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Outcomes of Vancouver B2-type and B3-type proximal femur periprosthetic fractures after revision surgery using cementless tapered modular stem: a retrospective case series of 39 fractures

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Summary

Objective. Evaluate outcomes of Vancouver B2-type and B3-type proximal femur periprosthetic fractures (PPFs) in elderly patients treated with a cementless tapered modular femoral stem.

Methods. 37 patients with a proximal femur PPF (34 B2-type and 5 B3-type) on primary or revision implants, with a minimum of 2-year follow-up, treated with revision of the failed stem using uncemented MP® reconstruction system stem (Waldemar Link®), were included.

Results. At last follow-up, the average Harris Hip Score was 91 ± 9.8, and average Numerical Rating Score was 0.7 ± 0.8, without a significant difference between B2-type and B3-type PPFs. X-rays at last follow-up revealed bone union in all patients. According to Beals and Tower's criteria, we found excellent radiological findings in 89.7% patients. Fourteen local surgery-related complications were reported (35.9%), and 4 patients required revision surgery (10.2%), without significant differences between B2-type and B3-type PPFs. We found involvement of both trochanters in fracture as a possible risk factor for dislocation.

Conclusions. Vancouver B2-type and B3-type PPFs can be effectively treated using a cementless modular stem, even without cortical struts graft, although further studies are needed regarding B3-type PPFs.

Key words: periprosthetic proximal femoral fractures, cementless femoral stem, Vancouver classification

Introduction

The number of primary and revision arthroplasty in the USA is expected to increase, respectively, by 174 and 127% within 2030 [1]. Nowadays, surgery is more frequently carried out in older patients with poor bone quality, due to the aging of the general population and to the enlargement of surgical indications, which is

related to innovative prosthetic materials and improvement in surgical technique [1]. In parallel with the rising numbers of total hip arthroplasty (THA), an increase in the number of complications, such as periprosthetic femoral fracture (PFF) are also observed [2]. PFF are defined as fractures around orthopaedics hardware like plates, nails or joint replacement [3]. The true incidence of PFF is uncertain [4], with estimated range from 0.1% to 2% after primary THA and up to 6% after revision procedures (range 4-6%) [5]. The 20-year overall probability to have a PFF after primary hip replacement is about 3.5% [3].

Several local risk factors have been described, including age, female sex, uncemented implants, longevity of the implant, bone loss [3] and osteoporosis [4].

Fractures can occur intra-operatively [6] but, more commonly, occur post-operatively, secondary to falls in a fragile elderly population [6].

The Vancouver classification system of periprosthetic femoral fractures [7] has gained broad acceptance [8] and has been shown to be reliable and has been widely adopted by surgeons [6]. This system is based on fracture location, implant stability and residual bone stock [5]. Fractures around the stem or just below it are defined as type B, which is subdivided into those adjacent to a stable stem (B1), to a loose stem but with adequate bone stock (B2), or to a loose stem with poor bone stock (B3) [5]. Type B fractures account for approximately 80% of PFF [3]. In type B1 fractures, osteosynthesis without implant revision is the treatment of choice [3] and is often performed using plating systems or cerclages wires [9]. Revision of the stem is recommended if the stem is loose. Several reconstruction options have been described in the literature: cemented stems with impaction grafting, monoblock extensively porous-coated uncemented stems, or modular tapered stems [5]. Bone grafting can be also considering in case of poor residual bone stock.

Treatment of PFF is multifaceted and requires expertise in both fracture fixation and revision arthroplasty. Many patients are elderly with significant comorbidities and surgery is associated with high complication rates [2]. Moreover, patients affected by PFF have a relatively poor outcome with higher mortality and morbidity compared to patients undergoing prosthesis revision for aseptic loosening[3]. Drew et al. calculated the combined risk of death or re-operation in the first year after a PFF to be 24% [10].

