Tapered Fluted Titanium Stems in the Management of Vancouver B2 and B3 Periprosthetic Femoral Fractures

Jacob T. Munro MBChB, Donald S. Garbuz MD, MHSc,
Bassam A. Masri MD, Clive P. Duncan MD, MSc

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Abstract

Background Surgeons have several implant choices when managing Vancouver B2 and B3 periprosthetic fractures about the hip. Few long-term studies have reported outcomes for tapered fluted titanium stems.

Questions/purposes We determined (1) survival, with femoral revision as the end point, of distal taper stems in the treatment of Vancouver B2 and B3 periprosthetic

fractures at our institution, (2) radiographic outcomes, and (3) quality of life and hip function after revision.

Methods Of the 200 patients with Vancouver B2 or B3 periprosthetic fractures treated with femoral revision between February 2000 and February 2010, 55 (38 B2, 17 B3) were treated with modular tapered titanium stems. Of the surviving 47 patients, one was lost to followup, leaving 46 (30 B2, 16 B3) available for review at a mean of 54 months (range, 24–143 months). Initial indications for using these implants were treatment of periprosthetic fractures where less than 4 cm of diaphyseal fit was available, but this evolved during the study period to all fractures unless no diaphysis remained, in which case complex revision techniques were used. Radiographs were assessed to establish fracture healing, stem subsidence, and bone stock restoration. Quality of life and hip function were assessed using WOMAC, Oxford, SF-12, UCLA activity level, and satisfaction scores.

Results Two femoral stems were revised: one subsided and was revised at 12 months; the other had deep infection and underwent two-stage revision at 49 months. Radiographic review showed one nonunion, with maintenance or improvement of bone stock in 89% of patients. Subsidence occurred in 24%. Mean Oxford score was 76 of 100, WOMAC function and pain scores were 75 and 82 of 100, satisfaction score was 91 of 100, and SF-12 mental and physical scores were 53 and 40 of 100.

Conclusions We report encouraging short-term results in terms of survival of distal taper stems in the treatment of B2 and B3 periprosthetic fractures. Although subsidence was frequent, most migrated less than 3 mm without correlation to poor pain and functional scores.

Level of Evidence Level IV, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

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J. T. Munro, D. S. Garbuz, B. A. Masri (✉), C. P. Duncan
Department of Orthopaedics, University of British Columbia,
910 West 10th Avenue, Room 3114, Vancouver,
BC V5Z 4E3, Canada
e-mail: Bassam.Masri@vch.ca; bas.masri@vch.ca

Introduction

The number of THA procedures continues to increase worldwide. The combination of broadening indications, greater functional expectations, and an aging population is likely to lead to increased prevalence of periprosthetic fractures [7]. Registry data indicate that periprosthetic fractures cause between 9.3% and 14.7% of THA revisions [2, 17, 19].

Fractures can be reliably classified according to the Vancouver classification [9] and this can assist in the decision-making process. Based on this classification, the treating surgeon has several options based on fracture location, implant stability, and bone stock and strength available to support a new implant. Vancouver Type B fractures are nonapophyseal (not the lesser or greater trochanter alone) but affect the femur around or just beside the stem. If the stem is solidly fixed, it is subcategorized as a B1. Fracture reduction and fixation are indicated. If the stem is loose with good remaining bone stock, it is subcategorized as B2. Fracture reduction and fixation, coupled with longer-stem revision, is usually preferred. Finally, if in addition to a loose stem there is inadequate bone to support a straightforward revision (such as severe comminution, osteolysis, or severe osteopenia), this is subclassified as B3. More complex reconstruction is usually used.

Revision THA with distally tapered fluted titanium cementless stems was originally described by Wagner in the 1980s [29, 30]. Axial stability of the implant is achieved by driving the tapered region of the stem into the femoral diaphysis that has been prepared using conical reamers. Longitudinal spines provide rotational stability. The original designs were monoblock in design except for head-neck modularity. The subsequent addition of stem modularity to a number of systems added to the versatility of the implant and to its broad application in revision hip arthroplasty and periprosthetic fracture management. This method of reconstruction has been successfully utilized in femoral revision after aseptic loosening [11, 12, 15, 21, 23–25, 28, 32]. Short-term survival of greater than 87% and good functional scores have been described for femoral revision with these stems in the presence of severe bone deficiency [26, 28]. In light of this, modular tapered stems also have become an attractive option in the treatment of Vancouver B2 and B3 fractures.

