

Clinical characteristics and risk factors of periprosthetic femoral fractures associated with hip arthroplasty

A retrospective study

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Abstract

Periprosthetic femoral fracture (PFF) is a complicated complication of both primary and revision hip arthroplasty with an increasing incidence. The present study aimed to summarize the clinical characteristics and identify the risk factors for PFF which would be potentially helpful in the prevention and treatment of PFF.

We retrospectively analyzed the clinical data of 89 cases of PFF, and a case-control study was designed to identify the potential risk for intraoperative and postoperative PFF in both primary and revision hip arthroplasty.

The overall incidence of PFF was 2.08% (intraoperative: 1.77%, postoperative: 0.30%, revision: 13.60%, and primary: 0.97%). The most commonly used treatment strategy was fixation with cerclage wire or band for intraoperative PFF, whereas long stem revision with plate or cortical allograft strut fixation was the main treatment strategy for postoperative PFF. The risk factors for intraoperative PFF in primary total hip arthroplasty (THA) included the diagnosis of development dysplasia of the hip (DDH) (odds ratio [OR]=5.01, 95%CI, 1.218–20.563, $P=0.03$) and CBR ≥ 0.49 (OR=3.34, 95%CI, 1.138–9.784, $P=0.03$). The increased age was associated with increased incidence of postoperative PFF in primary THA (OR=1.09, 95%CI, 1.001–1.194, $P=0.04$). As for the intraoperative PFF in revision THA, we found that receiving multiple operations before revision (OR=2.45, 95%CI, 1.06–5.66, $P=0.04$), revisions due to prosthetic joint infection (OR=6.72, 95%CI, 1.007–44.832, $P=0.04$), the presence of cementless implant before revision (OR=13.54, 95%CI, 3.103–59.08, $P=0.001$), and femoral deformity (OR=8.03, 95%CI, 1.656–38.966, $P=0.01$) were all risk factors.

Screening for high-risk patients, preoperative templating, and detailed discharge instructions may be the potential strategies to reduce the incidence of PFF. The treatment of PFFs should take into account Vancouver classification system, patient's characteristics as well as the experience of the operating surgeon.

Abbreviations: CBR = canal bone ratio, DDH = development dysplasia of the hip, PFF = periprosthetic femoral fracture, SD = standard deviation, THA = total hip arthroplasty.

Keywords: clinical characteristics, hip arthroplasty, periprosthetic femoral fractures, risk factors

1. Introduction

Total hip arthroplasty (THA), a highly effective treatment for patients with hip pain or dysfunction caused by various reasons, was lauded as “the operation of the century” by the Lancet.^[1]

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With the surgical indications broadened and the improvement of prosthetic materials for THA,^[2–4] the number of patients receiving THA is steadily increasing.^[5–7] Accordingly, the number of complications related to THA also has increased, including periprosthetic femoral fracture (PFF). PFF is one of the most important complications because it brings heavy burden to the patients both psychologically and economically as well as posing great challenges to orthopedic surgeons. PFF is also associated with poor clinical outcomes and high mortality rate,^[3,8–11] the prevention of PFF is therefore of great importance.

PFF can be divided into intraoperative fractures and postoperative ones. A literature review showed that the incidence of intraoperative and postoperative fractures ranges from 0.1% to 27.8% and 0.07% to 18%, respectively.^[12] The discrepancy may be accounted for by different demographic data, type of prosthesis, primary diseases, surgical history, the surgeon experience, and so on.^[13]

Published literature generally focused on the risk factors of PFF,^[9,12,14–17] current studies about PFF however do not usually emphasize the clinical characteristics. Our study both summarized the clinical characteristics and analyzed risk factors of PFF which would be potentially helpful in the prevention and treatment of PFF. Besides, we analyzed the risk factors for intraoperative and postoperative PFF in both primary and

revision hip arthroplasty, which might help orthopedic surgeons better target patients with high risk of PFF and develop treatment strategies. Our study also aimed to identify the incidence of intraoperative and postoperative PFF in both primary and revision hip arthroplasty in our Department of Chinese People's Liberation Army (PLA) General Hospital, which was one of the largest joint center in China.

