



Correlations between Vancouver type of periprosthetic femur fracture and treatment outcomes

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ABSTRACT

Objective: Periprosthetic femur fractures are one of the most severe complications of total hip arthroplasty.

Methods: The aim of this study was to assess outcomes of periprosthetic femur fractures based on the Vancouver classifications of fractures.

Results: Sixty-four patients were enrolled into the study. Type B1 fractures were the most common – 33 cases. In comparison to patients with type B3 fracture, patients with type B1 fracture significantly less often experienced postoperative pain.

Conclusion: Study shown that in the context of both objective outcomes of the operation and patient satisfaction, the most unfavourable prognosis is after type B3.

1. Introduction

Hip arthroplasty has become one of the most common orthopaedic surgeries over the last decades. By virtue of very good long-term outcomes, it is considered the gold standard in the treatment of hip osteoarthritis.¹ According to the American Joint Replacement Registry, 42,249 primary total hip arthroplasties were performed in 2014.² Furthermore, in Sweden the number of procedures was 16,565.³

Periprosthetic femur fractures are one of the most challenging complications of total hip arthroplasty (THA) to treat.⁴ As the number of total hip arthroplasties being performed increases, the number of their complications, including periprosthetic fractures, rises proportionally. According to the Swedish Hip Arthroplasty Register of 2014, 8.4% of revision hip arthroplasties were performed due to periprosthetic fractures in 2001–2014. This complication became the fourth most common cause of revision surgeries, following loosening/osteolysis (51.5%), infection (16.3%) and dislocation (18.7%), respectively.³ Moreover, according to the American Register, periprosthetic fracture was the sixth most common cause of revision surgeries (4%) in 2012–2014, following mechanical loosening (15.7%), other mechanical complications (16%), dislocation (13.9%), infection and inflammatory reaction (7.7%) as well as articular bearing surface wear (6.3%).² It is important to note the difference in the incidence of periprosthetic fractures between primary and revision THA. According to the data, the incidences are about 1% and as many as 4%, respectively.⁵

Periprosthetic fractures may be classified by the time of the occurrence, location and stability of the prosthesis. Intraoperative fractures are distinguished – in such cases an early diagnosis is particularly important.⁶ They occur most often during the implantation of cementless stems; 80% of such fractures occur in the proximal femur.⁷ Another group are periprosthetic postoperative fractures classified as early or late. Risk factors for fractures include weak bone (osteoporosis, osteopenia), past surgery of the proximal femur, osteolysis and aseptic component loosening,⁸ as well as rheumatoid arthritis and chronic steroid therapy.⁹ Moreover, the threat is also posed by neurological and internal diseases, which predispose to falls from own height. What is also significant is the patient's lifestyle and activity; fractures may be more frequent in young, physically active populations during the rehabilitation and return to activity (a higher risk for high-energy trauma) and in elderly patients (osteopaenia/osteoporosis).¹⁰ It should be noted that most periprosthetic fractures are caused by low-energy trauma events, patients often do not provide any traumatic history but only a gradually increasing pain.^{11,12}

There are no explicit algorithms for the management of periprosthetic fractures. Most authors suggest treatment protocols based on the Vancouver classification of fractures. It takes into account fracture location, the stability of the femoral component and the state of bone stock.¹³ It is an effective and reliable classification of fracture types which can be used not only by experts but also by less experienced staff.⁴

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2. Material and methods

The aim of this study was to assess the outcomes following the treatment of periprosthetic femur fractures based on the Vancouver classification of fractures. In total, 187 patients were treated in an Orthopaedics Department due to periprosthetic femur fractures in 1990–2012. Patients who filled in the Hip and Knee Arthroplasty Satisfaction Scale (HKASS) and Harris Hip Score (HHS) during outpatient visits after THA before fracture and after the occurrence and treatment of periprosthetic femur fracture and could be physically examined were enrolled. The study participants were divided into 4 groups based on the Vancouver classification of fractures (B1, B2, B3, AG types). Due to a very small number/the lack of patients with other fracture types, they were not included in the further analysis. All patients provided their informed consent for participation in this study. The study was accepted by the Regional Bioethics Committee and was conducted according to the Declaration of Helsinki. All enrolled patients filled in questionnaires in quiet, adapted conditions that ensured comfort and discretion. The results of the questionnaire were calculated by the researchers using anonymised patient data.

