2.** (*A*) The Frequency of pelvic ring injuries at a Swiss tertiary trauma center increased from 2007 to 2017 by 157%. In addition, the average patient age per year increased over the study period by 15% ($p = 0.031$). (*B*) No difference for increase existed between male (regression coefficient, 2.99; increase, 99%) and female patients (regression coefficient, 4.63; increase, 246%; p for comparing slope of linear regression, 0.347).

 

fracture type was compared for each year over the study period of 2007 to 2017. Increase/decrease was also quantified using the correlation coefficient and percentage increase/decrease for 10 years.

## Statistical Analysis

We tested normal distribution of continuous data (age, Injury Severity Score) with the Kolmogorov-Smirnov test, and since all continuous data were normally distributed, parametric tests were used. To compare continuous data over the study period, among age groups and fracture patterns, the analysis of variance was performed. If significant differences existed, pairwise comparison was performed with the independent and two-tailed *t* test with Bonferroni correction. Binominal data were compared using the $\chi^2$ test. To quantify an increase/decrease in frequency over the study period, a linear regression analysis was performed and the corresponding regression coefficient was calculated. The increase in frequency between 2007 and 2017 was calculated using the linear regression model. Increase/decrease in frequency of pelvic fractures was compared by comparing the slope of the linear regression among subgroups of fracture classifications, mechanisms of trauma, or sex using the analysis of covariance. Cluster analysis was performed for continuous parameters (age groups) using the Ward's method for hierarchical cluster analysis and for nominal data (fracture patterns) with the two-step