The aim of this case series was to evaluate clinical and radiological outcomes of Vancouver B2-type and B3-type PPFs in elderly patients treated with a cementless tapered modular femoral stem, using the same implant in all patients.

Materials and methods

A retrospective review of a single-centre prospectively maintained traumatological database was undertaken for all consecutive patients with a proximal femur PPF on primary or revision implants between 2005 and 2018. All PPFs were treated with revision of the failed stem. Patients with intra-operative fractures during primary surgery, inter-prosthetic fractures and fractures related to oncologic lesions were excluded.

The study was approved by the local Institutional Review Board. All patients consented to the use of their clinical information at the moment of admission to our institution and complete medical records and images were available for revision. For retrospective studies formal consent was not required.

Patients included in the study were retrospectively evaluated by pre-operative X-rays or CT and intra-operative evaluation to classify fractures according to the Vancouver system [7]. Type A fractures are those located in the proximal metaphysis apophyseal regions, which are further subdivided into those involving the greater trochanter (AG) or lesser trochanter (AL). Fractures around the stem or just below it are defined as type B, which is subdivided into those adjacent to a stable stem (B1), to a loose stem but with adequate bone stock (B2), or to a loose stem with poor bone stock (B3). Type C fractures are located well below the stem tip.

Patient information at baseline included age and gender. X-rays and reports were studied to identify the location of the fracture, causes and type of procedure used for first implant (primary THA, revision THA, hemiarthroplasty), type of fixation used (cemented or cementless), and time in months from previous implantation. Demographic characteristics are reported in Table I. Pre-operative comorbidities were collected and examined using and the American Society of Anesthesiologists (ASA) score. Comorbidities are reported in Table II. Minor diseases such as high blood pressure or dyslipidaemia were not included.

All surgeries were performed via lateral approach to the hip. Stem replacement was performed in all patients using uncemented MP® reconstruction system stem which is designed for replacement of loosened hip prostheses with extensive proximal femoral defects that no longer permit implantation of standard prostheses (Waldemar Link®, Germany). The system forsees the use of a modular, fluted, distally anchored tapered stem made of Tilastan® (titanium alloy). When required, the acetabulum component was replaced with the Continuum® Trilogy® Acetabular system, Zimmer®, Inc., USA) and open reduction and internal fixation (ORIF) were performed using cerclage wires and locking plates or cerclage wires alone.

The post-operative rehabilitation protocol for all patients entailed immediate hip and knee mobilization, and weight bearing was allowed on the basis of implant stability. Some patients had no permission to full weight bearing until radiological evidence of bone callus or absence of hip-related pain was gained. At the time of follow-up, radiological and clinical evaluation was performed. Only patients with follow-up > 24 months were included for clinical and radiological evaluations. Functional outcomes were assessed with the use of Harris hip score (HHS), and pain was evaluated using the Numerical Rating Scale (NRS). Radiological evaluation of the last images found

in our database was performed for all patients using Beals and Tower criteria. Following this classification, outcomes were assessed as excellent (stable prosthesis with minimal deformity), good (stable prosthesis with moderate deformity), or poor (loosening, non-union, severe deformity, sepsis or new fracture). A prosthesis was graded as stable if there were no radiolucent lines around the stem. The cementless femoral components were considered loose if there were progressive radiolucency of ≥ 2 mm wide involving > 50% of the bone-implant interface or femoral component migration. Clinical and radiological outcomes are reported in Table III.

Local risk factors were assessed on previous radiographs: periprosthetic osteolysis, loosening, malposition of the stem or considerable heterotopic ossifications (Brooker grades 3 and 4). Osteoporosis was considered to be present if there was low bone density demonstrated by densitometry (T-Score < -2.5); previous osteoporotic fractures (distal radius, vertebral, or hip); or cortical thickness index < 0.40 (measured on both anteroposterior and lateral radiographs of the hip).