2.1. Statistical analysis

Variables were analysed for normal distribution using the Kolmogorov-Smirnov test. Continuous variables were expressed as mean \pm standard deviation (SD). The statistical comparison was carried out using the Mann-Whitney *U* test or Student's *t*-test. Discrete variables were compared with the chi-squared test or Fisher test. *P* value of < 0.05 was considered as statistically significant. All statistical analyses were carried out by means of commercially available software (SAS 9.4, SAS Institute, Inc., Cary, NC, USA).

3. Results

Sixty-four patients, including 43 females (67.2%) and 21 males (32.8%), who met the inclusion criteria were enrolled into the study. The mean age of the study group was 75.6 years. The mean time of prosthesis use was 5.7 years and the follow-up period of the patients was 4.7 years. Type B1 fractures were the most common – 33 cases (51.6%). The subsequent most common fracture types were: B3 – 19 (29.7%) and B2 – 10 fractures (15.6%). Two fractures were classified as type AG (3.31%) (Table 1). In 5 patients, the intraoperative fracture was diagnosed. In other patients, the fractures were caused by a fall from a bicycle, a chair and a ladder, respectively. The remaining fractures resulted from a low-energy trauma – a fall from own height. For general characteristics of the study population and the percentage distribution of the fracture types, see Table 1.

Table 1
General characteristics of the study population.

Parameter	No. (%) or mean \pm SD
Age (years)	75.6 \pm 10.7
Male sex	21 (32.8%)
Prosthesis type	
- hemiarthroplasty	7 (10.9%)
- cemented	19 (29.7%)
- cementless	16 (25.0%)
- revision	22 (34.4%)
Time of the prosthesis use (years)	5.7 \pm 5.3
Time of observation (years)	4.7 \pm 3.1
Type of fracture according to the Vancouver scale	
- type B1	33 (51.6%)
- type B2	10 (15.6%)
- type B3	19 (29.7%)
- type AG	2 (3.13%)

Data are presented as mean \pm standard deviation (SD) or number (%).

Outcomes following the treatment of periprosthetic fractures based on the Vancouver classification of fractures were assessed. The most common fracture type was type B1 fracture – 33 cases. In this population, the treatment of choice was open reduction and internal fixation (ORIF). The following plates were used: integration (BHH Mikromed, Poland) – 14 patients, BMP (Biomet, USA) – 10 patients, and Accord (Smith&Nephew, USA) – 2 patients. Fractures were stabilised using metal loops (2 cases) and an AO plate with Partridge band (2 cases). In 1 patient, apart from stabilisation with an AO plate, allogeneic bone grafting supported with metal mesh was used. Another 2 patients with type B1 fracture were treated conservatively. In the case of type B2 fracture, the stem of the endoprosthesis was replaced with a new one, including without additional strengthening in 2 patients. In another two patients, the stem was strengthened with a plate and in six – with metal loops. There were 19 type B3 fractures in the study cohort. Five patients underwent rearthroplasty with replacement of the stem with a new one strengthened with a metal mesh and bone grafts, in another 3 patients the stability of the revision prosthesis was strengthened with metal loops and grafts. In two cases, a mesh and loops were used for stabilisation after rearthroplasty. One patient underwent rearthroplasty with replacement of the stem for a new one without any grafting. In two cases, after rearthroplasty the stability of the fracture was strengthened with a plate. In 6 patients, the implantation of post-resection prostheses was required. There were 2 fractures classified as AG. In one patient, they were treated with Weber's tension band. In the other case, the region of the greater trochanter was filled with bone grafts and supported with a metal mesh and loops as the fracture was caused by severe osteolysis.

In the study patient cohort, the baseline surgery before the fracture was hip hemiarthroplasty in 7 cases. 35 patients underwent primary total hip arthroplasty; 19 had cemented and 16 had cementless arthroplasty. Twenty-two patients underwent revision surgery.

There were statistically significant differences between groups regarding the outcomes assessed on the basis of both HHS and HKASS scales.