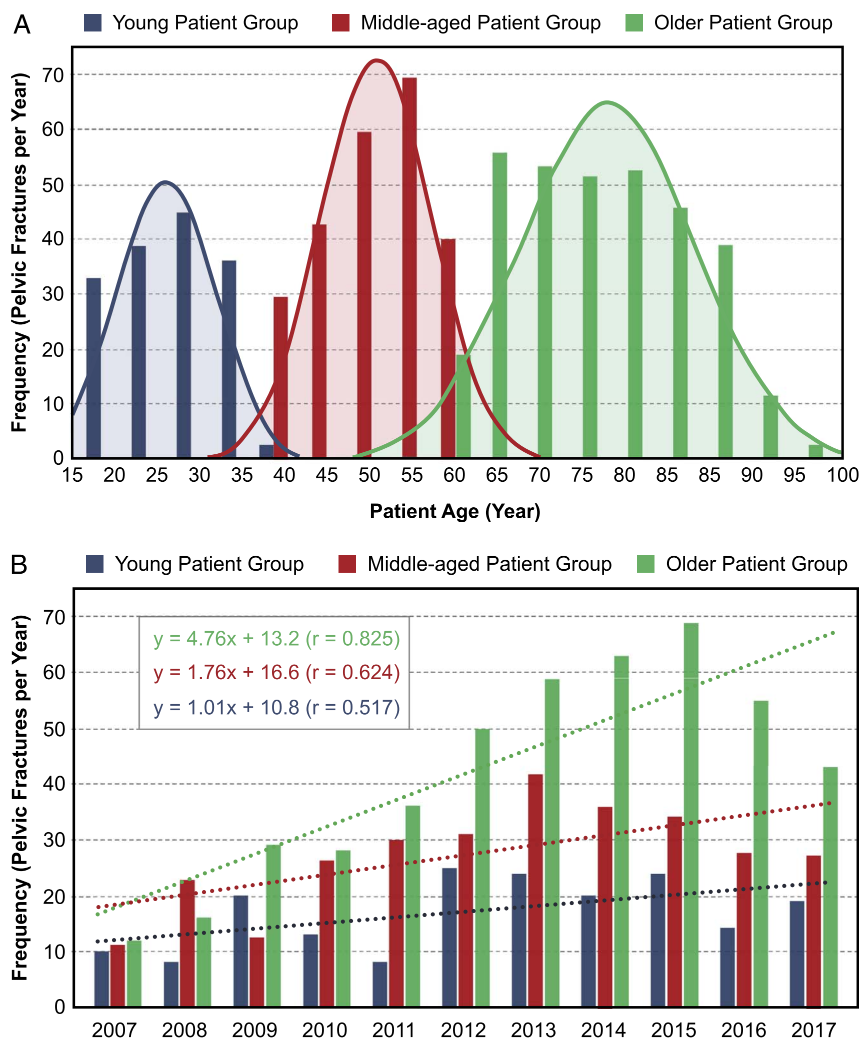


**Figure 3.** (*A*) With the Ward's method for hierarchical cluster analysis,[14] a trimodal age distribution was found for the pelvic ring injuries: the young patients group (total of 187 patients) had a mean ± SD age of 25 ± 6 (16–38) years, the middle-aged patient group (total of 305 patients) had a mean ± SD age of 49 ± 6 (36–62) years, and the older patient group (total of 466 patients) had a mean ± SD age of 74 ± 10 (58–98) years. (*B*) In all age groups, the frequency increased from 2007 to 2017; however, the increase differed among the three age groups (p for comparing slope of linear regression 0.008): the largest increase in frequency was found in the older age group (regression coefficient, 4.76; increase, 265%) compared with the middle-aged group (p for comparing slope of linear regression 0.038) or young age group ( p for comparing slope of linear regression 0.006). The middle-aged group (regression coefficient, 1.76; increase, 96%) and the young age group (regression coefficient, 1.01; increase, 86%) showed a comparable increase ( p for comparing slope of linear regression 0.380).

 

cluster analysis. Statistical analysis was performed using WinStat (Robert K. Fitch Software, Bad Krozingen, Germany) and IBM SPSS Statistics (version 25; IBM Corp., Armonk, NY).

## RESULTS

### Patient Characteristics

Of the 958 included patients, a majority of 677 patients (71%) were primary referrals, and 281 patients (29%) were referred from other hospitals. Overall, sex was equally distributed with 497 male patients (52%) and 461 female patients (48%; Table 1). The mean ± SD age was 57 ± 21 years (range, 16–98 years), and 365 patients (38%) were older than 65 years. A pelvic binder was present on admission in 269 patients (28%).

### Demographic Trends for Frequency, Age, and Sex of Patients With Pelvic Injuries

Over the study period from 2007 to 2017, the frequency for pelvic ring injuries increased by 157% (increase per decade; Fig. 2A). No difference in frequency existed between male (regression coefficient, 2.99) and female patients (regression coefficient, 4.63; $p = 0.347$; Fig. 2B). The average age increased by 15% ($p = 0.031$). Using cluster analysis, a trimodal age distribution was found for pelvic ring injuries (Fig. 3A): the young patients group (187 patients) had a mean ± SD age of 25 ± 6 (16–38) years, the middle-aged patient group (305 patients) had a mean ± SD age of 49 ± 6 (36–62) years, and the older patient group (466 patients) had a mean ± SD age of 74 ± 10 (58–98) years. In all age groups, the frequency of pelvic fractures increased from 2007 to 2017 (Fig. 3B); however, the increase in frequency among age groups differed (p for comparing slope of linear regression 0.008) with the largest increase in the older age group (regression coefficient, 4.76; increase, 265%). The percentage of female patients was higher in the older age group (61% female patients) compared with the middle-aged group (38% female patients; $p = 0.001$) or the younger age group (34% female patients; $p = 0.001$; Table 1).

### Changes in Trauma Mechanism for Pelvic Ring Injuries

Trauma mechanism for pelvic ring injuries changed over time (Table 1; Fig. 4; $p < 0.001$): the largest increase was found for low-energy fractures (regression coefficient, 3.55; increase, 249%), followed by fractures due to MVA, fall from height, sports accidents, and crush injuries (Fig. 4). Overall, low-energy fractures accounted for 43%, MVA for 25%, fall from height for 13%, sport injuries for 10%, crush injuries for 5%, and others for 4% of all pelvic ring fractures (Fig. 4).