Post-operative complications were recorded and classified according to Clavien-Dindo classification for all patients. It consists of 5 grades (I, II, III, IV, and V). Grade I refers to any deviation from the normal post-operative course without the need for pharmacological treatment (with drugs other than antiemetics, antipyretics, analgesics, diuretics and electrolytes) or surgical, endoscopic and radiological interventions. Grade II is for complications requiring pharmacological treatment or blood transfusions. Grade III is for complications requiring surgical, endoscopic or radiological intervention. Grade IV is for life-threatening complications. Grade V is for death. Post-operative complications are reported in Table IV.

Patients

A total of 40 patients were initially included in this study (Tab. I). Three patients were unavailable for clinical and radiological follow-up: 2 patients were lost to follow-up before 24 months, and one patient died. Of the remaining 37 patients, 26 patients were women (70.3%) and 11 men (29.7%). Minor trauma injury caused PPFs in all patients; none had an history of major trauma. The average age of patients at the time of surgery was 78.0 ± 7.8 years (range 54-89). The most frequent fractures, 48.7% (n = 19), occurred on the right side, while 41.0% (n = 16) on the left side and 2 patients had bilateral fractures (n = 4), which were synchronous in one case. Reasons for the previous prosthetic implant were primary coxarthrosis in 29 cases (74.4%), fractures in 7 (18.0%), secondary coxarthrosis in 2 (5.1%, 1 avascular necrosis of the femoral head, 1 developmental dysplasia of the hip) and aseptic acetabular loosening in one patient with THA (2.5%) (Tab. I). The PFF involved a primary THA in 36 cases (92.3%) and a revision THA in 3 (7.7%) (Tab. I). The type of fixation was cemented in 2 cases (5.1%), while it was cementless in 37 (94.9%). The average time from previous procedure to fracture was 113.5 ± 78.3 months (range 2-360). Local risk factors for PPFs were found in 33 patients (89.2%). Five patients presented two local risk factors. In details, we found osteoporosis in 26 cases (70.3% of total PPFs), previous dislocation in 3 (8.1%), loosening of the stem in 3 (8.1%), polyethylene wear in 2 (5.4%), previous periprosthetic joint infection in 2 (5.4%, one requiring previous revision surgery), previous PPF during first prosthetic implants in one case (2.7%) and one case of irradiated bone for a soft tissue tumour (2.7%) (Tab. I).

As for comorbidities (Tab. II), 33 patients (89.2%) had at least one concomitant pathology, and 26 patients (70.3%) had multiple comorbidities. At the time of surgery, ASA score was 4 in 3 patients (8.1%), 3 in 31 (83.8%) and 2 in 3 (8.1%) (Tab. I). The average operative time was 107.9 ± 62.3 min (range 63-201). The average number of blood units transfused was 2.9 ± 2.3 (range 0-13), with the most in patients with B3-type PPFs (4.4 ± 2.6).

In our study group, according to Vancouver classification, there were 34 B2-type PPFs and 5 B3-type PPFs (Tab. I). One patient (#5) was pre-operatively staged as Vancouver B1, and then upstaged to B2 intra-operatively due to findings of stem loosening. Another patient (#16) was pre-operatively staged as Vancouver B1 and treated with ORIF, without evidence of stem loosening during surgery. However, stem loosening occurred after two months, and stem revision was thus performed. We decided to include this patient in the Vancouver B2 subgroup of this cohort. Another patient (#17), presenting a B2-type PPF, was treated with ORIF without stem revision due to the several comorbidities and poor general conditions. However, considering the improvement in general conditions, stem revision was performed after three months.

A total of 25 B2-type PPFs and 1 B3-type PPF were treated with stem revision only (Tab. I). Twelve PPFs underwent stem revision + ORIF (10 B2-type and 2 B3-type) (Tab. I). ORIF consisted in cerclages alone in 10 patients, and cerclages and plates in 2 patients. One patient (#23) with previous THA, affected by acetabular loosening, was treated with complete revision of the implant. No bone grafts were used in this cohort. One intra-operative fracture occurred (patient #3) (Tab. I).

