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ORIGINAL ARTICLE

Management of Vancouver type B2 and B3 femoral periprosthetic fractures using an uncemented extensively porous-coated long femoral stem prosthesis

Kerem Canbora · Ozkan Kose · Atilla Polat · Faruk Aykanat · Mucahit Gorgec

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Abstract
Objective The purpose of this study was to evaluate the clinical results of femoral revision using an uncemented extensively porous-coated long femoral stems with or without onlay strut allografts in the treatment of Vancouver type B2 and B3 periprosthetic femoral fractures.
Materials and methods We retrospectively reviewed 17 cases of periprosthetic femoral fracture (eight B2 and nine B3) treated with the uncemented extensively porous-coated long femoral stem. Clinical outcomes were assessed with Harris Hip Score and Barthel ADL index. Radiological evaluations were conducted using Beals and Towers' criteria. Any complication during the follow-up period was recorded.
Results The average follow-up period was 41.7 ± 31.08 (range, 15–132) months. The average Harris Hip Score was 68.2 ± 18.4 (range, 32–100), and the average Barthel ADL index was 80.1 ± 19.75 (range, 30–100) points at the final follow-up. All fractures were united, and a good graft consolidation was achieved in 5 of 9 cases. There was femoral stem subsidence in 4 cases less than 10 mm without an evidence of loosening both radiologically and clinically. The radiological results using Beals and Towers' criteria were excellent in eight hips, good in five and poor in four.
Conclusions An uncemented extensively porous-coated long femoral stem together with or without onlay strut allografts provides a good fracture stability that promotes fracture healing and offers a successful solution for the management of Vancouver type B2 and B3 femoral periprosthetic fractures.

Keywords Periprosthetic fracture · Hip · Revision arthroplasty · Surgical management · Vancouver type B2 and B3

K. Canbora · A. Polat · F. Aykanat · M. Gorgec
Haydarpasa Numune Education and Research Hospital, Orthopaedics and Traumatology Clinic, Istanbul, Turkey

O. Kose (✉)
Antalya Numune Education and Research Hospital, Orthopaedics and Traumatology Clinic, Kultur mah. 3805 sk. Durukent Sitesi, F Blok Daire:22 Kepez, Antalya, Turkey
e-mail: drozkankose@hotmail.com

Introduction

Periprosthetic femoral fractures are challenging complication of hip arthroplasty. Although, the incidence of periprosthetic femoral fracture has been reported between 0.4 and 2.1 %, the incidence of periprosthetic femoral fracture is increasing due to the widened indications of joint replacement surgery, increasing average life expectancy and secondary increase of revisions [1]. Although the treatment of such fractures is technically demanding, surgical treatment has become the standard treatment due to high incidence of complications and compromised outcomes with non-operative treatment [2–4]. Duncan and Masri developed a system of classification of periprosthetic femoral fractures according to location, implant stability and residual bone stock (Vancouver Classification) and advocated an algorithm toward surgical treatment [5, 6] (Table 1). The Vancouver classification of periprosthetic femoral fractures is considered a reliable system which has gained the most acceptances, and now, it is commonly used worldwide [7].

Vancouver type B2 and B3 periprosthetic femoral fractures are the most challenging subtypes to manage

Table 1 Vancouver classification of postoperative periprosthetic femur fractures

Type and subtype	Location/characteristics	Treatment
Type A		
AL	Greater trochanter	Conservative (consider ORIF if large segment of medial cortex involved)
AG	Lesser trochanter	Conservative with abduction precautions (consider ORIF if displaced >2.5 cm)
Type B		
B1	At or around tip of prosthesis; prosthesis well fixed	ORIF with or without cortical strut allograft
B2	At or around tip of prosthesis; prosthesis loose	Revision THA with long stem prosthesis
B3	At or around tip of prosthesis; prosthesis loose, poor proximal bone stock	Revision THA and augmentation of bone stock with allograft versus oncologic prothesis
Type C	Distal to prosthesis tip	ORIF

because of loosened prosthesis and bone stock deficiency. Various surgical techniques and implants have been employed in the management of Vancouver type B2 and B3 periprosthetic femoral fractures in the present literature. However, there is still no consensus with respect to the ideal treatment for these difficult fractures [8]. The purpose of this study was to evaluate the clinical results of femoral revision using an uncemented extensively porous-coated long femoral stems with or without onlay strut allografts in the treatment of Vancouver type B2 and B3 periprosthetic fractures.