HHS score is shown in Table 2 as well as Fig. 1a and b. (Table 2, Fig. 1a, Fig. 1b). Significant differences between groups depending on the fracture type can be seen. Patients with type B1 fracture were significantly ($p < 0.05$) younger than patients with type B3 fracture (74.5 ± 11.1 vs. 79.2 ± 8.5) but significantly older than patients with type AG fracture (74.5 ± 11.1 vs. 72.5 ± 9.2). In comparison to patients with type B3 fracture, patients with type B1 fracture significantly less often experienced postoperative pain, had fewer problems with using public transportation and stairs as well as during daily activities such as putting on shoes ($p < 0.05$). Similarly, in the context of limping, maximum distance walked or daily activities, in patients with type B2 fracture in comparison with those with type B3 fracture the outcomes of the surgery were better. Furthermore, in type AG compared with type B3 fracture better outcomes were observed: less limping, longer walked distance, more frequent use of public transportation and stairs as well as fewer problems with daily activities. On this basis, it appears that the worst postoperative outcomes are noted in patients with type B3 fracture.

Overall outcomes of the surgery assessed using HHS were also different between groups; however, statistical significance was not observed. For these results, see Fig. 1.

As far as HKASS is concerned, the differences were statistically significant. Patients with type B1, B2 or AG fracture had significantly greater satisfaction with the surgery in terms of pain relief and overall outcome following the surgery than those with type B3 fracture. Regarding the possibility of playing sports and doing household chores, statistical significance was observed between groups B1 and B3 (Table 3).

Table 2
Results of the Harris hip score (HHS) according to the fracture type. Data are presented as mean ± standard deviation (SD) or number (%).

Parameter	Fracture type	Fracture type			
		Type B1 (n = 33)	Type B2 (n = 10)	Type B3 (n = 19)	Type AG (n = 2)
Age (years)		74.5 ± 11.1 ^{#*}	72.7 ± 12.9 [§]	79.2 ± 8.5	72.5 ± 9.2
Pain	prior to the surgery	37.1 ± 4.8	37.0 ± 4.8	34.7 ± 7.7	40.0 ± 0.0
	after the surgery	29.4 ± 7.0 [*]	28.0 ± 6.3	24.7 ± 7.7	35.0 ± 7.1
Limping	prior to the surgery	8.6 ± 2.7	8.6 ± 1.9	7.4 ± 2.2	9.5 ± 2.1
	after the surgery	5.5 ± 2.9	6.2 ± 1.5 [§]	4.9 ± 3.2 ¹	8.0 ± 0.0
Distance walked	prior to the surgery	7.7 ± 3.0	8.6 ± 2.4	6.9 ± 2.5 ¹	11.0 ± 0.0
	after the surgery	5.3 ± 2.9	6.5 ± 2.5 [§]	3.9 ± 2.6 ¹	8.0 ± 0.0
Sitting	prior to the surgery	3.9 ± 2.1	4.0 ± 2.1	3.2 ± 2.5	5.0 ± 0.0
	after the surgery	3.8 ± 2.2	4.0 ± 2.1	3.2 ± 2.5	5.0 ± 0.0
Using public transportation	prior to the surgery	0.4 ± 0.5	0.5 ± 0.5	0.2 ± 0.4 ¹	1.0 ± 0.0
	after the surgery	0.3 ± 0.5 ^{**}	0.3 ± 0.5	0.1 ± 0.2 ¹	1.0 ± 0.0
Using stairs	prior to the surgery	2.1 ± 1.4	2.6 ± 1.3 [§]	1.5 ± 0.8 ¹	4.0 ± 0.0
	after the surgery	1.0 ± 0.8 [*]	1.4 ± 1.2 [§]	0.4 ± 0.6 ¹	2.0 ± 0.0
Activities: putting on shoes, socks	prior to the surgery	2.5 ± 1.2	2.8 ± 1.0 [§]	1.9 ± 0.8 ¹	4.0 ± 0.0
	after the surgery	1.6 ± 1.5 ^{**}	2.0 ± 1.3 [§]	0.7 ± 1.0 ¹	4.0 ± 0.0
Joint deformations	prior to the surgery	3.5 ± 0.6	3.5 ± 0.5	3.4 ± 0.6	4.0 ± 0.0
	after the surgery	3.0 ± 0.5	3.1 ± 0.3	2.7 ± 0.7	3.0 ± 0.0
Joint motion	prior to the surgery	3.0 ± 0.2	3.0 ± 0.0	2.9 ± 0.2	3.0 ± 0.0
	after the surgery	2.7 ± 0.5	2.7 ± 0.5	2.5 ± 0.5	3.0 ± 0.0
Mean total score	prior to the surgery	68.6 ± 13.2	70.6 ± 10.4	62.1 ± 12.5 ¹	81.5 ± 2.1
	after the surgery	52.3 ± 15.0 [*]	54.2 ± 13.5 [§]	43.1 ± 13.6 ¹	69 ± 7.1
- Good score	prior to the surgery	10 (30.3%)	3 (30.0%)	1 (5.3%)	1 (50.0%)
	after the surgery	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
- Fair score	prior to the surgery	7 (21.2%)	2 (20.0%)	1 (5.3%)	1 (50.0%)
	after the surgery	6 (18.2%)	1 (10.0%)	1 (5.3%)	1 (50.0%)
- Poor score	prior to the surgery	16 (48.5%)	5 (50.0%)	15 (78.9%)	0 (0.0%)
	after the surgery	27 (81.8%)	9 (90.0%)	18 (94.7%)	1 (50.0%)