Clinical and radiological evaluation was performed in 37 patients (39 PPFs: 34 B2-type PPFs, 5 B3-type PPFs), with an average follow-up time of 39.5 ± 24.2 months (range 24-120) (Tabs. I, III). We found that gender, side and type of fracture, ASA, presence of contralateral prosthesis and type of surgery did not significant affect post-operative functional outcomes.

Statistical analysis

Parametric test was used to compare samples in case of normal distribution, homoskedasticity and appropriate numerousness. Shapiro-Wilk's test was used to verify normal distribution. The Levene test was used to analyze homogeneity of the variances. As parametric test, we used a two-tailed Student T-test for unpaired groups. As a non-parametric test, we used

Table I. Patient demographics.

Patients (n)	37
Peri-prosthetic femoral fractures Vancouver B2 Vancouver B3	39 34 5
Female/male	26/11
Fracture side Right side Left side Bilateral	 19 16 2
Local risk factors for PPF Polyethylene wear PJI Dislocation PPF Irradiated bone Osteoporosis Stem loosening	 2 2 (1 needing previous revision) 3 1 (intra-operative) 1 26 3 (1 needing previous revision)
Treatment (B2/B3) Stem revision Stem revision + ORIF Cerclage wiring Plate and screw* THA revision	 26 (25/1) 12 (10/2) 10 (8/2) 2 (2/0) 1 (0/1)
Mean age at surgery (years)	78.0 ± 7.8 (range 54-89)
Mean follow-up (months)	39.5 ± 24.2 (range 24-120)
Pre-operative ASA score	ASA 1: 0 ASA 2: 3 ASA 3: 31 ASA 4: 3
Time since implant surgery (months)	113.5 ± 78.3 (range 2-360)
Implant before PPF Primary THA Revision THA	 36 3
Explanted stem: cemented/uncemented	2/37
Indication for previous implant Primary arthrosis Secondary arthrosis Femoral neck fracture THA aseptic acetabular loosening	 29 2 7 1
Contralateral hip Native Primary THA Revision THA Endoprosthesis ORIF	 20 11 3 4 1

* #16 and #17: see text for details.
Abbreviations: PPF: Peri-Prosthetic Fractures; PJI: Peri-prosthetic Joint Infection; ORIF: Open Reduction Internal Fixation; THA: Total Hip Arthroplasty; ASA: American Society of Anesthesiologists.

Mann-Whitney U-test. Continuity correction was applied in case of discrete distribution. Odds ratios were used to quantify the strength of the association between the variables analysed and the complications/revisions rate, using the Chi-Square test to establish significance. Pearson coefficient was used to make correlations. Univariate analysis was performed to establish clinical associations between variables and outcomes. Multivariate analysis was performed only if statistical significance was found with univariate analysis. P-values < 0.05 were considered to be significant. All statistical analysis was performed using the Statistical Package for Social Science (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.).

Results

At last follow-up, the average HHS was 91 ± 9.8 (range 67.3-100) (Tab. III). The lowest average HHS score was obtained in the Vancouver B3 subgroup compared to B2 subgroup (89.7 ± 7.5 and 91.2 ± 10.1, respectively), but no significant difference was found (Tab. III). Moreover, according to the Vancouver classification, we found HHS > 90 (excellent result) in 70.3% of B2-type PPFs (26 out of 37 patients), and in 60% of B3-type PPFs (3 out 5 patients). At last follow-up, the average NRS score was 0.7 ± 0.8 (range 0-3). In particular, it was 0.6 ± 0.8 (range 0-3) in the B2 subgroup and 0.8 ± 0.5 (range 0-1) in the B3 subgroup, without no significant difference (Tab. III).