Materials and methods

Patients

We retrospectively reviewed a consecutive series of 17 periprosthetic femur fractures that underwent revision total hip arthroplasty (THA) using an uncemented extensively porous-coated distally fixed long femoral stem between February 2000 and December 2009 at our institution. The study was carried out according to the Declaration of Helsinki, and institutional review board approved the study. The fractures were classified according to the Vancouver classification system. Eight hips were classified as Vancouver type B2, and 9 were type B3 based on both preoperative radiographs and operation notes. There were eight men and nine women with an average age of 70.5 ± 10.2 years at the time of operation. In twelve patients, the fracture was caused by minor trauma (fall to the floor), and in one by major trauma (pedestrian traffic accident). In four patients, the fracture occurred spontaneously without a history of apparent traumatic event. The primary diseases were femoral neck fracture in 8 and the primary osteoarthritis in 9 hips. The status of primary arthroplasties was THA in 9 hips (5 cementless femoral stem) and hemiarthroplasty in 8 (1 cementless femoral stem). The average time interval between the periprosthetic fracture and the index operation was 77.2 ± 67.4 months. All patients were contacted either via mail or via telephone and asked to visit our outpatient clinic for the final follow-up. The average follow-up period was 41.7 ± 31.08 (range, 15–132) months. Demographic characteristics are summarized in Table 2.

Surgical technique

An extended posterolateral approach to the hip was performed in all cases. The femoral head was dislocated posteriorly with a bony hook inserted under the neck of the femoral prosthesis. The stems and the remaining cement were removed. An additional osteotomy was needed in three hips for the removal of cement remnants. After exposing a fracture site, the distal extremity of the fracture was identified, and cerclage wire or cable was applied just distal to the fracture to prevent fracture propagation during reaming or true stem impaction. The distal femur was then reamed using sized tapered reamers until a solid torsional grip was obtained to allow the insertion of the revision long stem. Then the femoral stem was inserted, and the fracture was reduced using long stem as an intramedullary nail. In cases whom bone stock and quality was insufficient (Vancouver type B3), cortical onlay strut allograft was used for the augmentation of bone stock. The stability of the acetabulum was checked in cases with previous THAs, and if there is instability, the acetabular component was revised. All bipolar hemiarthroplasty cases were converted to THA. In 12 cases, we have used Echelon Revision Hip System® (Smith and Nephew, Inc, Memphis, TN, USA), and in the remaining five cases, we have used ZMR Hip System® (Zimmer, Warsaw, IN, USA).

Table 2 Demographic characteristics of patients (M = male, F = female, THA = Total hip arthroplasty)

Case #	Age (years)	Gender	History of trauma	Index operation	Time interval between index operation and fracture (months)	Vancouver classification	Follow-up (months)
1	70	M	Minor	THA, cementless	72	B3	132
2	71	F	Spontaneous	THA, cementless	2	B2	80
3	71	M	Minor	Hemiarthroplasty, cemented	36	B2	73
4	88	F	Minor	Hemiarthroplasty, cemented	48	B3	49
5	49	F	Minor	THA, cementless	2	B2	51
6	74	M	Minor	Hemiarthroplasty, cemented	11	B3	40
7	76	F	Spontaneous	Hemiarthroplasty, cemented	144	B2	39
8	62	M	Minor	Hemiarthroplasty, cemented	132	B3	30
9	69	F	Minor	Hemiarthroplasty, cemented	156	B3	29
10	71	M	Minor	THA, cemented	120	B3	60
11	49	F	Spontaneous	THA, cemented	60	B3	28
12	78	F	Major	THA, cementless	3	B2	21
13	68	F	Spontaneous	THA, cemented	120	B2	15
14	72	F	Minor	THA, cemented	204	B3	15
15	87	M	Minor	Hemiarthroplasty, cementless	24	B2	15
16	72	M	Minor	Hemiarthroplasty, cemented	12	B2	15
17	72	F	Minor	THA, cemented	168	B3	17