### Changes in Fracture Patterns According to Tile

The frequency of all subtypes according to Tile[9] increased with a regression coefficient of 3.80, 2.07, and 1.47 for type B, A, and C fractures, respectively (Fig. 5A; p for comparing slope of linear regression 0.239). This corresponds to an increase of 140%, 393%, and 88% for type B, A, and C fractures, respectively (Fig. 5A). Overall, the most common injury type was the B2 (LC injury) with 39% (Supplementary Table 1, http://links.lww.com/TA/C191; Fig. 5B). In the older patient group, the prevalence of type C fractures was decreased (22%; $p < 0.001$), and the prevalence of type B fractures was increased (58%; $p = 0.014$) compared with the other two age groups (Supplementary Fig. 1, http://links.lww.com/TA/C193). The percentage of female patients was higher in fractures type A (51%) or B (53%) compared with type C (37%; $p = 0.004$ and $p < 0.001$, respectively). Low-energy fractures were the most common mechanism for fractures for all three subgroups according to Tile[9] with a frequency of 55% for type A, 44% for type B, and 31% for type C ($p < 0.001$; Table 1). Fall from height was more common in fractures type C (20%) than type A (13%; $p < 0.001$) or B (9%, $p < 0.001$; Table 1).

### Changes in Fracture Patterns According to Young and Burgess

Lateral compression fractures showed highest increase (regression coefficient, 4.48; increase, 158%; Fig. 6A) compared with the other subtypes (p for comparing slope of linear regression 0.003).

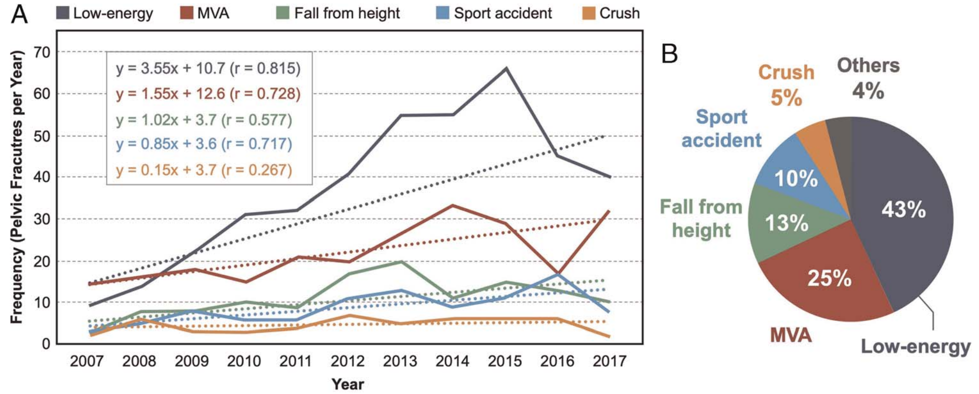


**Figure 4.** (*A*) The increase in frequency differed among the mechanisms for pelvic ring injuries (see also Table 1; p for comparing slope of linear regression <0.001): the largest increase in frequency of 249% was found for fractures due to low-energy fractures (regression coefficient, 3.55); the second largest increase of 110% was found for fractures due to MVAs including accidents of pedestrians (regression coefficient, 1.55), followed by fractures due to fall from height (regression coefficient, 1.02; increase, 216%). Minimal increase was found for sports accidents (regression coefficient, 0.85; increase, 191%) or crush accidents (regression coefficient, 0.15; increase, 39%). (*B*) Overall, low-energy fractures accounted for 43% of trauma.

 