Radiographic assessment at last follow-up revealed bone union in all patients, with an average union time of 3.3 ± 1.7 months (range 1-6) (Tab. III). In particular, the average union time was 3.4 ± 1.7 months (range 1-6) in the B2 subgroup and 3.2 ± 1.9 months (range 1-5) in the B3 subgroup (p > 0.05). According to Beals and Tower's criteria, we obtained excellent radiological findings in 89.7% patients (35 of 39 PPFs) (Tab. III). According to the Vancouver classification, for B2-type PPFs, we found excellent results in 91.2% of cases (31 of 34), good results in 5.9% (2 of 34) and poor results in 3% (1 of 34). In the B3 subgroup, results were excellent in 80% of cases (4 of 5), and good results in 20% (1 of 5). However, no significant difference was found between groups (Tab. III).

A total of 53 complications were reported (Tab. IV). There were major or minor complications in 27 patients. According to Clavien-Dindo classification, there were 3 grade I complications, 25 grade II, 17 grade III and 8 grade IV. There were 14 local surgery-related complications (35.9%), but only 4 required revision surgery (10.2%). In detail, local surgery-related complications included: 8 dislocations (20.5%), 2 early and 1 late peri-prosthetic joint infections (7.7%), 2 subfascial haematomas (5.1%) and 1 aseptic loosening of the stem (2.5%) (Tabs. III, IV). Dislocations were correlated with the involvement in fracture of both trochanters. In fact, dislocations were seen in 3 of 4 of metaphyseal B2-type PPFs involving both trochanters. This finding was significant as a risk factor at univariate analysis compared to both other B2-type PPFs (p = 0.033) and B2-type + B3-type PPFs (p = 0.037). The complication rate in Vancouver B2 subgroup was 35.3% (12 of 34 PPFs), and 40% in Vancouver B3 subgroup (2 of 5 PPFs) (Tab. III). Revision surgeries consisted of: one revision of the proximal components of the stem to treat a recurrent dislocation, 2 implant removals (the first for aseptic stem loosening and the second for a late peri-prosthetic joint infection) and a surgical debridement to treat a large subfascial haematoma causing post-operative anaemia (Tab. III). The revision rate in the Vancouver B2 subgroup was 8.8% (3 of 34 PPFs), compared to 20% in the Vancouver B3 subgroup (1 of 5 PPFs) (Tab. III). However, no significant differences were found in complication or revision rates between groups (Tab. III).

Table II. Pre-operative comorbidities (37 patients).

Disease	Patients (n)
Chronic kidney disease	2
Stroke	3
Malignancy	4
Acute myocardial infarction	4
Peripheral neuropathy	7
Diabetes	12
Dementia	8
Chronic obstructive pulmonary disease	7
Atrial fibrillation	10
Chronic liver disease	4
Venous insufficiency	5
Chronic obstructive peripheral arteriopathy	2
Hypertensive heart disease	16
Heart transplantation	1
At least one comorbidity	33
Multiple comorbidities	26

The small sample size in this study had a low power of detecting statistically significant differences and a low power to identify independent risk factors. We found that gender, side and type of fracture, presence of contralateral prosthesis and type of surgery, ASA score, local risk factors and Vancouver classification were not associated with functional outcomes at univariate analysis. Clinical and radiological outcomes seemed to be better in patients with B2-type PPFs compared to B3-type PPFs, but no statistically significant difference was found.

Discussion

Periprosthetic femoral fractures with a loose implant (Vancouver B2 and B3) are challenging and, per consensus, most are

Table III. Implant outcomes (37 patients).

