The majority of periprosthetic femoral fractures are treated surgically.

Surgical treatment may be revision only, revision in combination with open reduction and internal fixation (ORIF), or ORIF only.

The treatment decision is dependent on whether the stem is loose or not, but loose stems are not always identified, resulting in unsatisfactory treatments.

This article presents an algorithmic approach to identifying loose stems around proximal femoral periprosthetic fractures, taking patient history, stem design, and plain radiographs into consideration. This approach may help identifying loose stems and increase the probability of effective treatments.

**Keywords:** algorithm; loose stem; periprosthetic femoral fracture; revision total hip arthroplasty

Cite this article: EFORT Open Rev 2020;5:449-456. DOI: 10.1302/2058-5241.5.190086

**Introduction**

Femoral periprosthetic fractures are serious complications of total hip replacement (THR) with an expected incidence of 0.1–18% after THR. A fracture around the implant has been reported as the third leading cause for revision in the first two years after surgery and the second leading cause for revision in the long run. Furthermore, the incidence has been increasing in recent years, with a reported up to 2.5-fold increase over the past two decades. This observation may be explained partly by the increasing frequency of primary joint replacement surgeries and the increased life expectancy. The incidence of periprosthetic femoral fractures has been shown to increase with age. With the aging of the global population, an ever larger population is at risk. Other contributors to the increasing number of proximal femoral periprosthetic fractures are revisional THR and uncemented femoral fixation; both are increasingly being carried out today.

Treatments for periprosthetic femoral fractures are frequently accompanied by complications such as infection, dislocation, secondary loosening or non/malunion with poor functional outcome, and further surgeries. They also carry a significantly higher mortality risk than primary hip arthroplasties. An evidence-based optimal treatment is therefore of great social and economical interest.

Currently, a majority of periprosthetic femoral fractures are treated surgically (with or without open reduction internal fixation, ORIF); although non-operative measures are also used. In general, it is accepted that Vancouver B1 fractures can be treated with ORIF, and some newer studies on Vancouver B2 fractures have also found good clinical results following ORIF in selected cases. However, most loose stems must be revised. Whether or not a revision is necessary, or whether ORIF alone is sufficient, is not a straightforward decision. The first consideration is whether the stem is loose, and, if it is, whether this is due to the fracture or occurred prior to the fracture. To ease the decision-making process, several authors have tried to create a fracture classification system. The results are classification systems that take not only the fracture localization into consideration, but also the fracture type, implant stability, and bone quality. One of these proposed classification systems is the Vancouver classification by Duncan and Masri, which was later further expanded into the Unified Classification System. An algorithmic treatment approach for femoral periprosthetic fractures according to the Vancouver classification...
system is currently widely recommended. It classifies the fracture according to the fracture location. Type A fractures are located in the trochanteric region; type B fractures are located around the stem or just below it, and type C fractures are well below the tip of the stem. Type B fractures are further divided based on the implant stability and bone quality into three subtypes: well-fixed stem (B1), loose stem but good proximal bone (B2), and poor quality or severely comminuted proximal bone (B3).

Although the Vancouver classification has been tested for validity and reliability with results showing interobserver reliability of substantial agreement,26,27 several authors have reported, paradoxically, a higher rate of failure for osteosynthesis around prostheses that were considered well fixed.1,23,28 Presumably, not all loose stems were identified, resulting in an unsatisfactory treatment outcome. In agreement with this presumption, the data from a Swedish hip registry showed that up to 47% of stems in periprosthetic fracture are ‘unknown loose’, meaning that the surgeon found the stem to be loose only during the revision – clearly, a better clinical and radiologic criteria to detect stem loosening is needed.1,23 In this manuscript, we combined the concepts from Baba et al29 and Ninan et al23 with our own, and constructed an algorithmic approach to identify loose stems around periprosthetic fractures using patient history, stem design, and plain radiographs.

---

**Fig. 1** An algorithm for better identifying loose stems in patients suffering a periprosthetic fracture after total hip replacement (THR).