2. Methods

2.1. Clinical characteristics of PFF

We retrospectively analyzed the clinical data of all patients who received primary or revision hip arthroplasty in Chinese PLA General Hospital between January 2010 and December 2014. We identified 3912 primary and 375 revision hip arthroplasties in total. The intraoperative fractures were confirmed based on X-rays and medical records, while the postoperative fractures were identified by at least 12-month follow-up information, that is, all the patients who presented with postoperative PFF before December 2015 following primary or revision THA performed between January 2010 and December 2014 were included in our study. A total of 117 patients were lost to follow-up, as a result we obtained 97.3% of follow-up data of all eligible patients. The study was approved by the Institutional Review Board of Chinese PLA General Hospital. Because it is a retrospective study and all patient information was deidentified before analysis, the informed consent was not required.

According to the time when PFF occurred, the patients were divided into 4 groups, that is, PFF occurring during primary THA (DP group), after primary THA (AP group), those during revision THA (DR group), and after revision THA (AR group). We retrieved all available data of patients with PFF according to medical records and X-rays, including demographics information, preoperative diagnosis, comorbidities, medical history, fracture pattern, and treatment. We also explored the operation time and amount of bleeding of patients with intraoperative PFF, and the surgical expense of patients with postoperative PFF. Vancouver classification system was used for intraoperative and postoperative PFF, that is, the intraoperative PFF classification is based on fracture location, pattern, and stability,^[16] and the postoperative PFF takes into account fracture location, stability, and the remaining bone stock.^[18] Details are shown in Tables 1 and 2.

2.2. Risk factors for PFF

We designed a case-control study to identify the potential risk factors for intraoperative and postoperative PFF. The controls, matched with a 2:1 ratio to the patients with PFF, were selected in the same period from the patients who did not suffer from PFF (no less than 12 months follow-up) and who received similar primary or revision THA as PFF patients.

The following items were included in our statistical analysis: demographic characteristics (age, sex, and body mass index), preoperative diagnosis, comorbidities, medical history, type of

Table 2

Vancouver classification system for postoperative fractures.

Classification	Description
Type A	Trochanter fracture
A _G	At greater trochanter
A _L	At lesser trochanter
Type B	Fracture around the stem
B1	Around or just below a fixed stem
B2	At or just below a loose stem
B3	Poor bone stock
Type C	Fracture located below the stem

stem fixation (cemented or uncemented), the reason for revision THA, and the number of operations before fractures. Canal bone ratio (CBR), which was a ratio between inner and outer diameters of proximal femur at 10 cm below the less trochanter, was used to assess the bone quality. The proximal femur was more likely to be considered as osteoporosis with a $CBR \geq 0.49$.^[19]

2.3. Statistic analysis

Categorical variables were reported as percentages and frequencies, and continuous variables were reported as mean \pm standard deviation if the data followed normal distribution. The demographic characteristics were compared between cases and controls by Student *t* test or Wilcoxon signed-rank test for continuous variables, and Chi-square test for categorical variables. As to the risk factors, we performed conditional logistic regression analysis. First, we allowed $P < 0.15$ in univariate analysis in order to identify potential significant variables, then analyzed these potential variables by multivariate analysis. SPSS 22.0 (SPSS Inc, Chicago, IL) was used to perform this analysis in order to obtain odds ratio with 95% confidence interval. $P < 0.05$ was considered to be significant.

3. Results

3.1. Clinical characteristics of PFF

During the selected study period, the PFF occurred in 89 surgery cases, representing an overall incidence of 2.08%. The demographic characteristics of cases are shown in Table 3. There were 30 cases in DP group (19 Vancouver A2, 4 Vancouver A3, 3 Vancouver B2, and 4 Vancouver B3), 8 cases in AP group (2 Vancouver AG, 1 Vancouver AL, 1 Vancouver B1, 3 Vancouver B2, and 1 Vancouver B3), 46 cases in DR group (1 Vancouver A2, 12 Vancouver A3, 5 Vancouver B2, 24 Vancouver B3, and 4 Vancouver C3), and 5 cases in AR group (2 Vancouver B1, 1 Vancouver B3, and 2 Vancouver C). The incidence of intraoperative and postoperative PFF was 1.77% (76/4287) and 0.30% (13/4287), respectively. The incidence of PFF of revision THA was higher than that of primary THA (13.60% vs 0.97%; $X^2 = 268.45$, $P = 0.00$). All patients in AP group and 4 out of 5 patients in AR group had the medical history of a low energy fall.