In this study, we determined (1) the survival, with femoral revision as the end point, of distal taper stems in the treatment of Vancouver B2 and B3 periprosthetic fractures at our institution, (2) the radiographic outcome in patients with these fractures treated with this stem, and (3) the quality of life and hip function after revisions performed for this indication with this implant.

Fig. 1A–C Photographs show the ZMR[®] and Revitan[®] stems: (A) ZMR[®] stem with a 3.5° taper and (B, C) two sizes of the Revitan[®] stem and modular bodies with a 2° stem taper.

Patients and Methods

Between February 2000 and February 2010, we performed 200 femoral revisions for periprosthetic fractures in patients with Vancouver Type B2 and B3 fractures. This included 34 proximal femoral replacements performed for severe bone loss and a nonsupportive diaphysis. We identified 55 patients treated with one of two tapered modular fluted titanium stems. The ZMR[®] (Zimmer, Inc, Warsaw, IN, USA) has a 3.5° distal taper while the Revitan[®] (Zimmer, Inc) has a 2° distal taper (Fig. 1). No patient treated with a tapered stem was excluded. Of the 55, 38 had a B2 fracture and 17 had a B3 fracture. Eight patients died at a mean of 23 months after surgery (range, 6 days to 42 months). None of the femoral stems were revised in this group. Of the surviving 47 patients, one who had moved overseas was lost to followup, leaving 46 patients with 30 B2 and 16 B3 fractures for review. All previous radiographs were obtained and hospital notes reviewed for surgical data and complications. Minimum followup for surviving patients was 24 months (mean, 54 months; range, 24–143 months). Average age was 72 years (range, 44–93 years) at surgery and 76 years (range, 47–96 years) at followup.

The general indications for use of tapered stems evolved during the study period. In the earlier period, they were reserved for Type B3 fractures with less than 4 cm of diaphyseal fit and therefore insufficient for a cylindrical

Fig. 2A–D Images illustrate revision of a Type B2 fracture using a 14-mm-diameter tapered fluted modular titanium stem. **(A)** A preoperative radiograph shows a fracture around a loose cemented stem. **(B)** An initial postoperative view shows position of the tapered

stem. **(C)** The undersized stem has clearly subsided. **(D)** The patient was revised to a 20-mm stem and had excellent results at 12 months. A constrained liner had been used because of severe abductor deficiency and high risk of dislocation.

Fig. 3A–C Images illustrate revision of a Type B3 fracture with an allograft strut in a 63-year-old woman. **(A)** An AP radiograph of the femur demonstrates a fracture around a cemented stem with an extensive cement mantle. After removal of the cement, there was severe bone loss. **(B)** An immediate postoperative view shows the tapered stem with allograft to restore lateral bone stock. **(C)** Eight

years later, the fracture has not united, but the onlay allograft has united to the femur. There is obvious bone loss (Type A) around the proximal implant. Her cup acetabular cage construct was revised for loosening and pelvic discontinuity by plating the posterior column and using an enhanced fixation surface cup.

fully porous cobalt-chromium stem, our commonly used revision stem at the time. After concerns about stress shielding with cylindrical stems and positive results with tapered stems, they became our stem of choice for all B2 and B3 fractures. The Revitan® stem with a 2° taper was

used in smaller patients with B2 fractures as it required less bone resection than the ZMR® system.