Group	N	Mean HHS at last FU*	Beals and Tower score at last FU	Mean NRS at last FU	Time to bone-union (months)	Surgery-related post-op complications	Revision surgeries
Vancouver B2	34	91.2 ± 10.1 (range 67.3-100)	31 excellent 2 good 1 poor	0.6 ± 0.8 (range 0-3)	3.4 ± 1.7 (range 1-6)	12 (35.3%) 7 dislocations 3 deep infections 2 hematomas	3 (8.8%) 1 component revision 1 implant removal 1 surgical debridement
Vancouver B3	5	89.7 ± 7.5 (range 77.7-96)	4 excellent 1 good 0 poor	0.8 ± 0.5 (range 0-1)	3.2 ± 1.9 (range 1-5)	2 (40%) 1 stem aseptic loosening 1 dislocation	1 (20%) 1 implant removal
P-value	/	0.752	0.497	0.592	0.809	0.838	0.442
Total	39	91 ± 9.8 (range 67.3-100)	35 excellent 3 good 1 poor	0.7 ± 0.8 (range 0-3)	3.3 ± 1.7 (range 1-6)	14 (35.9%)	4 (10.2%)

Abbreviations: HHS: Harris Hip Score; NRS: Numerical Rating Scale; FU: follow-up.

treated with revision THA with or without internal fixation [10]. Femoral revision bypassing the distal extent of the fracture, by at least two diaphyseal diameters, is the mainstay of treatment and has demonstrated good outcomes in the literature [5]. However, in this case series, we preferred the use of stems that passed the fracture by at least 6 cm.

Although in case of severe osteoporosis or relevant femoral bone loss, reconstruction with a cemented stem prostheses can be hypothesised, uncemented stems are more commonly used for management of both B2-type and B3-type PPFs [10].

The literature reports that in almost one-quarter of all patients requiring revision of the stem the monoblock Wagner SL stem (Zimmer Biomet, Warsaw, Indiana) is used [10]. The tapered fluted shape of the stem provides reliable and versatile distal diaphyseal fixation, which overcomes concerns about proximal stress shielding and the difficulties associated with advanced proximal bone loss [10]. Nowadays, modular tapered fluted titanium stems has gained consensus in the management of Vancouver B2-type and B3-type PPFs.

The MP® reconstruction Link prosthesis is a system designed for revision surgery of the hip, where an extensive proximal femoral bone defect is present. It is a modular system composed of a prosthetic head, stem, tapered neck segment, spaces for equalising leg length and an expansion bolt. The stem can be cemented or cementless. In the non-cemented implant, the system provides a distal anchoring of the stem made of biocompatible porous-coated titanium alloy (Tilastan®) with micro-porous surface (PoroLink®) promoting secondary biologic fixation. The proximal part of the stem has curvature that hypothetically reduces the need for shaft osteotomies, which is often necessary when longer straight stems are used. Various modular neck components provide intra-operative flexibility for offset and control of the component anteversion; furthermore, spacers allow intra-operative correction of leg length up to 30 mm.

Revisions in B3-type PPFs are much more complex than B2-type due to bone loss [11]. Although the ideal treatment of Vancouver B3-type PPFs remains controversial [12], several previous studies have suggested the use of revision implant by adding bone graft to compensate the bone defect [3,11-14]. Despite 5 Vancouver B3-type PFFs in our series, we routinely used a cementless modular fluted, tapered stem, avoiding the use of bone graft. In fact, on one hand, cortical allografts could provide additional support to the rotational stability [14] and enhance osteogenesis increasing bone stock [14,15]; however, on the other hand, they increase the risk of infections, fractures, soft tissue stripping and loosening of the graft. Moreover, the use of the cortical structs prolongs the time required for graft incorporation [16,17], increasing blood loss in patients [18] who often are elderly with multiple comorbidities.

Many studies in the literature have reported that osteoporosis is a significant risk factor for PPFs [1]. Coherently, in our cohort, osteoporosis was the most common local risk factor, followed by previous dislocation, loosening of the stem and polyethylene wear.