The treatment patients received depended on the Vancouver classification system for PFF, patient's characteristics, and experience of operating surgeon.^[20] The most commonly used treatment strategy was fixation with cerclage wire or band for intraoperative PFF, followed by revision with a long stem implant. As to the postoperative PFF, the main treatment was long stem revision with plate or cortical allograft strut fixation (Table 4).

Table 1

Vancouver classification system for intraoperative fractures.

Classification	Fracture site	Subclassification	Description
Type A	Proximal metaphysis	Subtype 1	Cortical perforation
Type B	Diaphysis	Subtype 2	Nondisplaced crack
Type C	Distal to the stem tip	Subtype 3	Displaced and unstable

Table 3**The demographic characteristics of 89 cases.**

Group	DP	AP	DR	AR	Total
Number of cases	30	8	46	5	89
Age (years \pm SD)	41.50 \pm 16.26	60.50 \pm 13.82	55.37 \pm 11.55	52.00 \pm 11.92	50.97 \pm 15.03
Sex (M/F)	7/23	5/3	24/22	2/3	38/51
Height (m \pm SD)	1.60 \pm 0.07	1.64 \pm 0.08	1.65 \pm 0.07	1.64 \pm 0.08	1.63 \pm 0.08
Weight (kg \pm SD)	56.67 \pm 8.55	64.25 \pm 5.29	65.51 \pm 10.79	60.60 \pm 13.63	62.14 \pm 10.54
BMI (kg/m ² \pm SD)	20.31 \pm 3.88	24.02 \pm 3.34	24.07 \pm 3.53	22.28 \pm 3.28	23.37 \pm 3.67
Preoperative diagnosis (numbers)					
DDH	19	1	–	–	20
Avascular necrosis	6	4	–	–	10
Ankylosing spondylitis	2	2	–	–	4
Femoral neck fracture	2	1	–	–	3
Osteoarthritis	1	0	–	–	1
Aseptic loosening	–	–	25	4	29
Prosthetic joint infection	–	–	13	1	14
Pain after THA	–	–	8	0	8

AP group = PFF occurred after primary THA, AR group = PFF occurred after revision THA, BMI = body mass index, DDH = development dysplasia of the hip, DP group = PFF occurred during primary THA, DR group = PFF occurred during revision THA, SD = standard deviation, THA = total hip arthroplasty.

Table 4**The treatment strategies for periprosthetic femoral fractures.**

Group	A _G	A _L	A2	A3	B1	B2	B3	C
DP	–	–	Cerclage wire/band (19)	Cerclage wire/band (4)	–	Cerclage wire/band (3)	Cortical allograft strut (1); plate (1); cerclage wire + long stem (2)	–
DR	–	–	Cerclage wire/band (1)	Cerclage wire/band (12)	–	Cerclage wire/band (5)	Cerclage wire + long stem (19); cortical allograft strut (4); plate (1)	Plate (2); plate + allograft strut (2)
AP	Revision + cerclage wire (2)	Revision + cerclage wire (1)	–	–	ORIF (1)	ORIF + revision (3)	Revision + allograft strut (1)	–
AR	–	–	–	–	ORIF (1); no treatment (1)	–	ORIF + revision (1)	ORIF (2)

AP group = PFF occurred after primary THA, AR group = PFF occurred after revision THA, DP group = PFF occurred during primary THA, DR group = PFF occurred during revision THA, ORIF = open reduction with internal fixation, THA = total hip arthroplasty.

The mean operation time and amount of bleeding of intraoperative PFF patients in primary THA were 143 minutes and 577 mL, respectively, greater than those of controls (110 minutes, $P=0.0006$; 362 mL, $P=0.00$). As for intraoperative PFF patients in revision THA, the mean operation time and amount of bleeding were also greater than those of controls (263 vs 189 minutes, $P=0.00$; 1361 vs 1055 mL, $P=0.02$). The mean surgical cost of patients with postoperative PFF in primary THA was \$10,722.9 (range, \$4907–\$13,459), for PFF after revision THA, the mean surgical cost was \$9345 (range, \$5343–\$13,374).