Surgery was performed through a posterior extensile approach, using the transfemoral modification to facilitate removal of the loose stem and cement. All cases underwent

Fig. 4A–C Images illustrate revision of a Type B3 fracture in an 83-year-old woman. (A) An AP radiograph of the femur demonstrates a fracture with osteolysis of the proximal femur. (B) An initial postoperative view shows allograft positioned medially with thinning of the cortical bone. (C) Followup at 34 months shows recovery of proximal bone and incorporation of the allograft strut. Despite the subsidence of the stem, the patient was asymptomatic.

preoperative templating. Stem length was planned to obtain 4 to 8 cm of distal fit with an estimate of diameter required. A prophylactic wire or cable was routinely used at the level of intact diaphyseal bone. Preparation of the femur was conducted with hand reamers to the pretemplated depth with increasing diameter until axial and coronal/sagittal stability of the reamer were established. Trial stems were used to check stability and trial bodies suitable restoration of length and offset. We initially used onlay allograft to support the proximal implant whenever bone was weakened or contained defects were present but currently only use this when proximal bone is absent, usually the medial calcar. The fracture occurred after primary arthroplasty (including one hemiarthroplasty) in 47 patients and after revision THA in eight. Thirty were cemented stems and 25 cementless stems. The existing stem was removed using the fracture as an extended osteotomy. Cortical onlay allografts were used in 14 of the B3 fractures to support the proximal implant. Fracture fragments were reduced around the proximal stem and secured with Luque wires in 15 patients, cerclage cables in 38, and heavy suture in two. In four patients, a claw plate with cables was used to secure the greater trochanter. Patients were managed with partial weightbearing for 6 weeks if stem fixation was judged to be secure and toe-touch weightbearing for 6 weeks followed by partial weightbearing (50%) for 6 weeks if there was any doubt.

Radiographs that included the full length of the femoral component in AP and lateral plain views were obtained along with the original films of the fracture and postoperative views. Subsidence was measured as movement relative to anatomic landmarks and checked against wires or cables. The known size of the femoral head was used to

confirm scale. Subsidence was classified into three groups: up to 3 mm, 3 to 10 mm, and greater than 10 mm. Measurements on plain radiographs have a reported error of up to 1 to 5 mm but acceptable intra- and interobserver error of greater than 0.8 [5, 14]. Changes in femoral bone stock were classified according to the system of Böhm and Bischel [6]: A (increasing defects), B (constant defects), or C (osseous restoration). Osseous restoration is calculated by comparing immediate postoperative radiographs to the latest followup images. A comparison of cortical thickness to bone diameter establishes a ratio, and if increasing, is defined as osseous restoration. Femoral union was defined as bone bridging across the fracture site on three of four cortices [18, 22]. Complete sets of radiographs were available for 38 patients, including 24 B2 fractures and 14 B3 fractures. This included three of the deceased patients who survived longer than 24 months. The five other deceased patients did not have sufficient followup. Twelve other patients were missing films for comparison or lived in geographically remote locations and did not wish to or were unable to attend for new imaging.

To assess patient quality of life and hip function, the 47 surviving patients were invited by mail to complete a standardized self-administered questionnaire incorporating the Oxford Hip Score [8], the WOMAC Osteoarthritis Index [3], the SF-12 [31], the Hip and Knee Arthroplasty Satisfaction questionnaire [13], and the UCLA activity score [1]. When patients did not return questionnaires, they were contacted by telephone, asked to complete the assessment themselves, and then contacted again to report their answers. Of the surviving 47 patients, the two with failed tapered fluted stems were excluded from self-assessed evaluation. One patient was lost to followup. Four

patients did not wish to participate. Four patients did not return the questionnaire despite repeated efforts to retrieve the information. Ten patients were unable to answer due to inability to comprehend the questionnaire, medical comorbidity, or a language barrier. We included three self-assessment scores from deceased patients with minimum 2-year followup. A total of 28 complete assessments (16 for B2 and 12 for B3) were available for evaluation.

Comparisons of quality of life and hip function between cohorts were assessed with two-sample t-tests using SAS® Version 9.3 (SAS Institute Inc, Cary, NC, USA).

