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How Should Vancouver B1-Periprosthetic Fractures at the Tip of a Cemented or Uncemented Femoral Stem Be Treated?

Pablo A. Slullitel, MD [a], Jakob Van Oldenrijk, MD, MSc, PhD [b], Shang-Wen Tsai, MD [c, d], Stanislav Bondarenko, MD, DMSc [e], David Rodriguez-Quintana, MD [f], Eric L. Smith, MD [g], Scot A. Brown, MD [h], Eric B. Smith, MD [h], Manuj Wadhwa, MS, MCh [i], Khalid Merghani, MBBS, MCh [j], Karan Goswami, MD [h, *]

[a] Carlos E. Ottolenghi Institute of Orthopaedics, Italian Hospital of Buenos Aires, Buenos Aires, Argentina
[b] Department of Orthopedic Surgery and Sports Medicine, Erasmus Medical Center, Rotterdam, Netherlands
[c] Department of Orthopaedics and Traumatology, Taipei Veterans General Hospital, Taipei, Taiwan
[d] Department of Orthopaedics, School of Medicine, National Yang Ming Chiao Yung University, Taipei, Taiwan
[e] Sytenko Institute of Spine and Joint Pathology, National Academy of Medical Sciences of Ukraine, Kharkiv, Ukraine
[f] Department of Orthopedic Surgery, University of Texas Health Science Center at Houston, Houston, Texas
[g] Department of Orthopedics, New England Baptist Hospital, Boston, Massachusetts
[h] Rothman Orthopaedic Institute at Thomas Jefferson University Hospital, Philadelphia, Pennsylvania
[i] Elite Institutes of Orthopaedics & Joint Replacement, Mohali, India
[j] Department of Trauma and Orthopaedic Surgery, Midlands Regional Hospital, Tullamore, Ireland

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How should Vancouver B1 periprosthetic fractures at the tip of a cemented or uncemented femoral stem be treated?

Response/Recommendation: The literature supports the notion that transverse or short-oblique B1-periprosthetic femoral fractures (PFFs) at the level or just below the tip of the stem (either cementless or cemented) have poorer results and suboptimal outcomes when treated with a single lateral plate osteosynthesis alone. This is due to increased strain at the fracture level, and thus, a higher risk of subsequent nonunion. We, therefore, recommend revision arthroplasty with a longer cementless distally-fixed stem, as this approach bypasses the fracture and enables both early weight-bearing and quicker healing. The decision between revision or fixation should take into account a patient's age, comorbidities, and stem integration. If fixation is chosen, single lateral plate fixation should be avoided; instead, fixation should be augmented with an additional orthogonal plate or a cortical strut allograft. Given the lack of high-quality studies, the true gold standard for the treatment of these fractures still needs to be defined.

Level of Evidence: Moderate.

Agree: 80.7%; Disagree: 14.0%; and Abstain: 5.4% (Total: N = 150).

Rationale

Periprosthetic femoral fractures, which can occur either intraoperatively or postoperatively, are usually classified according to the Vancouver system [1]. The reported incidence of postoperative PFF after primary total hip arthroplasty ranges between 0.4 and 1.2%, depending on several factors such as patient age, sex, previous stress shielding, previous implant stability, and type of fixation [2]. While fractures with a loose stem (Vancouver B2 and B3 fractures) are usually treated with revision with a longer femoral component that bypasses the fracture level, most fractures with a well-fixed

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* Address correspondence to: Karan Goswami, MD, Rothman Orthopaedic Institute at Thomas Jefferson University Hospital, 925 Chestnut Street, 5th Floor, Philadelphia, PA 19107.

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stem (Vancouver A, B1, and C) are treated with open or minimally-invasive reduction and internal fixation [3,4].

The binary classification of PFFs has been challenged [5]. Fracture patterns and location relative to the stem, as considered in the Cooke and Newman classification, are often overlooked. Fractures at the tip of a fixed stem (Cooke-type 3) present unique challenges due to concentrated forces in areas of limited cortical contact creating a stress riser [6]. Treatment options for these fractures remain debated [7]. While long-stem revision is often recommended, it may not be ideal for low-demand patients who have difficult-to-remove components. Plate fixation offers an alternative, but no clear treatment algorithm exists. This study aims to systematically review the outcomes of treating Vancouver B1-PFF at the tip of fixed stems.

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, we conducted a systematic search of the MEDLINE and PubMed databases from inception through March 2024 to identify studies on Vancouver-type B1-PFF about the tip of the stem. Exclusion criteria consisted of biomechanical or cadaveric studies, editorials, commentaries, case reports, reviews, technique articles without patient data, and articles not written in English. Coauthors independently screened the 1,777 titles and abstracts, applying the selection criteria. Disagreements were resolved by consensus after reading the full text. We reviewed the full text of 58 articles and ultimately included 17 articles for final analysis.