There were a total of 9 cases in DR group treated with plate and/or cortical allograft strut, and all of them adopted the MP reconstruction prosthesis (LINK, Hamburg, Germany). The mean surgical cost of 9 cases was \$14,095 (range, \$11,488.8–\$19,947.9), higher than that of controls with the same revision stem (\$12,163.2; $T=167$, $P<0.05$).

3.2. Risk factors for PFF

There were 178 patients in the control group, including 76 primary THAs and 102 revision THAs. The univariate and multivariate analysis were performed separately for each group (DP, AP, DR, and AR). The risk factors for intraoperative PFF of primary THA identified by univariate were female, development

dysplasia of the hip (DDH), and $CBR \geq 0.49$. The increased height and weight could slightly reduce risk of PFF. The diagnosis of osteonecrosis of the femoral head (ONFH) was associated with a decreased risk. The multivariate analysis showed that diagnosis of DDH and $CBR \geq 0.49$ were associated with increased incidence of intraoperative PFF in primary THA (Table 5).

The risk factors for postoperative PFF in primary THA identified by univariate analysis were increased age and a $CBR \geq 0.49$. In the multivariate analysis, we found that increased age was associated with increased incidence of postoperative PFF in primary THA (Table 6).

The risk factors for intraoperative PFF in revision THA identified by univariate analysis were female, multiple operations before revision, systemic steroid administration, the revision due to prosthetic joint infection, the use of cementless implant before revision, and femoral deformity. Revision due to implant loosening and the use of cemented implant before revision were both associated with a reduced risk of infection. In the multivariate analysis, we found that receiving multiple operations before revision, revisions due to prosthetic joint infection, the presence of cementless implant before revision, and femoral deformity were all associated with increased incidence of intraoperative PFF in revision THA (Table 7). However, no risk factor was identified for postoperative PFF in revision THA.

Table 5

Univariate and multivariate analysis of risk factors for intraoperative PFF in primary THA.

Variable	Univariate analysis		Multivariate analysis	
	OR (95%CI)	P	OR (95%CI)	P
Female	3.51 (1.310–9.415)	0.01	1.64 (0.465–5.771)	0.44
Age	0.98 (0.949–1.004)	0.09	–	–
Height	0.94 (0.886–0.999)	0.05	0.99 (0.912–1.070)	0.77
Weight	0.95 (0.907–0.993)	0.02	0.96 (0.912–1.011)	0.12
BMI	0.94 (0.835–1.048)	0.25	–	–
DDH	7.69 (2.860–20.696)	0.00	5.01 (1.218–20.563)	0.03
AS	0.79 (0.143–4.309)	0.78	–	–
ONFH	0.29 (0.102–0.799)	0.02	0.99 (0.247–4.014)	0.99
CBR ≥ 0.49	3.00 (1.198–7.514)	0.02	3.34 (1.138–9.784)	0.03
Previous surgery	2.30 (0.725–7.324)	0.16	–	–
Systemic steroid	4.21 (0.366–48.461)	0.25	–	–

AS = ankylosing spondylitis, CBR = canal bone ratio, CI = confidence interval, DDH = development dysplasia of the hip, ONFH = osteonecrosis of the femoral head, OR = odds ratio, PFF = periprosthetic femoral fracture, THA = total hip arthroplasty.

Table 6

Univariate and multivariate analysis of risk factors for postoperative PFF in primary THA.

Variable	Univariate analysis		Multivariate analysis	
	OR (95%CI)	P	OR (95%CI)	P
Female	1.00 (0.173–5.772)	1.00	–	–
Age	1.10 (1.013–1.187)	0.02	1.09 (1.001–1.194)	0.04
Height	1.02 (0.920–1.127)	0.72	–	–
Weight	1.00 (0.940–1.054)	0.87	–	–
BMI	0.99 (0.811–1.199)	0.89	–	–
DDH	0.43 (0.040–4.637)	0.49	–	–
AS	9.00 (0.75–107.39)	0.08	–	–
ONFH	1.67 (0.300–9.272)	0.56	–	–
CBR ≥ 0.49	7.22 (1.076–48.48)	0.04	5.40 (0.551–52.856)	0.15
Previous surgery	2.33 (0.264–20.66)	0.45	–	–
Systemic steroid	5.00 (0.379–66.016)	0.22	–	–

AS = ankylosing spondylitis, CBR = canal bone ratio, CI = confidence interval, DDH = development dysplasia of the hip, ONFH = osteonecrosis of the femoral head, OR = odds ratio, PFF = periprosthetic femoral fracture, THA = total hip arthroplasty.