Results

Two stem revisions were required (4%). One stem required revision for loosening. It was a Type B2 fracture in which the stem subsided more than 10 mm. Revision at 12 months to a stem that was 6 mm larger in diameter led to an excellent outcome (Fig. 2). The fracture was found to be united at revision. A second stem required revision at 49 months for the two-stage management of a late-onset bacteremic periprosthetic infection due to *Streptococcus oralis*. The initially inserted tapered fluted titanium stem was solidly fixed. One asymptomatic fracture nonunion was identified. However, the femur was in continuity. This occurred in a 63-year-old woman with a B3 fracture around a primary cemented stem. At 8-year followup, her allograft strut had bonded proximally and distally (Fig. 3).

Subsidence was noted in nine of 38 patients (24%). This was less than 3 mm in five patients, 3 to 10 mm in two, and greater than 10 mm in two, including the stem that failed (Fig. 2). Subsidence occurred in six B2 fractures (25%) and three B3 fractures (21%). Bone stock was classified as Type A (diminished) in 11% (Fig. 3), Type B (unchanged) in 63%, and Type C (increased) in 26% (Fig. 4). Eleven of 14 allografts were imaged and eight were radiographically incorporated (Fig. 4).

Self-assessed pain and function scores were generally good (Table 1). There was no significant difference in outcome scores when comparing the B2 and B3 fractures. With the low numbers available, subsidence was not associated with a difference in WOMAC pain ($p = 0.745$) or functional scores ($p = 0.962$). As patients presented immediately after a fracture, preoperative pain and functional scores could not be obtained.

Eight reoperations were required in the 54 patients not lost to followup, in addition to the two requiring stem exchange. Three patients had dislocations, including one of those who was deceased. One patient with a 36-mm head underwent closed reduction after a single dislocation in the early postoperative period. It did not recur. The other two, both with 40-mm heads, required revision of the acetabular

Table 1. Quality-of-life and hip function scores for Vancouver B2 and B3 fractures

Scoring system	B2 fractures (n = 16)	B3 fractures (n = 12)	p value
Mean patient age (years)	73	71	0.501
Mean WOMAC global score (points)*	76	77	0.822
Mean WOMAC function score (points)*	75	75	0.989
Mean WOMAC stiffness score (points)*	70	76	0.496
Mean WOMAC pain score (points)*	80	85	0.499
Mean Oxford Hip Score (points)*	74	77	0.637
Mean satisfaction score overall (points)†	96	94	0.781
Mean satisfaction score pain (points)†	98	92	0.341
Mean satisfaction score function (points)†	90	90	0.856
Mean satisfaction score recreation (points)†	86	80	0.542
Mean UCLA activity score (points)‡	4	5	0.404
Mean SF-12 physical summary score (points)	41	38	0.802
Mean SF-12 mental summary score (points)	53	54	0.803

* WOMAC and Oxford Hip Scores are normalized to a range of 0 to 100 points, with 0 being worst and 100 being best; †satisfaction scores range from 0 to 100 points; ‡a UCLA activity score of 4 correlates to regular participation in mild activities and a UCLA score of 5 to sometimes participates in moderate activities.

component and head. None of the stems had subsided and all were noted to be well fixed at the time of rerevision. Two patients sustained supracondylar femur fractures (Vancouver Type C) after falls 12 and 14 months after revision. In both patients, the fractures were well distal to the implants and were treated with reduction and internal fixation. One patient with an acetabular reconstruction cage construct for pelvic dissociation required revision of the acetabular component after cage failure (Fig. 3). The stem was stable. One aseptic superficial hematoma was washed out, and one patient had late removal of a claw plate because of soft tissue irritation.