Although biomechanical reports were excluded from the literature search, the study by Moazen et al. should be noted. The authors analyzed the effect of fracture stability using progressive loading, finding that mechanical stress on a lateral femoral plate was substantially higher in unstable fracture configurations (e.g., with fracture gaps $\geq$ 10 mm or transverse patterns), suggesting that in such cases, revision with a longer stem bypassing the fracture gap would be a valid option [8]. In a retrospective cohort study of 41 B1-PFFs, a transverse-type fracture pattern at the tip of the stem was significantly associated with nonunion ($P = 0.04$) [9]. Additional clinical studies corroborate these findings. Tsiridis et al. reported two fixation failures at the level of the stem tip among three B1-fractures treated with a Dall-Miles plate [10], and three additional nonunions (i.e., failures) out of seven B1-fractures treated with a dynamic compression plate, including one plate fracture [11]. Similarly, Buttaro et al. described a series of B1-PFFs where six of 14 fractures treated with a lateral locking compression plate due to an index fracture at the level of the tip of a cemented stem (either transverse or short-oblique fracture) resulted in a new fracture of the plate at the same level [12]. The authors strongly recommended using an additional strut graft alongside the plate for added biological and mechanical stability, since all failures except one occurred in constructs lacking a cortical strut allograft. The authors also strongly suggested that even in patients who had well-fixed stems with this fracture pattern, stem revision with a longer component bypassing the fracture (and reaming at the fracture level) should be considered [12].

In accordance with these findings, Min et al. described a failure rate of three out of seven cases when using single locking-compression plate osteosynthesis in seven cases with a transverse PFF below (i.e., at the tip of) a well-fixed stem [13]. Furthermore, Chakrabarti et al. found that in 15 transverse B1 fractures around cemented stems treated with open reduction and internal fixation (ORIF) using lateral cable plates without bone grafts, four cases developed nonunion and plate failure within 7 to 12 months. In contrast, no nonunions were observed in patients who had long-oblique B1 fractures in both cemented (n = 8) and cementless (n = 16) stems [14]. The authors recommended either prosthesis revision or the use of additional cortical strut grafts for transverse B1 fractures [14]. A retrospective cohort study by Powell-Bowns et al. of 129 consecutive unilateral Vancouver-B-fractures around cemented Exeter stems, including 31 B1 fractures, found that transverse patterns were associated with increased relative risk of reoperation (odds ratio 4.22; 95% confidence interval (CI): 1.63 to 10.9, $P = 0.008$) [15]. Limited studies have shown successful healing after the fixation of these fractures. In a study using lateral locking-compression-plates plus an anterior cortical strut allograft for 17 patients who had a B1-PFF around an uncemented stem, all fractures (seven transverse) healed in 12 to 30 weeks [16]. Another study documented the successful treatment of 22 B1 fractures (17 transverse, five short-oblique), using a locking plate (Intrauma, Rivoli, TO, Italy), without bone grafting. Only one patient who had a short-oblique fracture and uncemented stem experienced nonunion. Cement presence did not affect healing rates [17].

Few studies compared different methods for the treatment of this specific subgroup of B1 fractures, and most were biomechanical reports [18,19]. Lindahl et al. examined 321 PFFs, including 90 B1 fractures [20]. Of these, nine patients underwent revision surgery, with three requiring additional surgery. There were five patients who underwent both revision arthroplasty and ORIF, with one needing further surgery. There were 74 patients who were treated with ORIF-only, with 22 requiring additional procedures. Although the authors did not specifically subanalyze fracture patterns and levels, they speculated that many of the ORIF-only cases that failed may be related to the use of single plating alone, without use of either an additional strut graft or a supplementary orthogonal plate [21,22]. In a recent study, Gausden et al. reported a high 36% nonunion rate (95% CI: 15 to 70) for transverse or short-segment B1 fractures treated with single lateral plates, compared to a 20% nonunion rate (95% CI: 5 to 59) for those treated with dual-plating ($P = 0.16$) [23].

In another study reviewing 202 PFFs, Pavlou et al. found that transverse B1-fractures at the tip of the stem treated with stem revision compared to those treated with ORIF with a plate showed a nonsignificant trend toward improved overall union rate (odds ratio = 2, $P = 0.6$, 95% CI: 0.14 to 28.4) and significantly shorter time to union ($P = 0.038$, mean 12 ± 6.6 months versus 4.5 ± 0.8 for stem revision) [24]. The authors, thus suggested that stem revision for transverse B1 fractures was a viable treatment option to achieve axial stability and healing, as this configuration is difficult to control with single plating. However, patients who had B1-fractures treated with cemented stem revision (n = 17) showed higher reoperation rates at 2-year follow-up (29.4 versus. 5%, $P = 0.002$) and increased local complications (47.1 versus. 8.6%, $P < 0.001$) compared to those treated with ORIF (n = 116) [25].

The optimal treatment strategy should be adjusted based on the patient's age, comorbidities, and stem integration. In many cases, damage control using double plating may be a more straightforward approach for patients at high risk of perioperative mortality, with or without the addition of systemic anabolic treatments such as teriparatide [26,27]. However, particularly in frail patients, revision offers the major benefit of early weight-bearing, a reduced risk of nonunion, and minimizes the need for further surgeries.

CRediT authorship contribution statement

Pablo A. Slullitel: Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Jakob Van Oldenrijk:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shang-Wen Tsai:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis, Data curation. **Stanislav Bondarenko:** Writing – review & editing, Supervision,

Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **David Rodriguez-Quintana:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Eric L. Smith:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Scot A. Brown:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Eric B. Smith:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Manuj Wadhwa:** Writing – review & editing, Conceptualization. **Khalid Merghani:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Karan Goswami:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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