@ - significant difference between fracture type B1 and B2.
 & - significant difference between fracture type B2 and AG.
 #- significant difference between fracture type B1 and AG.
 * - significant difference between fracture type B1 and B3.
 § - significant difference between fracture type B2 and B3.
 # - significant difference between fracture type AG and B3.

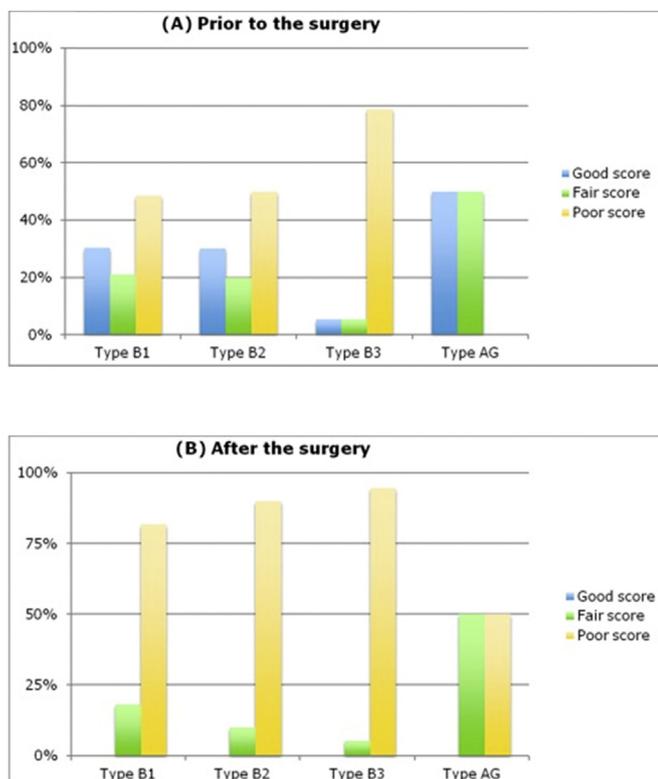


Fig. 1. Summary of HHS before (a) and after (b) the surgery by the fracture type.

4. Discussion

Due to the global increase in the number of THA performed, the number of periprosthetic femur fractures also grows.^{14,15} Such surgeries are also technically challenging owing to frequent coexistence of the fracture, implant loosening and bone loss.¹⁶ The rate of complications following the treatment of the periprosthetic fracture is high and they are estimated to occur in 26%–43% of cases.¹⁷ According to the data, periprosthetic fractures are associated with significant deterioration in patient functionality¹² and increased mortality.¹⁶ They are also a negative phenomenon in the economical aspect as fracture treatment and rehabilitation generate considerable costs.⁴

The number of available papers on outcomes following the treatment of periprosthetic fractures is limited and the methodology often differs, which hinders the comparison of the results of various authors.^{18,19} Available data compare overall outcomes following fracture treatment based on the fracture type, treatment methods used and the type of the primary surgery prior to the fracture. The main factor affecting the choice of treatment method is the Vancouver classification of fractures. However, some authors emphasize that the algorithm related to the classification should not be strictly followed, but the treatment method should be modified depending on coexisting hip pathology, patient functional state and activity.²⁰

Moreta et al. analysed functional and radiological treatment outcomes of 59 periprosthetic femur fractures.¹² According to the Vancouver classification, in the study cohort there were: 8 type A, 24 type B1, 14 type B2, 8 type B3 and 5 type C fractures. HHS was used to evaluate patient functionality while Beals and Tower's criteria to assess radiological results. Follow-up averaged 33 months. Fracture union was achieved in 54 cases within 6 months. Radiological results were

Table 3Results of the HKASS score according to the fracture type. Data are presented as mean \pm standard deviation (SD) or number (%).