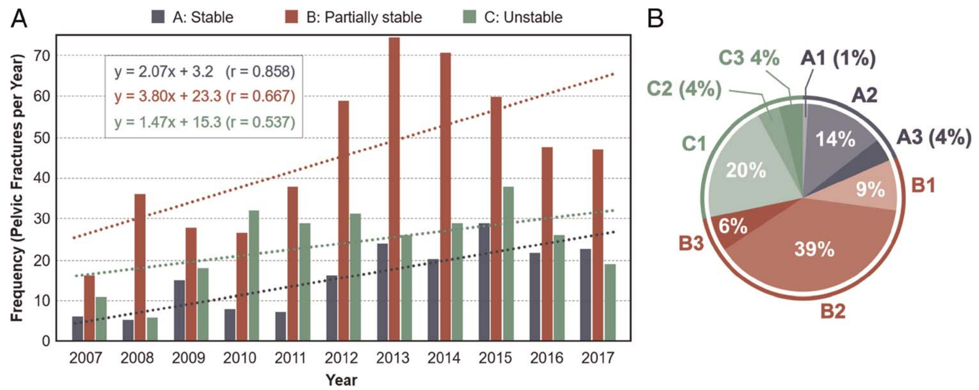


**Figure 5.** (*A*) Pelvic ring injuries classified according to Tile[9] (total of 944 patients [99%]) with increasing frequency in all subgroups from 2007 to 2017 (p for comparing slope of linear regression 0.239): injuries classified as B (partially stable) showed the largest increase over the study period (regression coefficient, 3.80; increase, 140%), followed by injuries classified as A (stable) (regression coefficient, 2.07; increase, 393%) and C (unstable) (regression coefficient, 1.47; increase, 88%). (*B*) Overall, the most common injury type was the B2 (LC injury) with 39% followed by C1 (unilateral complete disruption of posterior arch) with 20% and A2 (iliac wing or anterior arch fracture) with 14%.

No or minimal increase was found for APC (regression coefficient, 0.03; increase, 3%) or VS injuries (regression coefficient, 0.76; increase, 187%; p for comparing slope of linear regression 0.142; Figure 6A). Overall, the most common pelvic ring injury was the LC injury type 1 with 64% (Fig. 6B) (Supplementary Table 1, http://links.lww.com/TA/C191; Fig. 6B). The mean ± SD age of LC fractures was 58 ± 21 (16–98) years and higher than in APC (53 ± 15 [17–84] years; $p = 0.006$) or VS injuries (49 ± 18 [19–88] years; $p < 0.001$; Table 1). In the older patient group, the prevalence of LC fractures was increased (81%; $p < 0.001$), and the prevalence of APC (12%; $p < 0.001$) and VS (7%; $p = 0.002$) injuries were decreased compared with the other two age groups (Supplementary Fig. 1, http://links.lww.com/TA/C193). The percentage of female patients was higher in LC fractures (58%) than in APC (13%; $p < 0.001$) or VS injuries (32%; $p < 0.001$). Low-energy fractures were the most common reason for LC fractures (48% vs. 15% in APC [$p < 0.001$] or 23% in VS. [$p < 0.001$]). Fall from height was more common in VS fractures (28%) compared with APC (14%; $p = 0.016$) or LC fractures (10%; $p < 0.001$; Table 1).

## Changes in Fragility Fracture Patterns According to Rommens and Hofmann

In patients older than 65 years, a distinct increase in the frequency for nondisplaced posterior injuries could be found (regression coefficient, 2.48; increase, 453%; p for comparing slope of linear regression < 0.001; Fig. 7). The other three subgroups showed a marginal increase in frequency over the study period (regression coefficient ranging from 0.15 to 0.45; Fig. 7). Overall, the prevalence of nondisplaced posterior injuries was 62% (Fig. 7).

## Cluster Analysis of Demographic Characteristics and Fracture Patterns (Evaluated for the Entire Patient Sample)

Using cluster analysis, we found five clusters for each the Tile[9] or Young and Burgess[10] classification (Table 2).