Table 3 Beals and Towers' criteria for radiological evaluation

Outcome	Arthroplasty	Fracture
Excellent	Stable	Healed with minimal deformity without shortening
Good	Stable subsidence	Healed with moderate deformity and shortening
Poor	Loose	Nonunion, sepsis or new fracture with severe deformity and shortening

Clinical and radiographic evaluations

At the final follow-up, clinical evaluations were performed using Harris Hip Score (HHS) and Barthel activities of daily living (ADL) index [9, 10]. Plain radiographs were examined for evidence of nonunion, loosening and subsidence. Union was defined as bony bridging across an osteotomy site or no migration of the fracture fragment. Subsidence of the stem was measured from the shoulder of the prostheses to the most medial point of the lesser trochanter, as described by Malchau et al. [11]. When the lesser trochanter was absent or not visible on radiographs, the measurements were conducted using the tip of the greater trochanter or cerclage wire as a marker and were recorded. Radiological evaluations were conducted using Beals and Towers' criteria (Table 3) [12]. Any complication during the follow-up period was recorded.

A descriptive analysis of the continuous and categorical data was performed using proportions, frequency distributions, means and standard deviations. No statistical analysis was performed in this descriptive follow-up study.

Results

The average Harris Hip Score was 68.2 ± 18.4 (range, 32–100), and the average Barthel ADL index was 80.1 ± 19.75 (range, 30–100) points at the final follow-up. All fractures were united, and a good graft consolidation was achieved in 5 of 9 (Vancouver type B3) cases (Figs. 1, 2). There was femoral stem subsidence in 4 cases less than 10 mm without an evidence of loosening both radiologically and clinically. There were two superficial wound infections that were treated with antibiotherapy. *S. aureus* was isolated from the wounds. No cases had deep implant infection that required removal of the implant (prosthesis), but, in one case, we had to remove the distal cerclage wires that were thought as the focus of infection (Fig. 3). Posterior hip dislocation occurred in one patient at the 2nd postoperative month and was managed with closed reduction and abduction bracing and bed rest (Fig. 4). A new fracture occurred at the tip of the revision stem (Vancouver type B1) in one patient and was fixed with Dall-Miles plate, screws and cerclage wires (Fig. 5). No systemic complications occurred. The radiological results using Beals and Towers' criteria were excellent in 8 hips, good in 5 and poor in 4. All results are summarized in Table 4.

Fig. 1 **a** 49-year-old female with Vancouver type B2 periprosthetic femoral fracture (Case #5). **b** Early postoperative radiograph. **c** Final hip radiograph at 51-month follow-up after revision showing union

Discussion

The goals of treatment in periprosthetic femoral fractures are providing fracture union, anatomic alignment, return of functional status, early mobilization, achieving a stable prosthesis at the end of fracture healing and a reasonable survivorship of the prosthesis [6, 13]. However, it is not always easy to obtain all these goals in these patients. Osteoporosis, poor bone stock, limited competence for mobility and often presence of co-morbidities due to advanced age may be listed as major obstacles. Among periprosthetic femoral fractures, Vancouver type B2 and B3 are the most challenging subtypes. According to Duncan and Masri, the treatment of type B2 fractures necessitates a revision surgery for femoral stem as the femoral stem is loose, with or without additional extramedullary fracture fixation. On the other hand, in type B3 fractures, poor bone stock should be reconstituted with allografts in addition to revision of the femoral stem [5, 6].

Long femoral stems have been favored for the treatment of Vancouver type B2 and B3 periprosthetic fractures in the present literature. Long femoral stem prosthesis act as an intramedullary nail and lock at the distal attachment; thus, both the revision arthroplasty and the fracture fixation can be achieved simultaneously. Furthermore, point of the fixation is remote from the fracture; therefore, the stability of the stem is not influenced by the fracture, and the fracture healing is not influenced by the undesirable effects of the fixation [14]. The prosthesis can be replaced by a cemented or non-cemented femoral stems. However, the cement may leak to the fracture site and impede fracture healing. In order to avoid detrimental effect of cement on fracture healing, distally cemented modular femoral stem have been used [15]. Besides high rate of nonunion, early loosening and refracture rate seems to be higher with cemented technique [8, 12, 16].