Table 7

Univariate and multivariate analysis of risk factors for intraoperative PFF in revision THA.

Variable	Univariate analysis		Multivariate analysis	
	OR (95%CI)	P	OR (95%CI)	P
Female	2.92 (1.376–6.181)	0.005	2.57 (0.966–6.844)	0.06
Age	0.98 (0.949–1.010)	0.17	–	–
Height	1.01 (0.971–1.057)	0.55	–	–
Weight	1.01 (0.973–1.042)	0.69	–	–
BMI	0.99 (0.906–1.083)	0.83	–	–
Primary disease				
Femoral neck fracture	0.78 (0.366–1.671)	0.53	–	–
AS	2.15 (0.653–7.082)	0.21	–	–
ONFH	1.25 (0.610–2.571)	0.54	–	–
No. of operations before revision	2.68 (1.447–4.968)	0.002	2.45 (1.06–5.66)	0.04
Systemic steroid administration	7.22 (1.849–28.164)	0.004	5.47 (0.919–32.594)	0.06
Reason for revision				
Prosthetic joint infection	4.14 (1.571–10.89)	0.004	6.72 (1.007–44.832)	0.04
Implant loosening	0.25 (0.114–0.553)	0.001	0.51 (0.133–1.966)	0.33
Pain	3.02 (0.979–9.297)	0.05	–	–
Implant type before revision				
Cementless	4.17 (1.970–8.820)	0.000	13.54 (3.103–59.08)	0.001
Cemented	0.19 (0.069–0.525)	0.001	0.95 (0.191–4.745)	0.95
Spacer	0.81 (0.375–1.769)	0.60	–	–
Femoral deformity	9.32 (2.453–35.437)	0.001	8.03 (1.656–38.966)	0.01

AS = ankylosing spondylitis, CI = confidence interval, ONFH = osteonecrosis of the femoral head, OR = odds ratio, PFF = periprosthetic femoral fracture, THA = total hip arthroplasty.

4. Discussion

PFF is a serious complication of primary and revision hip arthroplasty, and the incidence of it appears to be steadily increasing.^[6,10,20,21] According to our study, the operation time and amount of bleeding of patients with intraoperative PFF in primary THA were all significantly greater than those of controls, and the financial cost for the treatment of PFF was also considerably higher, especially for those using plate or cortical allograft strut during revision. Besides, PFF posed great challenges to orthopedic surgeons because of its common associations with poor follow-up outcomes and high mortality rate.^[3,8-11] In recent years, most of the prostheses used in primary THA in Chinese PLA General Hospital were cementless prostheses, and as for the revision arthroplasty, most of prostheses were MP modular femoral prostheses. So, identifying the risk factors and analyze the characteristics of PFF in recent years are important for its prevention and proper treatment. The aims of our study were to: identify the incidence of intraoperative and postoperative PFF in both primary and revision hip arthroplasty; summarize the clinical characteristics; and analyze risk factors for intraoperative and postoperative PFF in both primary and revision hip arthroplasty.

According to a literature review, the incidence of intraoperative PFF ranges from 0.1% to 27.8% (primary: 0.3% to 18%; revision: 0.1% to 27.8%) and of postoperative PFF ranges from 0.07% to 18% (primary: 0.07% to 11.1%; revision: 1.19% to 18%).^[12] In our study, the incidence of intraoperative PFF was 1.77% and of postoperative PFF was 0.30%, the incidence of PFF of revision THA was higher than that of primary THA (13.60% vs 0.97%), which were all comparable to other reports in the literature.^[12,17]

We found that PFFs occurred during primary THA were seen most frequently in patients with DDH, most of which belonged to Vancouver type A2 characterized by nondisplaced crack of proximal metaphysis. After analysis by our case-control study, we confirmed that DDH was associated with increased incidence of intraoperative PFF in primary THA, which has been consistently identified by other studies.^[15,22] Due to the stenosis of the medullary canal and leg length discrepancy of DDH patients, we usually choose S-ROM prosthesis (DePuy, Warsaw, IN) with or without subtrochanteric shortening osteotomy. As the proximal part of S-ROM prosthesis is tapered in shape, the fracture generally occurs in the process of reaming of the medullary canal and inserting of the prosthesis stem. The treatment of PFF in our study was dependent on the Vancouver classification system, patient's characteristics, and experience of surgeon,^[20] this type of PFF can be treated by fixation with cerclage wire or band.