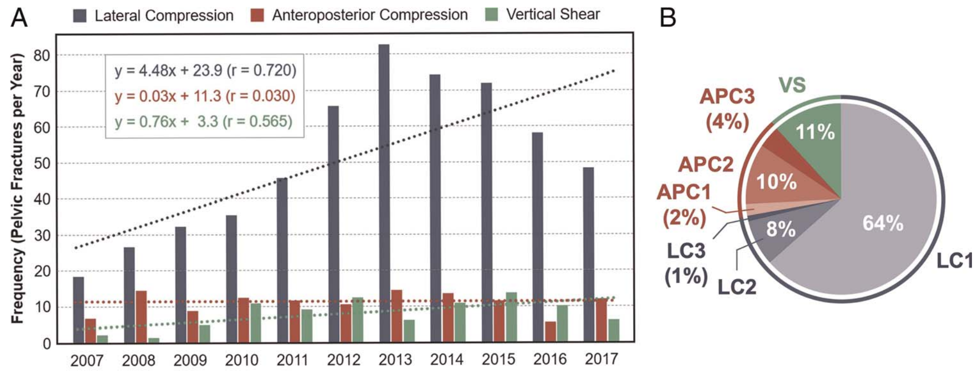


**Figure 6.** (*A*) Pelvic ring injuries classified according to Young and Burgess[10] (total of 772 patients [81%]) from 2007 to 2017 showed significant differences for increase of frequency among the subgroups (p for comparing slope of linear regression 0.003). The LC injuries showed a marked increase in frequency of pelvic fractures (regression coefficient, 4.48; increase, 158%) compared with APC (p for comparing slope of linear regression 0.009) or VS ( p for comparing slope of linear regression 0.025) injuries. No or only marginal increase was found for APC injuries (regression coefficient, 0.03; increase, 3%) or VS injuries (regression coefficient, 0.76; increase, 187%; p for comparing slope of linear regression 0.142). (*B*) Overall, the most common pelvic ring injury classified according to Young and Burgess was the LC injury type 1 with 64%.

 

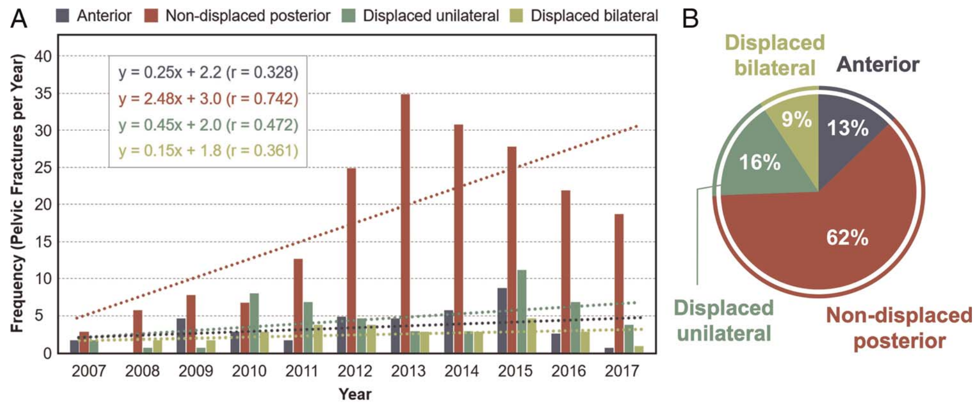


**Figure 7.** (*A*) Fragility fractures of the pelvis in patients 65 years or older classified according to Rommens and Hofmann[8] are shown (total of 320 patients [33%]). A distinct increase in nondisplaced posterior injuries could be found between 2007 and 2017 (regression coefficient, 2.48; increase, 453%; p for comparing slope of linear regression among subgroups, <0.001). (*B*) The nondisplaced posterior injuries accounted for 62% of all fragility fractures.

The most prevalent cluster included predominantly female and older patients with type B[9] or LC[10] pelvic ring fractures (prevalence of 30% and 27%, respectively) due to low-energy fractures (Table 2). In younger and predominantly male patients, we found a prevalence of type C[9] or VS and APC injuries[10] pelvic ring fractures due to high-energy trauma (prevalence of 25% and 18%; Table 2). The third most prevalent cluster included the middle-aged group with type B/C[9] or LC and APC injuries[10] due to high-energy trauma (prevalence of 12% to 23%; Table 2).

## DISCUSSION

Because of the increasing life expectancy, osteoporotic fractures are on the rise.[15] For pelvic ring injuries, an increased frequency has been reported for the older patient population.[3,4] This is in accordance with the results from the current study from a Swiss tertiary trauma center. The strongest increase was found for the older patients group. We found distinct patterns of pelvic ring injuries (Table 2): the most prevalent cluster comprised older and mostly female patients with a compression fracture due to low-energy fracture. The younger patient group included a higher percentage of instable, VS, or APC injuries due to high-energy trauma (Supplementary Fig. 1, http://links.lww.com/TA/C191). In contrast to classic publications reporting a bimodal age distribution for pelvic ring injuries,[6,7] we found a trimodal age distribution (Fig. 3A). The middle-aged patients group comprised (Fig. 3) both LC and APC injuries due to sports or MVAs (Table 2).