Discussion

Surgeons have several implant choices when managing Vancouver B2 and B3 periprosthetic fractures about the hip. We reviewed our results to determine (1) the survival

Table 2. Outcomes for Vancouver B2 and B3 periprosthetic fractures treated with tapered fluted stems reported in the literature

Study	Number of patients	Followup (months)*	Number of B2/B3 fractures	Number of stems revised for any reason	Number of stems with deep infection	Union rate	Number of stems revised for loosening	Number of intraoperative fractures	Subsidence (mm)	Clinical outcomes
Berry [4] (2003)	8 (1 died)	18 (12–24)	0/8	0	0	100% healed by 12 months	0	0	0	5 patients with no pain, 2 with mild pain 3 walking independently, 2 with cane, 2 with walker
Mulay et al. [16] (2005)	24 (2 died)	NR	10/14	0	1	91% healed by 12 months	0	1 (anterior cortex femur)	5 (2–10) in 17 patients	HHS (points)*: 69 (34–97)
Park et al. [22] (2009)	27	58 (36–122)	16/11	0	1	93%	0	2	> 5 in 1 stem > 10 in 1 stem	HHS (points)*: 85 (64–94)
Neumann et al. [18] (2012)	55 (2 died)	67 (60–144)	35/20	2	1	100% healed by 6 months	2	0	> 5 in 2 stems	HHS (points)*: 72 (45–97)
Current study	55 (8 died)	54 (24–143)	38/17	2	1	98% healed by 24 months	1	0	< 3 in 5 stems 3–10 in 2 stems > 10 mm in 2 stems	Oxford Hip Score (points)*: 76 WOMAC global score (points)*: 76 Satisfaction score (points)*: 95

* Values are expressed as mean, with range in parentheses; NR = not reported; HHS = Harris hip score.

Table 3. Comparison of reported quality-of-life and hip function scores for TFMT stems in femoral revision

Scoring system	Richards et al. [24]		Van Houwelingen et al. [28]	Current study
	TFMT stems	CNCC stems		
Mean WOMAC global score (points)*			77	76
Mean WOMAC function score (points)*			75	75
Mean WOMAC stiffness score (points)*	76	68	76	73
Mean WOMAC pain score (points)*	84	78	85	82
Mean Oxford Hip Score (points)*	77	69	77	76
Mean satisfaction score overall (points) [†]	97	90	94	95
Mean satisfaction score pain (points) [†]			92	95
Mean satisfaction score function (points) [†]			90	90
Mean satisfaction score recreation (points) [†]			80	83
Mean UCLA activity score (points) [‡]	5.1	4.6	4.9	4.6
Mean SF-12 physical summary score (points)	39	38	38	40
Mean SF-12 mental summary score (points)	53	51	54	53

Note the comparison with CNCC stems from Richards et al. [24], which showed significant differences in patient quality-of-life scores when comparing the two stem types; * WOMAC and Oxford Hip Scores are normalized to a range of 0 to 100 points, with 0 being worst and 100 being best; [†]satisfaction scores range from 0 to 100; [‡]a UCLA activity score of 4 correlates to regular participation in mild activities and a UCLA score of 5 to sometimes participates in moderate activities; TFMT = tapered fluted modular titanium; CNCC = cylindrical nonmodular cobalt-chromium.

of distal tapered fluted modular titanium stems in the treatment of Vancouver B2 and B3 periprosthetic fractures, using femoral revision as the end point, (2) the radiographic outcome, and (3) the quality of life and hip function after revision.

We note several limitations of the study. The study is retrospective and has no control group. The use of standardized outcome measures does allow us to compare this cohort with similar groups undergoing revision for different reasons or with different implants. Additionally, our stem selection evolved during the study period. Initially, we reserved tapered stems for Type B3 fractures but currently use them for the majority of B2 and B3 fractures that require revision. This should however mean that we have captured those patients with more severe bone loss and only one B3 fracture was lost. Unfortunately, several patients were medically unwell and unable to complete questionnaires. While this was not necessarily due to their hips, the results are biased toward those patients doing well. In this series, we had complete data (radiographic and quality-of-life assessment) on only 51% of patients treated. Thus, the results must be regarded as the best-case scenario as patients with incomplete followup are more likely to have inferior scores. We did obtain self-assessed quality-of-life data for 12 of 16 potentially assessable B3 fractures, a group we would expect to have more subsidence and poorer functional outcomes. Finally, reports of bone remodeling must be interpreted with caution. Plain radiographs can only detect reduction in bone stock when at least 30% of mineral density has been lost [10, 33].