In this study, the results of revision hip arthroplasty with long distally fixed uncemented femoral stem in the management of Vancouver type B2 and B3 were investigated. In 13 out of 17 cases, we achieved excellent and good results. Fracture union was achieved in all cases. Four patients had poor results. Two of these patients with poor results had infection. Of these patients, one was a heavy smoker (20/day for 25 years) and had chronic renal failure. The other patient with infection had Type II diabetes mellitus and overweight (BMI = 29.3). One patient had refractured at the distal end of the revision stem with minor trauma. This patient had osteoporosis (BMD, *T* score

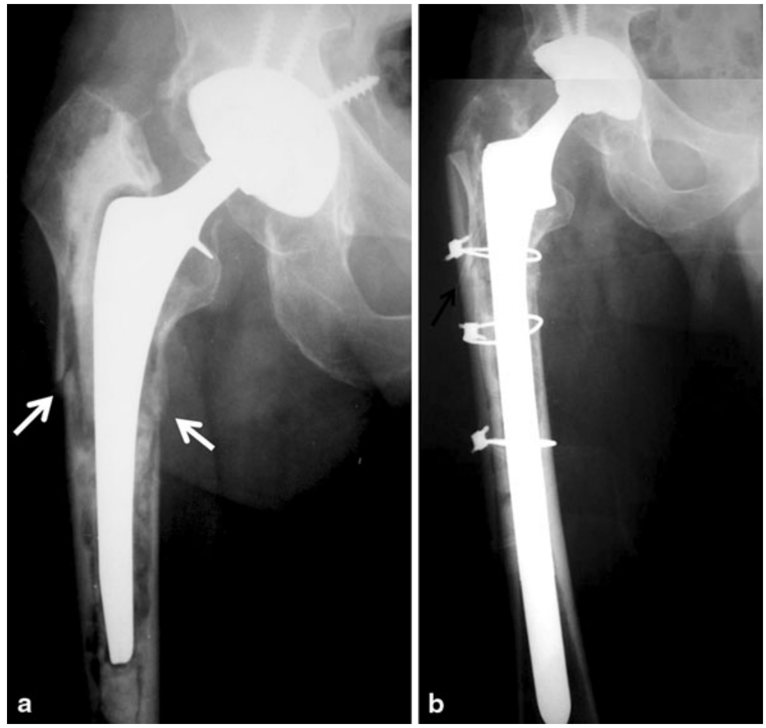

Fig. 2 **a** 49-year-old female patient with Vancouver type B3 periprosthetic fracture (*white arrows*) (Case #11). **b** Hip radiograph at the final follow-up 28 months after the operation. *Black arrow* shows the initial localization of the fracture with union and graft consolidation