We found an increasing frequency of pelvic fractures over the study period from 2007 to 2017 (Fig. 2). This is in accordance with other reports[1–4] (Table 3): an increase of 26% in 27 years (1990–2007) has been reported for patients of any age (Table 3).[1] For patients older than 65 years, an increase of 24%[2] or 37%[4] has been shown after an observation period of 17 and 25 years, respectively (study periods from 1980/90s to 2010s; Table 3). In patients from Finnland older than 80 years, an increase of 499% for an observation period of 43 years (1970–2013) was reported.[3] In the current study, an increase of 157%

**TABLE 2.** Cluster Groups for the Tile[9] and Young and Burgess[10] Classifications of Pelvic Ring Injuries

**Tile Classification**

| Age Group | Sex | Fracture Type | Trauma Mechanism | Prevalence (%) |
|---|---|---|---|---|
| Older | Female | B2, B3, A | Low-energy fracture | 30 |
| Young, middle aged | Male | C, A | Fall from height, MVA | 25 |
| Young, middle aged | Female | B2, C1 | Sport, fall from height, MVA | 18 |
| Older | — | C, B2 | MVA, fall from height | 15 |
| Middle aged | Male | B1, C1 | Sports, crush | 12 |

**Young and Burgess Classification**

| Age Group | Sex | Fracture Type | Trauma Mechanism | Prevalence (%) |
|---|---|---|---|---|
| Older | Female | LC1 | Low-energy fracture | 27 |
| Middle aged, young | — | LC1 | MVA, fall from height | 23 |
| Young, middle aged | — | VS, APC2, APC3 | MVA, fall from height | 18 |
| Middle aged, young | Male | LC, APC | Sport | 18 |
| Older | Male | LC, APC | Low energy, MVA | 14 |

The three age groups were young patients (187 patients with mean ± SD age of 25 ± 6 [16–38] years), middle-aged patients (305 patients with mean ± SD age of 49 ± 6 [36–62] years), and older patients (466 patients with mean ± SD age of 74 ± 10 [58–98] years). See also Figure 3. Tile[9] classification: A, stable; B, partially stable; and C, unstable fractures. Young and Burgess classification[10]: LC, APC, and VS.

 

in 10 years (Fig. 2) was found, which is comparable with the study from Finnland[3] but higher than most reported rates[1,2,4] (Table 3). This could be due to the fact that osteopenic pelvis fractures are steeply rising in aging societies[3] and that the current results are from a more actual patient series starting in 2007 than in the other studies (starting between 1970s and 90s; Table 3). In the study period, the population in the closer area of the hospital (canton of Bern) rose by 7% and in the entire country by 12% (data from Federal Statistical Office of Switzerland, https://www.bfs.admin.ch/bfs/en/home/statistics/population.html, accessed November 16, 2020; Supplementary Table 2, http://links.lww.com/TA/C192). Therefore, an increase of 155% (Fig. 2) for pelvic injuries cannot be explained by the population increase alone. During the study period, the population older than 65 years increased by 21% and 25% for the closer area and Switzerland, respectively (data from Federal Statistical Office of Switzerland, https://www.bfs.admin.ch/bfs/en/home/statistics/population.html, accessed November 16, 2020; Supplementary Table 2, http://links.lww.com/TA/C192). This disproportional growth of the elderly population could be an explanation for the steep increase of pelvic injuries, especially low-energy and osteopenic fractures (Fig. 6). Accordingly, the mean ± SD age of the patient series in the current study increased over the study period by 15% to 55 ± 20 (16–89) years in 2017 (Fig. 2A). In contrast to previous publications reporting a bimodal age distribution for pelvic ring injuries,[6,7] we found a trimodal age distribution (Fig. 3). In addition, a female predominance has been reported,[3,4,20] which we could not find with an overall prevalence of 48% female patients (Table 1). However, we found distinctive groups of pelvic ring injuries using the cluster analysis (Table 2): in older and predominantly female patients, we found LC[10] or partially stable[9] pelvic ring fractures due to low-energy fractures (Table 2; Supplementary Fig. 1, http://links.lww.com/TA/C193). In younger and predominantly male patients, we found a high prevalence of VS and APC injuries[10] or unstable[9] pelvic ring fractures due to high-energy trauma (Table 2; Supplementary Fig. 1, http://links.lww.com/TA/C193). This bimodal distribution has been previously reported.[6,7,20] In addition, we found a relatively large middle-aged group (Fig. 3)