1. Increasing pain or reduced mobility due to hip problems prior to the fracture could be a sign of stem loosening.
2. Comminution around the stem is a sign of a loose stem.
3. Non-cemented stems: (i) an intra- or postoperative fracture in the first few weeks is indicative of a loose stem; (ii) in the presence of stem subsidence and (iii) significant osteolysis, the stem is most likely loose; (iv) if the fracture is at the primary level of fixation, the stem is expected to be loose; (v) if the stem is stable intraoperatively, then open reduction and internal fixation (ORIF) should be considered.
4. Cemented stems: a fracture around a composite beam-type stem should be considered loose; a polished-taper stem may still be well-fixed if the cement mantle is not fragmented or deficient. If the cement mantle is fragmented or deficient, a stem should be considered loose.

Note. p.o., post operation.
Considerations beyond the Vancouver classification

As illustrated in Fig. 1, two conditions signal a high likelihood of having a loose stem: (1) the patient has increasing thigh pain on weight bearing or reduced mobility due to hip problems prior to the fracture;23 (2) the patient has no pain but the fracture is comminuted prior to the periprosthetic fracture.30,31 If the patient has no pain and the fracture is not comminuted, the next question is whether the stem was cemented or not. The decision path from here on splits depending on whether the stem was cemented or not:

Non-cemented stems

For patients with non-cemented stems, the algorithm in Fig. 1 describes a stepwise diagnosis: (1) Fractures around non-cemented stems that occur intraoperatively or in the first few weeks after implantation should be considered as having loose stems because the stems would not have the chance to become integrated, (2) subsidence of the stem, (3) presence of major osteolysis, (4) location of the periprosthetic fracture, and (5) intraoperative testing of loose stems.

In integrated stems, femoral stem subsidence is a known reason for failure of total hip arthroplasty and needs to be considered by comparing radiographs taken after the periprosthetic fracture with earlier ones. If any subsidence of the stem can be identified in sequential radiographs such as the ones shown in Fig. 2A and Fig. 2B,32–36 we recommend that the stem can be assumed to be loose and that a stem revision should be undertaken. If subsidence is not evident, the presence of osteolysis around a stem indicates stem loosening and a revision should be considered. Osteolysis may be more evident on computed tomography (CT) than on plain radiographs. In the case of major osteolysis (clearly visible osteolysis in radiographs), the stem should be considered loose and must be revised.37,38 In cases where no previous radiographs are available, we recommend that a CT with a Metal Artefact Reduction algorithm could be performed. Subsidence and osteolysis can often be correctly diagnosed in this way.39

Next, the location of the periprosthetic fracture is crucial to identify loose stems. When the proximal femoral fracture occurs at the level of stem fixation, at least one of the bone fragments will have lost its bonding to the stem. This is often obvious on plain radiographs, but CT may help to clarify any uncertainty. When the fracture is comminuted, we assume that the stem is loose (Fig. 3A–D).39 In straight stems that achieve proximal fixation, a fracture in the metaphyseal area means the stem is loose and needs revision. In tapered stems that achieve fixation in the diaphyseal area, a fracture affecting the diaphyseal area means the stem is loose and needs revision. In fully coated stems, however, due to the fixation along the whole stem, the stem may still be well-fixed if only the metaphyseal or only the diaphyseal area is affected. Although modular designs offer a combination of proximal and distal fixation, because the proximal fixation is the crucial fixation, a fracture around the proximal area most probably means that the stem is loose and needs revision. The anatomic design offers stability through the metaphyseal fill and distal curve. A fracture around the metaphyseal area and distal curve probably means the stem is loose and needs revision. If the fracture is not at the level of primary fixation of that specific implant, then the last step to rule out a loose stem is intraoperative testing.