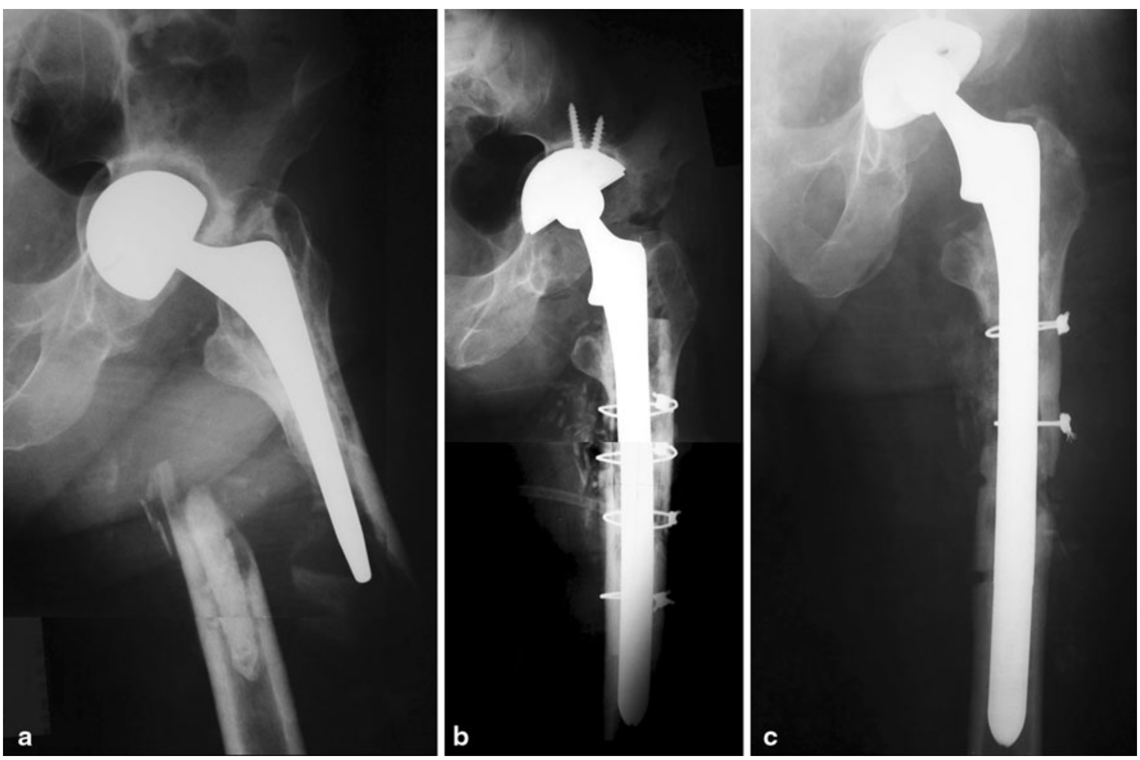

Fig. 3 **a** 74-year-old male patient with Vancouver type B3 periprosthetic fracture (Case #6). **b** Revision surgery with long femoral stem, onlay strut graft and cerclage wires. **c** Final radiographs at 40 months after the surgery. Distal two cerclage wires were removed due to infection. Fracture union and graft consolidation was achieved

<−2.5). Finally, one had posterior dislocation. In this patient, index fracture was an intertrochanteric fracture with greater trochanteric comminution, and the abductor lever was damaged. Complications and poor results were seen in patients with associated co-morbidities and risk factors. Preoperative identification of these risk factors may