**TABLE 3.** Selected Literature on Demographic and Epidemiological Trends in Patients With Pelvic Ring Injuries

| Author (Year) | No. Patients (Observation Period) | Results |
|---|---|---|
| Gänsslen et al.[16] (1996) | 1,842 (1972–1993) | MVA account for 60%, fragility fracture for 26%, and falls from height for 8%; 55% Tile[9] type A, 25% type B, and 21% type C fractures |
| Pohlemann et al.[7] (1996) | 1,140 (1991–1993) | Bimodal age distribution: first peak around age of 20 to 35 years, second peak for male patients around age of 50 years and for women around 80 years; 64% type A, 21% type B, and 16% type C according to Tile[10] |
| Balogh et al.[6] (2007) | 157 (2005–2006) | 61% Tile[9] type A, 26% type B, and 13% type C; high-energy fractures in predominantly male, younger, and more severely injured patients; types B and C fractures more common in high-energy fractures or fractures with prehospital death. |
| Nanninga et al.[4] (2014) | 34,307 (1986–2011) | Pelvic fractures in patients aged >65 y: increasing incidence of 0.52/1,000 patients in 1986 to 0.71/1,000 patients in 2011 (increase of 37% in 25 years); constant ratio of male/female of 1:4 |
| Sullivan et al.[2] (2014) | 522,831 (1993–2010) | Pelvic fractures in patients aged >65 y: 24% increase in pelvic fractures for the period of 17 years; in the same time increase in elderly population (>65 y) of 30% |
| Kannus et al.[3] (2015) | n.a. (1970–2013) | Low-energy trauma in patients aged >80 years: increasing incidence over study period from 0.73 to 3.64/1,000 (fivefold increase); higher incidence for women and increasing age |
| Ojodu et al.[17] (2015) | 84 (2001–2012) | Complex pelvic fractures in patients aged >70 y: 86% of Tile[9] type B and 14% type C; 10% mortality rate |
| Buller et al.[1] (2016) | 1,464,458 (1990–2007) | Increasing incidence from 0.27 to 0.34/1,000 (26% increase), declining mortality from 4.2% to 2.8%, increasing surgical fixation from 7.2% to 10.4%, and decreasing hospital stay from 11.2 to 6.5 d over the 17-y observation period |
| Hermans et al.[18] (2017) | 537 (2004–2014) | 39% Tile[9] type B, 35% type C, and 26% type A fractures; mean ISS of 26 (ISS 19 in type A, 26 in type B, 33 in type C); fractures were due to high-energy trauma in 87% (MVA, fall from height, crush accident) and low-energy trauma in 13% |
| Pereira et al.[19] (2017) | 66 (2012–2014) | Trauma mechanism includes MVA in 45%, fragility fracture in 25%, fall from height in 6%, and others in 24% (total high-energy trauma, 74%); a majority were Tile[9] type A fractures with 55%, type B in 29%, and C in 17% |
| Rollmann et al.[20] (2017) | 5,665 (1991–2013) | Patients aged >60 y: incidence of Tile[9] type A fractures decreased (from 85% to 44%) and increased for types B (14%–42%) and C (7%–8%) over the study period; stable proportion of 75% of females; type A more frequently in female, types B and C more in male |
| Mann et al.[5] (2018) | 3,915 (2005–2015) | High-energy pelvic ring fractures with an ISS >16: constant incidence of 0.046/1,000 over study period; increased proportion of patients with ISS >50 over the study period; MVA and pedestrian struck by vehicle accounting for more than half of fractures |
| Current study | 958 (2007–2017) | Increasing frequency (female > male patients) and mean age over study period; trimodal age distribution with strongest increase in frequency in older patients; leading trauma mechanism include low-energy fractures and MVA with increasing frequency for both; most common fracture with increasing incidence was B2 (partially stable) according to Tile[9] and LC1 (lateral compression) according to Young and Burgess[10] |

Assessed November 16, 2020.
ISS, Injury Severity Score; n.a., not applicable.

with a prevalence of 32% (Table 1) with LC and APC injuries[10] and (partially) unstable fractures[9] due to high-energy trauma (Table 2; Supplementary Fig. 1, http://links.lww.com/TA/C193).