Comparing our study with previous reports, we have found better clinical outcomes with an average post-operativel HHS of 91 ± 8. In fact, Moreta et al., in a series that evaluated outcomes of either modular and monoblock stems, reported an average HHS of 73 in a group of 31 B2-type and 12 B3-type

PPFs [5]. Other publications, in which only modular stems were utilised, reported HHS ranging from 69 to 83 [19-23]. Our better results could be related to two factors. The first is the low number of B3-type PPFs in our series compared to other cohorts. As reported in the literature, B3-type PPFs often result in a lower HHS post-operatively compared to B2 PPFs [1,3,14]. In our study, better functional results were achieved in the B2 subgroup compared to the B3 subgroup, but no significant difference was found. Furthermore, in patients with bone loss and extensive scar tissue, a modular prosthesis allows independent control of length of the leg, anteversion and offset. This results in a more anatomical reconstruction, decreasing the risk of leg length inequality and muscular weakness due to insufficient or excessive soft tissue tension. Moreover, in our opinion the surgical technique is easier and is associated with greater respect for soft tissues compared to the use of monoblock implants.

Radiological outcomes of B2/B3-type PPFs, according to Beal and Tower, is good or more often excellent when modular long stems are implanted in revisions whatever fixation system is used [3,14,24,25]. Our experience is comparable with that reported in the literature, with excellent radiological findings in 89.7% patients (91.2% B2-type PPFs and 80% B3-type PPFs).

In our series, we obtained radiological bone union in all patients. Using the MP® reconstruction link prosthesis, Mulay et al. (10 B2-type and 14 B3-type), reported fracture healing in 91% of patients [20]. Moreta et al. (31 B2-type and 12 B3-type) reported a fracture healing of 93% [5]. Both Abdel et al. (25 B2-type and 19 B3-type) and Munro et al. (38 B2-type and 17 B3-type) reported 98% of fracture healing [19,22]. Fink (22 B2-type and 10 B3-type) et al. and Canbora et al. (8 B2-type and 9 B3-type) reported a consolidation rate of 100% [14,21]. These excellent results are probably related to avoiding the use of cement, which could leak to the fracture site and impede fracture healing [14,26]. As reported in the literature, a long femoral stem prosthesis can act as an intramedullary nail, avoiding undesirable effects of the fixation [14-21]. Subsequently, the choice to not use bone grafts could permit further careful handling of soft tissue near the fracture site and avoid bone devascularization.

We found 14 local surgery-related complications (35.9%): 8 dislocations, 3 peri-prosthetic joint infections, 2 subfascial haematomas and 1 aseptic loosening of the stem. Specifically, only 4 complications (10.2%) required revision surgery. These results are consistent with previous papers that reported an overall complication rate of 26-40% [3] and a re-intervention rate of 11-32% [1]. In agreement with the literature [10], we observed a higher revision rate in the B3 subgroup compared to the B2 subgroup, respectively 20% and 8.8%; however, no significant differences were found.

Despite the wider options of version, offset and length of the stem available using a modular prosthesis, a high dislocation rate still seems to be a problem in elderly patients [12]. Dislocation has been reported by previous authors with a rate ranging from 0% to 22.7% [19,20,27]. Several studies have demonstrated success with the use of modular component exchange for correction of recurrent dislocation after THA [28-30]. In fact, femoral offset, leg length and anteversion represent 3 fundamental points for hip stability [28]. In line with this, Mulay et al. claimed that non-modular stems with a single offset without modularity could increase the risks of shortening and dislocation [20]. However, despite the use of a modular stem in all our patients, we observed a dislocation rate which is at the upper limit of this range (20.5%). Two possible causes reported in the literature are impingement due to excess scar tissue on the medial side of the proximal femur not removed through the fracture window [12,20], and subtle implant subsidence causing shortening and loss of soft tissue tension [5,12]. Cementing the stem could selectively reduce the occurrence of stem subsidence caused by poor bone stock, but discussion of whether this would help balance the other pitfalls of using cemented stems is beyond the scope of this paper. Furthermore, Moreta el al. reported a 57% rate of neurological impairment, such as advanced dementia or

Table IV. Post-operative complications (37 patients).