We observed excellent short-term survival of tapered fluted titanium stems used in the management of B2 and selected B3 periprosthetic femoral fractures. This represents one of the largest reported series for tapered fluted titanium stems used for this indication. At a mean followup of 54 months, two (4%) femoral components had been revised. Only one femoral component failed for mechanical reasons. In this case, the stem (Fig. 2) was unable to resist axial load. This emphasizes the critical surgical step of reaming an adequate taper into the distal femur to receive an appropriately sized stem. Few studies have assessed survival of distally tapered stems used specifically in the management of periprosthetic fractures (Table 2). Mulay et al. [16] reviewed 10 B2 and 14 B3 fractures managed with a modular fluted tapered stem (Link® MP™ Hip Stem; Waldemar, Hamburg, Germany). The only revision was in a patient with deep infection treated with excision arthroplasty. Park et al. [22] observed similar performance with the same stem at mean followup of 58 months. Two stems in their series failed, one due to deep infection and one due to subsidence and loosening. Neumann et al. [18] recently reported survival of a modular tapered titanium stem used to treat 35 B2 and 20 B3 fractures (Modular Plus System®; Smith & Nephew, London, UK). Two stems failed due to uncontrolled subsidence. Of note, this system has a curved stem that requires a different approach when preparing the distal femur. A small series of eight B3 fractures was reported by Berry [4], with no failures at a short minimum followup of 12 months. Other management options have been assessed. Springer et al. [27] reported

outcomes from the Mayo Clinic registry for 118 femoral revisions after periprosthetic fracture. Fully coated cylindrical stems had superior survival compared to partially coated prostheses and cemented stems. Kaplan-Meier analysis demonstrated 90% survival at 5 years, falling to 79% at 10 years. O'Shea et al. [20] assessed 22 B2 and B3 fractures managed with extensively coated stems. Two stems failed: one used in a B2 fracture subsided and did not stabilize and one used in a B3 fracture became infected. We have previously used these stems but have found the rate of subsidence unacceptable when less than 4 cm of bone is available distally.

Subsidence was observed in 24% of patients although the majority were less than 3 mm. Overall, only 9% subsided more than 3 mm and only one patient was symptomatic and required revision. We did not see any subsidence occurring beyond 12 months. Two stems subsided more than 10 mm, one of which failed. It must be noted that 31% of the cohort had incomplete radiographic followup; thus, the true rate is unknown. Similar rates of subsidence have been reported after revision for aseptic loosening [12, 21, 25]. Mulay et al. [16] reported mean subsidence of 5 mm (range, 2–10 mm) occurring in 17 of 24 patients. Several authors have reported favorable bone remodeling and osseous integration after revision with tapered titanium stems for aseptic loosening [15, 24, 25]. These results have been similar to our experience, with the majority of patients demonstrating stable bone or restoration of bone stock with increasing cortical volume and healing of defects [6, 25]. While plain radiographs are not the most accurate means of determining bone remodeling, we have not observed the marked proximal stress shielding seen with cylindrical cobalt-chromium stems [24, 26].

Pain and functional scores were acceptable for those assessed, especially as there were no differences in outcomes between B2 or B3 fractures. Richards et al. [24] performed a cross-sectional cohort study comparing 103 tapered fluted modular titanium stems to 114 cylindrical nonmodular cobalt-chromium stems. The surgical indication was aseptic loosening in 78%, periprosthetic fracture in 10% and second-stage reconstruction after infection in 12%. Despite a larger number of patients with severe bone loss, both pain and functional scores were significantly higher for the tapered stems than for the cylindrical stems (Table 3). Van Houwelingen et al. [28] found similarly favorable scores when reviewing the longer-term followup of patients revised with tapered fluted modular titanium stems with severe (Paprosky Type IIIB and IV) bone loss (Table 3) [26]. The same questionnaire was used in our study. Scores reported by our group of patients were closely aligned to scores reported in both studies.

We believe the continued use of tapered fluted titanium stems in the treatment of Vancouver B2 and B3 fractures is

justified, and further followup is needed to ensure that patients with asymptomatic subsidence do not become symptomatic.

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