Parameter	Fracture type			
	Type B1	Type B2	Type B3	Type AG
How satisfying for you are the results of operation in terms of pain?	17.5 \pm 4.2 ^{#*}	16.7 \pm 3.3	15.0 \pm 3.3 ¹	25.0 \pm 0.0
How satisfying for you are the results operation in terms of ability to perform household and gardening works?	12.5 \pm 4.2 [*]	11.7 \pm 4.2	10.0 \pm 4.2 ¹	16.7 \pm 0.0
How satisfying for you are the results of operation in terms of ability to do sports and recreation?	13.3 \pm 4.2 [*]	14.2 \pm 4.2	10.8 \pm 5.0	16.7 \pm 0.0
How satisfying for you are the results of operation in general?	15.0 \pm 3.3	14.2 \pm 4.2	12.5 \pm 5.0	16.7 \pm 0.0
Total mean	56.6 \pm 14.1^{#*}	53.3 \pm 15.8	45.8 \pm 14.2¹	75.0 \pm 0.0

@ - significant difference between fracture type B1 and B2.

§ - significant difference between fracture type B2 and B3.

& - significant difference between fracture type B2 and AG.

- significant difference between fracture type B1 and AG.

* - significant difference between fracture type B1 and B3.

- significant difference between fracture type AG and B3.

excellent or good in 42 patients. However, it did not correlate with clinical and functional states. None of the patients improved their mobility prior to the fracture, and 31 patients did not regain their postfracture mobility. The mean postoperative HHS was 67.9. There were complications in 33 patients, and 11 patients required further surgery.

Agrawal et al. assessed outcomes following the treatment of type B1 periprosthetic fractures.²¹ Sixteen patients who underwent a primary total hip or hemiarthroplasty were included in the study. 7 patients had cemented stems, and the others had cementless prostheses. In most patients, the treatment of choice was stabilisation using a cable-grip plating system. In one case, a dynamic compression plate and in another only the wire loops were used. The minimum follow-up was 1 year. The time between the arthroplasty and the fracture was variable and ranged from the direct postoperative period to 11 years. Functional and clinical outcomes were assessed using HHS. There was a statistically significant difference in the scale score between the pre-fracture (86.8) and post-fracture (73.4) period. Moreover, 4 patients had a major complication: 2 patients had a deep infection, 1 had nonunion (an amputation), and 1 had persistent pain requiring removal of all metalwork, including the hip prosthesis. The importance of differentiation between type B1 and B2 fractures due to their distinct treatment is highlighted. Unfortunately, while the fracture itself is easy to diagnose, component loosening often remains unrecognised. According to Larsen et al., a history of increasing pain in the hip area before the fracture may be an important clue.²² In their paper, they present principles which should be followed during the fixation of type B1 fractures. These are: anatomical reduction of the fracture, using long plates from the trochanter to the supracondylar area and secure fixation of the plate over the stem.

Findings from Holder et al. research including 45 patients demonstrated a high percentage of complications following the treatment of periprosthetic fractures.¹⁷ Based on the Vancouver classifications 2 patients had AL fractures, 9 had AG, 15 had B1, 24 had B2, 2 had B3 and 4 had C fractures. Overall, 82% of fractures united with a mean time of 15 months. 27 patients underwent revision arthroplasty and ORIF, whereas the remaining 18 patients had ORIF alone. Fourteen patients experienced complications during the treatment: 6 had infections, 6 had nonunions and 2 had aseptic component loosening. Eleven patients required a revision surgery.

In the study by Hoffman et al., of 2016, outcomes following polyaxial locking plate treatment of fractures were evaluated.⁹ In the study cohort, 33 patients had Vancouver type B1 and 18 had Vancouver type C fractures. Follow-up averaged 25 months. Cemented components were implanted in 19 patients and cementless in the remaining ones. Trauma causing the fracture was determined as high-energy only in 4 cases. In the remaining cases, injuries were of low-energy or not identified (86.3%). It is consistent with our results. Forty-six of 51 patients

(90.2%) had favourable outcome defined as bone union. 5 fractures healed in malalignment (5.3°–8.5° varus). Another 5 patients required revision surgery with 1 patient developing an infection and requiring multiple operative debridements. Unfortunately, functional clinical scale score were not given in the study. Therefore, evaluation of patient fitness prior to and after the surgery was impossible. According to the study results, the treatment of fractures continues to be challenging. An increased risk of nonunion is related to interprosthetic fractures and AO/OTA type B fractures.