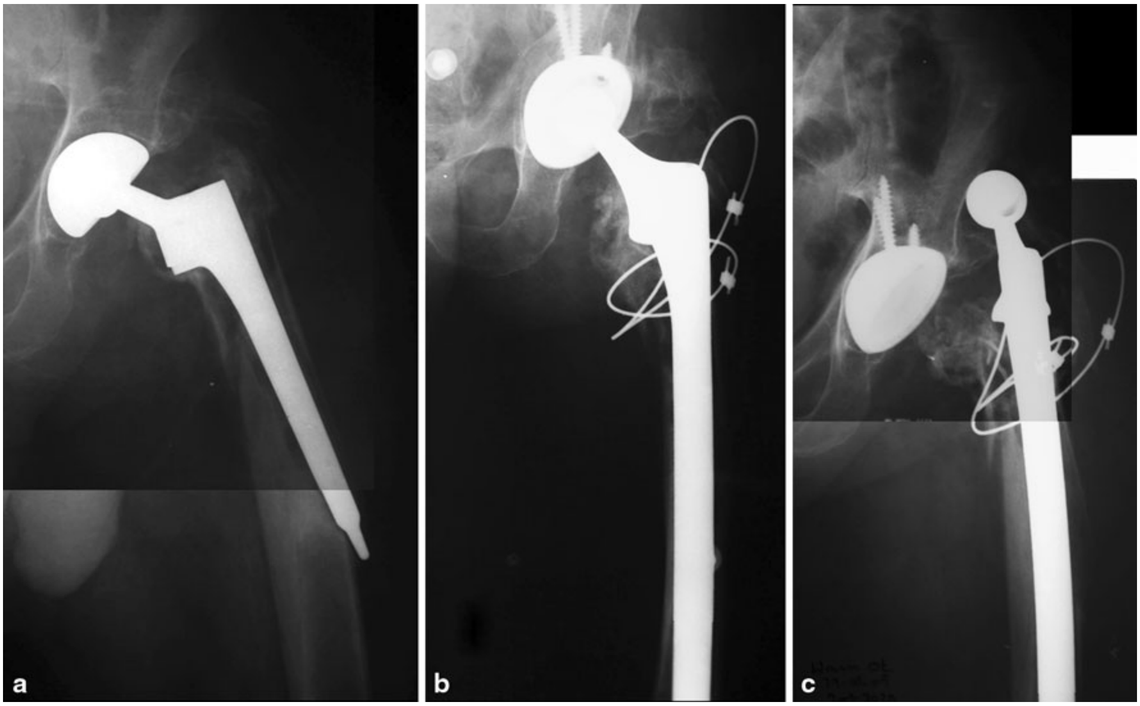

Fig. 4 **a** 71-year-old female patient Vancouver type B2 periprosthetic fracture (Case #3). **b** Early postoperative hip radiograph. **c** Dislocation occurred at the 2nd postoperative month

guide surgeons to predict the possible complications and prognosis.

The results of our series are similar to those previous reports which used distally locked uncemented femoral stems. Fink et al. prospectively reviewed 32 cases of periprosthetic femoral fractures (22 type B2 and 10 type B3) who were treated with non-cemented, modular tapered and fluted distally fixed titanium revision stem with a mean follow-up of 32 months. All patients in his series resulted with excellent outcome without nonunion, or subsidence [14]. Oshea et al. performed a retrospective clinical and radiographic assessment of 22 patients (10 B2, 12 B3) with a mean follow-up of 33.7 months. Uncemented extensively porous-coated distally fixed femoral stems were used for the revision. They reported 91 % of union rate. The outcome was excellent in 18 cases, good in one and poor in three. These three included the patient with residual infection, one with nonunion and one with unstable subsidence of the prosthesis [3]. Mulay et al. reviewed 24 patients (average age, 74 years) with types B2 and B3 fractures managed with a cementless, tapered, fluted and distally fixed stem using a transfemoral approach. Similarly, they reported 91 % of union rate. Fourteen of the 24 patients made an uneventful recovery without any major or minor complication [17]. Park et al. retrospectively analyzed 27 hips with periprosthetic femoral fractures (types B2 and B3) treated with distal fixation using a modular, fluted, femoral stem. The average follow-up was 4.8 years. Most fractures (25 hips) were united (92.6 %). Treatment failure occurred in 2 patients; one due to infected nonunion and the other due to subsidence ($\geq$10 mm) associated with nonunion [18].

Modular femoral stems have some advantages over non-modular stems in control of leg length inequality. Mulay et al. [17] claimed that non-modular stems with a single offset without modularity may give rise to problems of over advancement of the definitive stem with possible increased risks of shortening and dislocation. In our series, there was subsidence in five patients, which were all less than 10 mm, and only one posterior dislocation. Similar subsidence and dislocation rates were also reported with modular femoral stems in the relevant literature [3, 18]. Cortical onlay allografts not only provide additional support to the rotational stability, but also enhance the osteogenesis of both fracture and regain the deficient bone stock in Vancouver type B3 fractures [19, 20]. In current study, we have used onlay strut grafts which were fixed with cerclage wires in all B3 fractures. At the final follow-up, there was no complication related to use of onlay strut grafts in this series.

Although this study has some limitations which include the retrospective nature of data collection, relatively short-term length of follow-up and the small patient population, uncemented long femoral stems together with or without