The bone quality of proximal femur is an important factor for surgeons to consider before primary THA; however, it maybe not practical for each patient to have the bone mineral density examination after admission. According to a cadaveric study, the bone quality of proximal femur can be assessed by CBR, when $CBR \geq 0.49$, the proximal femur is more likely to be considered as osteoporosis.^[19] Our study showed that the patients presented with $CBR \geq 0.49$ were associated with increased incidence of intraoperative PFF in primary THA. Decreased BMD and poor bone quality are related to both intraoperative and postoperative PFF,^[12] and the increased age is often associated with osteoporosis. In our study, though the mean age of patients in AP group was 60.5 years old, $CBR \geq 0.49$ was not identified as a risk factor for postoperative PFF in primary THA. This may be

partly due to the relatively small sample size. On the other hand, the older patients may be more careful after primary THA because we have a detailed discharge instruction for patients to avoid accidental fall.

Most of PFFs occurred during revision THA were displaced and unstable (Vancouver A2, A3), and the majority of revision femoral prostheses used were MP modular femoral prostheses (44/46), among which 31 fractures occurred during reaming of the medullary canal or inserting of the prosthesis stem, and 13 cases occurred when removing prostheses or spacers. Although it is difficult to achieve proximal fixation in some revision cases with severe proximal bone loss, the geometry of MP stem can ensure stability in distal femur. According to one of our previous studies, the most common complication was indeed PFF when revised with MP prostheses, which was the most frequently used prosthesis in revision hip arthroplasty in our hospital. The data showed that the use of cementless implant before revision was a risk factor for intraoperative PFF in revision THA. If the fracture occurred distal to the stem tip, a long stem revision should be used to gain a distal fixation with cortical allograft strut and/or plate as well as cerclage wires and locked screws.

The presence of multiple previous operations of the affected hip is associated with an increased incidence of intraoperative PFF in revision THA. As for prosthetic joint infection, the standard treatment is 2-stage exchange arthroplasty. If there still exist ongoing infection during the 2nd stage, then the spacer will be exchanged, which increases the number of operations. Previous operations may result in bone remodeling, deformity, bone loss, or osteolysis.^[15,23] Our study demonstrated that the reason for femoral deformity included the increasing number of operations before revision, prosthesis fracture, history of fracture, and prosthetic loosening. There were 6 cases presented with femoral deformity in our study, and the fracture sites were where the femoral deformities had developed, probably because of the stress concentration during the implant fixation.^[15] Under such circumstances, preoperative template measurement and intraoperative X-rays will be helpful for the prevention of intraoperative PFF.

As for the postoperative PFFs, 12 out of 13 patients had the history of low energy fall, which is comparable with the data in the literature.^[12] Increased age is a major risk factor for accidental falls and osteoporosis, which may be an explanation as for why the increased age was identified in our study as a risk factor for postoperative PFF in primary THA. Most of postoperative PFFs were type B, the treatment of which should take into consideration fracture pattern, stability, and bone stock, whereas for type C, surgical fixation strategy should be decided according to principles of trauma.^[20]

The study has a number of limitations. First, it is a retrospective case-control study and this design has inherent problems. Second, all the analyzed variables were retrieved according to the medical records and X-rays, which may miss some important information, and further miss some potential risk factors. Third, nondisplaced crack fractures sometimes are clinically unrecognized, and still there were some patients lost to follow-up, so the incidence of PFF we identified may be lower than that of the reality. Finally, there were only 5 patients presented with postoperative PFF in revision THA, which may be the reason why the study failed to identify the risk factors for postoperative PFF in revision THA.

In summary, identification of the risk factors for PFF is of great importance because of the complexity of PFF to the operating surgeon and the heavy burden thus posed to the patients. Screening for high-risk patients, preoperative templating, and detailed discharge instructions may be the potential strategies to

reduce the incidence of PFF. The treatment of PFFs should take into account Vancouver classification system, patient's characteristics as well as the experience of the operating surgeon.