The demographic changes have a direct influence on the fracture pattern of pelvic ring injuries (Figs. 5, 6, 7) and are associated with different trauma mechanism (Fig. 4). Both low-energy fractures and MVA (including pedestrian accidents) showed a strong increase over the study period (Fig. 4). We found a lower percentage of high-energy trauma of 53% compared with literature ranging from 68% to 87% (Table 3).[16,18,19] Consequently, we had a higher percentage of low-energy trauma of 43% compared with literature (Table 3). According to the increasing number of older patients with osteopenic fractures (Fig. 3B), we found an increasing number of LC fractures[9,10] (Fig. 6). Among the patients older than 65 years, we found a substantial increase in the fractures with nondisplaced posterior pelvic fractures[8] accounting for an overall 62% of all fragility fractures (Fig. 7). According to the classification of Tile,[9] the most prevalent fracture was the type B (partially stable posterior fracture) with 54% followed by type C (unstable posterior fracture) with 28% and type A (stable posterior fracture) with 18% (Table 1 and Fig. 5). This in contrast to most results in literature (Table 3) reporting the highest prevalence for type A fractures followed by B and C.[6,7,16,19,20] The more prevalent type B and C fractures in the current study could also be due to a selection bias, since more severe fractures potentially needing surgical treatment are usually referred to a tertiary trauma center (see also limitations of the study in the next paragraph). Comparable results with a higher prevalence of type B and C fractures have been reported from another referral center for pelvic injuries in the Netherlands.[18]

This study has several limitations. First, there is a selection bias with 29% of the patients referred to the tertiary trauma center from smaller hospitals. These patients potentially had a more severe pelvic injury. This might be a reason why unstable fractures (type C according to Tile[9]) were more frequent than stable fractures (type A; Fig. 5), which is in contrast to most publications[6,7,16,19,20] (Table 3) reporting a higher frequency for type A than C fractures. Despite this selection bias, the group with partially stable fractures (type B according to Tile[9]) and mainly conservative treatment[8] showed the largest increase over the study period. A second limitation is the reliability of the classification systems for pelvic ring injuries, which sometimes only showed a moderate level of reliability, especially for less experienced observers.[12,13] In addition, CT imaging was missing in 7% of the patients, which could have further decrease reliability of classification.[21] Also, some pelvic fractures cannot be classified without any doubts according to Tile[9] or Young and Burgess[10] (see Patients and Methods section). A strength of the study is that all fractures were classified by the same observers (K.V., S.D.S.) and no classifications from medical records were used. Therefore, comparison among the years over the study period or subgroups is not susceptible for interobserver disagreement.

The current study shows in a year-by-year fashion the demographic shift in patients with pelvic ring injuries from 2007 to 2017. Low-energy fractures in elderly patients are on the rise, more than in any other patient subgroup (Fig. 3B). In contrast to classic reports on pelvic ring injuries from the 90s, we found a trimodal age distribution (Fig. 3A): most prevalent are low-energy fractures in the elderly patients followed by high-energy trauma in younger patients (Table 2). In addition, we found a third subgroup with middle-aged patients with fractures due to mainly high-energy trauma. A strength of the study is the detailed and year-by-year evaluation of the fracture pattern spanning a decade. The demographic shift could be shown to have a direct impact on fracture pattern with a disproportionate increase in partially stable compression fracture of the pelvis. The current results corroborate the trend of increasing frequency of fragility fractures in an aging society, representing a major public health burden. The descriptive radiographic results serve as the basis for future interventional studies.

## AUTHORSHIP

All authors have significantly contributed to either concept and study design, ethical approval, data acquisition, imaging analysis, interpretation of data and statistics, creation of figures, writing of initial draft, manuscript editing, or critical review.

## DISCLOSURE

The authors declare no conflicts of interest.
The study protocol was approved by the local ethics committee (approval number KEK-BE 2016-00625).

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