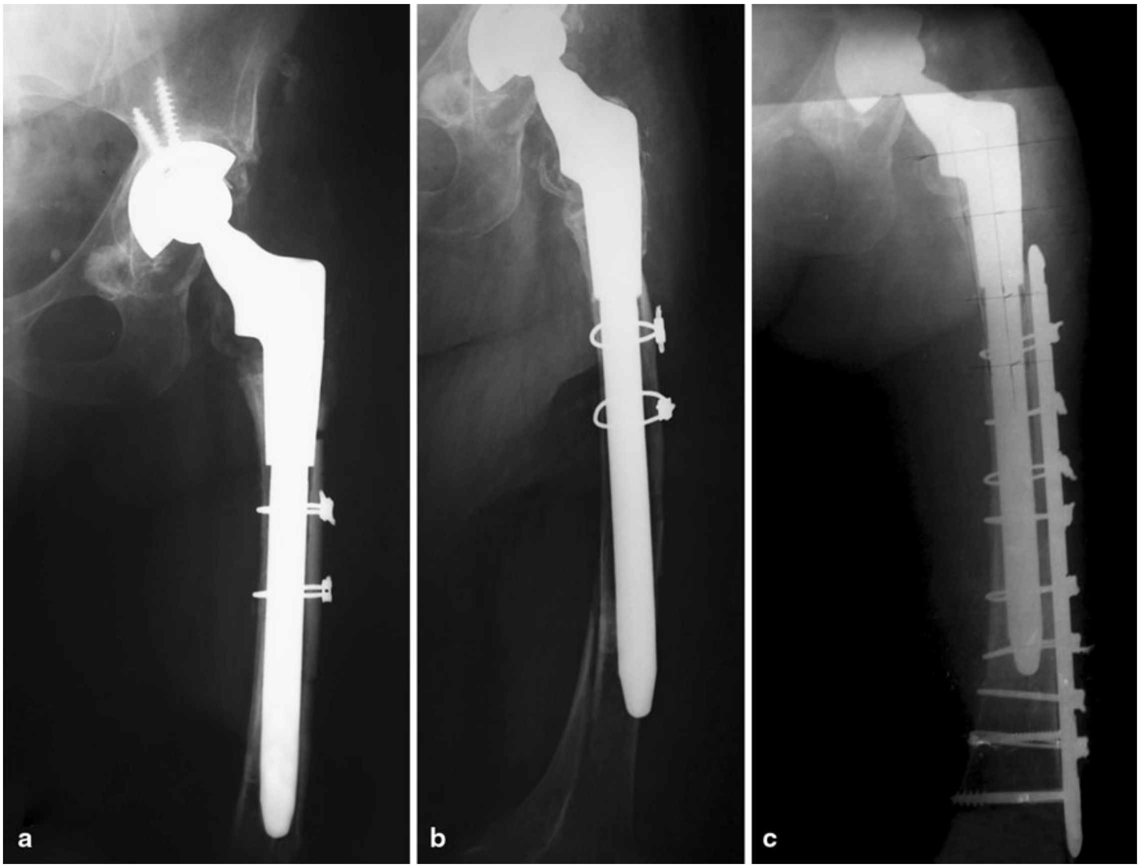

Fig. 5 **a** Hip radiograph of 71-year-old male patient who was operated for Vancouver type B3 fracture (Case #10) with a modular femoral stem. **b** A new fracture at the tip of the revision stem occurred 26 months after the operation (Vancouver type B1). **c** Fixation of the fracture was achieved with Dall-Miles plate, screws and cerclage wires

Table 4 Summary of results

Case #	Harris Hip Score	Barthel index	Union	Subsidence	Beals and Towers' criteria
1	60	85	+	–	Good
2	55	65	+	–	Good
3	40	45	+	–	Poor
4	65	90	+	Stable subsidence (5 mm)	Good
5	85	95	+	–	Excellent
6	32	60	+	Stable subsidence (7 mm)	Poor
7	85	100	+	–	Excellent
8	62	100	+	–	Excellent
9	77	90	+	–	Excellent
10	100	92	+	–	Poor
11	65	85	+	Stable subsidence (3 mm)	Good
12	65	75	+	–	Poor
13	85	90	+	–	Excellent
14	90	95	+	–	Excellent
15	60	30	+	Stable subsidence (5 mm)	Good
16	80	90	+	–	Excellent
17	55	75	+	–	Excellent

onlay strut allografts provide a good fracture stability that promotes fracture healing. Types B2 and B3 femoral periprosthetic fractures represent one of the most difficult reconstructive surgeries. Uncemented distally locked long femoral stems with or without cortical onlay strut allografts offer a useful and successful solution.

Conflict of interest The authors declare that they have no conflict of interest.

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