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References

- [1] Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. *Lancet* 2007;370:1508–19.
- [2] Thien TM, Chatziagorou G, Garellick G, et al. Periprosthetic femoral fracture within two years after total hip replacement: analysis of 437,629 operations in the Nordic arthroplasty register association database. *J Bone Joint Surg Am* 2014;96:e167.
- [3] Marsland D, Mears SC. A review of periprosthetic femoral fractures associated with total hip arthroplasty. *Geriatr Orthop Surg Rehabil* 2012;3:107–20.
- [4] Shah RP, Sheth NP, Gray C, et al. Periprosthetic fractures around loose femoral components. *J Am Acad Orthop Surg* 2014;22:482–90.
- [5] Wähnert D, Schröder R, Schulze M, et al. Biomechanical comparison of two angular stable plate constructions for periprosthetic femur fracture fixation. *Int Orthop* 2014;38:47–53.
- [6] Rocca Della GJ, Leung KS, Pape H-C. Periprosthetic fractures: epidemiology and future projections. *J Orthop Trauma* 2011;25(Suppl 2):S66–70.
- [7] Stange R, Raschke MJ, Fuchs T. Periprosthetic fractures. *Unfallchirurg* 2011;114:688–96.
- [8] Dumont GD, Zide JR, Huo MH. Periprosthetic femur fractures: current concepts and management. *Seminars in Arthroplasty* 2010;21:9–13.
- [9] Katz JN, Wright EA, Polaris JJ, et al. Prevalence and risk factors for periprosthetic fracture in older recipients of total hip replacement: a cohort study. *BMC Musculoskelet Disord* 2014;15:168.
- [10] Rupprecht M, Sellenschloh K, Grossterlinden L, et al. Biomechanical evaluation for mechanisms of periprosthetic femoral fractures. *J Trauma* 2011;70:E62–6.
- [11] Streit MR, Merle C, Clarius M, et al. Late peri-prosthetic femoral fracture as a major mode of failure in uncemented primary hip replacement. *J Bone Joint Surg Br* 2011;93:178–83.
- [12] Sidler-Maier CC, Waddell JP. Incidence and predisposing factors of periprosthetic proximal femoral fractures: a literature review. *Int Orthop* 2015;39:1673–82.
- [13] Lindahl H. Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. *Injury* 2007;38:651–4.
- [14] Cook RE, Jenkins PJ, Walmsley PJ, et al. Risk factors for periprosthetic fractures of the hip: a survivorship analysis. *Clin Orthop Relat Res* 2008;466:1652–6.
- [15] Nowak M, Kusz D, Wojciechowski P, et al. Risk factors for intraoperative periprosthetic femoral fractures during the total hip arthroplasty. *Pol Orthop Traumatol* 2012;77:59–64.
- [16] Davidson D, Pike J, Garbuz D, et al. Intraoperative periprosthetic fractures during total hip arthroplasty. Evaluation and management. *J Bone Joint Surg Am* 2008;90:2000–12.
- [17] Watts CD, Abdel MP, Lewallen DG, et al. Increased risk of periprosthetic femur fractures associated with a unique cementless stem design. *Clin Orthop Relat Res* 2015;473:2045–53.
- [18] Duncan CP, Masri BA. Fractures of the femur after hip replacement. *Instr Course Lect* 1995;44:293–304.
- [19] Yeung Y, Chiu KY, Yau WP, et al. Assessment of the proximal femoral morphology using plain radiograph—can it predict the bone quality? *J Arthroplasty* 2006;21:508–13.
- [20] Ricci WM. Periprosthetic femur fractures. *J Orthop Trauma* 2015;29:130–7.
- [21] Cooper HJ, Rodriguez JA. Early post-operative periprosthetic femur fracture in the presence of a non-cemented tapered wedge femoral stem. *HSS J* 2010;6:150–4.
- [22] Mayle RE, Valle Della CJ. Intra-operative fractures during THA: see it before it sees us. *J Bone Joint Surg Br* 2012;94:26–31.
- [23] Hsieh PH, Chang YH, Lee PC, et al. Periprosthetic fractures of the greater trochanter through osteolytic cysts with uncemented MicroStructured Omnifit prosthesis: retrospective analyses of 23 fractures in 887 hips after 5–14 years. *Acta Orthop* 2005;76:538–43.