Other author group analysed the outcomes following the treatment of fractures with prosthetic component loosening, i.e. B2, in elderly patients with other problems and treatment goals.⁴ Early mobilisation is important; however, it should not delay the fracture healing. 31 patients with type B2 fractures were included in the study. The mean age of the patients was 82 years and the mean time interval from the primary surgery to the fracture was 103 months. Most patients had a fracture around a primary and 3 of them – around a revision hip arthroplasty. All patients underwent the revision arthroplasty with a long cemented stem with bone grafts or plate fixation. It was followed by early/immediate rehabilitation with full weight bearing of the operated limb. 6 patients had major complications within the 3 months following the surgery: 3 patients died, 2 had a deep joint infection, and 1 female patient sustained another fracture of Vancouver type C. Fifteen patients died within the first year after the surgery. None of the implants had to be revised at the mean follow-up of 46 months. The authors suggest that their technique is a good choice in the study population and one of its main advantages is the possibility of early patient mobilisation. Moran presented positive results following the treatment of 3 type B2 and 1 type B3 fractures.²³ All patients underwent a revision total hip arthroplasty using a curved, extensively coated femoral component. Follow-up was a minimum of 2 years. In all cases, clinical outcomes assessed using HHS were good or excellent, and radiographs demonstrated fracture healing as well as satisfactory osseointegration.

According to the study of Korbel et al., the treatment of fractures based on the Vancouver classification gives a positive result. They evaluated 47 periprosthetic femur fractures within the mean 27-month follow-up period. The mean age of the patients was 72 years. For the clinical evaluation, modified Merle d'Aubigné scoring system was used. None of the patients had a poor outcome, but also none of them had an excellent one. In all cases, clinical results of the surgery ranged from fair to good. Most fractures in the study group were of type B2 – 24 cases. 18 patients were treated with a revision arthroplasty and 6, with LCP (3 were complicated by a broken plate). In the whole study population, a relatively high percentage of complications were observed which is consistent with the results reported by other authors. The complications included: 1 LCP plate dislocation (B1), 2 superficial infections (B1, B3), 1 deep infection (B2), 2 prosthesis luxations (B2), 2 femoral nerve palsies (B2), 1 haemorrhagic shock (B2), 1 broken stem

(B2) and 3 broken LCP plates (B2). Like other authors, Korbel et al. highlight the legitimacy of the use of cemented stems in younger and more active patients and cementless ones in elder patients.²⁴

In one of his papers, Berry reported outcomes following the treatment of 8 B3 periprosthetic fractures.²⁵ The mean age of the patients was 68 years (range of 34–80). All patients were treated with revision surgery using a long modular fluted tapered uncemented stem with retention of the proximal femur. One patient died within 1 week after the surgery. Follow-up averaged 1.5 years in the remaining patients. All patients had stable implants and all fractures healed during this period. None of the patients had more than mild pain.

According to the data, periprosthetic femur fractures are a challenging complication, both in clinical and economic aspects.¹⁷ In accordance with numerous studies, including ours, they are usually due to low-energy trauma, most commonly a fall from own height or with no history of trauma.⁹ They significantly impair patients' quality of life and functionality. These operations are difficult owing to their extensive range, considerable blood loss and the risk of complications.¹⁶ Attention should be given to the suitable preparation of the femur canal, and any bony defects should either be grafted or bypassed with a long stem.¹¹ It is worth mentioning that 70% of periprosthetic fractures occur in patients with loose stems, most commonly unrecognised prior to the fracture. Thus, a thorough analysis of radiographs is an important issue.¹¹

Interestingly, there is a higher rate of complications following the treatment of periprosthetic fractures around well-fixed stems compared with those primarily considered to be loosened. It may result from unrecognised peri-implant pathology.¹¹ According to the data, 20% of loose femoral stems go unnoticed during preoperative assessment. Moreover, many of them remain unnoticed during the examination in the operation room.¹¹

5. Conclusions

It has been shown that outcomes following the treatment of periprosthetic femur fractures based on the Vancouver classification differ. In the context of both objective outcomes of the operation and patient satisfaction with fitness as well as experiencing pain following the surgery, it seems that the most unfavourable prognosis is after type B3 fractures. It might be partly due to a significantly older age of patients included in the study.

Conflicts of interest

Authors declare no conflict of interest.

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