Post-operative complication	N
Surgery-related complications (requiring revision) Early peri-prosthetic joint infection Late peri-prosthetic joint infection Wound infection Dislocation Non-union Stem aseptic loosening Subfascial hematoma	14 (4) 2 1 (1) 0 8 (1) 0 1 (1) 2 (1)
Sepsis	1
Nerve palsy	2
Anemia requiring post-operative blood transfusions	21
Deep venous thrombosis	3
Sub-ileus	2
Gastro-intestinal tract bleeding	2
Gastro-intestinal tract infection (Clostridium Difficile)	1
Acute myocardial infarction	1
Acute heart failure	1
Acute kidney failure	1
Transient ischemic attack	1
Lower urinary tract infection	3
Clavien-Dindo classification Grade I Grade II Grade III Grade IV	 3 25 17 8

a late stage of Parkinson disease, in patients with dislocation [5]. In our series we have found a high rate of neurological impairment in patients with dislocation (4 of 8), although no significant significance was found at univariate analysis (p = 0.068). Considering this subgroup to be at higher risk of dislocation, dual mobility cups, constrained liners[5] and larger femoral heads diameters [19] should be evaluated in all patients with neurological diseases. Another possible contributing cause in 3 of the 8 dislocation cases might have been the presence of high B2-type fractures with isolated involvement of both trochanters. Metaphyseal complex fractures frequently cause implant loosening, especially considering the increasing use of primary metaphyseal or meta-diaphyseal anchored stems. In these cases, even if stability of the revision stem with diaphyseal anchorage is obtained, it is much more complex to achieve optimal reconstruction of the metaphyseal region and a proper re-tensioning of the muscles (in particular of the gluteus medius muscle), thus increasing the risk of dislocation. In our opinion, one of the limitations of the Vancouver classification is the inability to differentiate B2-type fractures based on fracture site, thus limiting the possibility of stratifying treatments and outcomes. In particular, the Vancouver classification does not contemplate damage to the tendon and muscle structures resulting from the fracture of the metaphyseal region which could lead to implant instability. However, in our series, only one of 8 dislocations required revision surgery, replacing the proximal components of the stem, without acetabular cup revision.

Finally, although other frequent complications reported in the literature are re-fractures and non-union, both with an average rate of 24% [3], in our study series we did not observe any cases of these complications. Furthermore, we did not observe any case of subsidence of the stem, another main complication reported in the literature [10,31]. This is possibly related to our average follow-up of less than 5 years; it is likely that significant subsidence would have occurred after that time.

Our study presents several limitations. First, its retrospective nature correlated with the biases exclusive to the study design. We had partial clinical information available for each patient with the lack of appropriate pre-operative functional hip scores. Moreover, we had a relatively short-term follow-up, and the sample size was relatively small and not homogenous for risk factors, limiting the ability to carry out more accurate statistical analyses. We also had a low number of patients with type B3-type PPFs and this could increase our functional results compared to other studies. Nevertheless, the main advantage of our series is the homogeneity of the choice of treatment. All our patients were treated using the same implant, avoiding the use of strut allografts or tools of internal fixations.

Conclusions

In conclusion, according to the literature, B2-type and B3-type proximal femur periprosthetic fractures can be effectively treated with cementless stem revision. We observed good results in terms of clinical outcomes, fracture healing and stability using a cementless modular stem. Moreover, we found involvement of both trochanters in the fracture as a possible risk factor for dislocation. Our results and complication rates are comparable with the literature, even without application of cortical strut grafts, although further studies are needed to confirm these findings in B3-type PPFs.

Ethical consideration

The Authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). The study was approved by the institutional review board of our hospital. Written informed consent was obtained from the patient.

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Conflict of interest

The Authors have no conflicts of interest to declare.

Author contributions

Alfonso C conceived the study; Alfonso C e De Paolis M revised the paper; Fiore M and Giannini C drafted the manuscript and collected and interpreted the data; Zucchini R and Sambri A participated in planning and revising the manuscript. All the authors read and approved the final manuscript.

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