Cemented stems

Cemented implants can be divided into two general designs: shape-closed (i.e. composite beam) versus force-closed (i.e. polished taper) fixation. A shape-closed design achieves fixation at the stem/cement interface with the cement gripping the surface of the stem. These stems are usually pre-coated or have matt textured surfaces that enable perfect bonding between the cement and the stem. The force-closed system achieves fixation through the balance of forces, which is derived from the ability of a polished tapered stem to subside over short distances.
within the cement mantle, therefore a bond between the stem and the cement is not needed.\textsuperscript{40}

Because a composite beam stem must be rigidly bound to the cement to achieve fixation independent of whether the cement mantle is intact, a periprosthetic fracture around a composite beam stem should be revised as demonstrated in Fig. 4A–C.\textsuperscript{40} Whereas in polished taper stems, failures commonly occur through loosening at the

---

**Fig. 3** A 67-year-old female patient suffered a periprosthetic Vancouver B2 fracture three years after receiving an uncemented primary total hip replacement (a). According to the algorithm, revision of the stem should have been performed. However, in the belief that the implant was well-fixed, femur osteosynthesis was performed (b). Six weeks postoperatively, the stem had subsided and stem loosening was evident (c). Stem revision surgery was indicated (d).

**Fig. 4** An 82-year-old male patient suffered a periprosthetic Vancouver B2 fracture 10 years after receiving a cemented (composite beam) primary total hip replacement (a). Revision surgery should have been performed, instead, femur osteosynthesis was carried out (b). Three months postoperatively, the stem had subsided, indicating revision surgery (c).
cement/bone interface and are associated with loss of bone stock, presence of radiolucent lines, and osteolysis.\textsuperscript{41,42} Clinical experience is that polished tapered stems usually provide exceptional long-term fixation, despite the appearance of debonding at the stem/cement interface.\textsuperscript{43} Thus, in patients with a femoral periprosthetic fracture around a polished taper stem, the stem is considered loose if there are signs of a broken or deficient cement mantle that interferes with the cement/bone interface (Fig. 5A–C).\textsuperscript{44} A polished tapered stem can be considered well-fixed if the cement/bone interface is intact as illustrated in Fig. 6A–C.\textsuperscript{44}

**Discussion**

In this article we have combined our own concept with steps published by various authors into an algorithm in the hope of achieving better diagnosis of periprosthetic fractures of the proximal femur.\textsuperscript{5,22,23,29} In fracture management, it is generally accepted that Vancouver B1 fractures should be treated with ORIF alone, and that Vancouver B2 fractures should be revised. Although the differentiation between Vancouver B1 and B2 fractures seems straightforward, it has been suggested that the actual rate of stem loosening may be underestimated,
resulting in patients who should have been treated with revision being treated with ORIF. This suggestion is supported by a study showing that 47% of fractures diagnosed as Vancouver B1 were actually Vancouver B2 fractures, and may explain why a higher proportion of patients classified as having Vancouver B1 fractures and treated solely with ORIF eventually needed revisions.\textsuperscript{1,45} It may also explain why significantly higher rates of complications after ORIF treatment have been observed.\textsuperscript{28}

To help improve the classification of these fractures, Ninan et al established an algorithm where the choice of treatment is based mainly on whether the patient sensed hip pain before the fracture or not (‘unhappy’, loose stem; ‘happy hip’, well-fixed stem).\textsuperscript{23} They showed that 93% (25 of 27) of patients with unhappy hips had intraoperative evidence of a loose stem, while only 9% (2 of 23) of patients with happy hips required subsequent revision due to a loose stem. Even then, the evaluation of Ninan and colleagues’ own patients according to their classification showed that the proportion of patients with loose stems was initially slightly underestimated. Aside from Ninan et al, Baba et al\textsuperscript{29} also proposed a classification system that was supposed to overcome the lack of objectivity in evaluating implant stability. In this system, whether cement was used and the location of the fracture in relationship to the implant are taken into account. We agreed with both approaches and incorporated them with our additional criteria in designing an algorithm so that the fracture in its entirety may be systematically examined. Under this algorithm, a thorough evaluation will be carried out to examine the radiographs before and after fractures, history of pre-existing pain, stem designs, and implantation techniques. This new algorithm is radiograph-based and needs no additional diagnostic tools, therefore it can be easily applied. This feature is important because it allows early decision-making when further investigational tools, such as CT scans, are not available. Furthermore, it is objective and not dependent on a surgeon’s experience.

A few aspects may be considered as limitations of the proposed algorithm. Although the algorithm serves to identify loose stems, it is not a sole guide for the best treatment option, i.e. patient factors such as age and health conditions have to be considered too. For example, the one-year mortality after a periprosthetic fracture of the femur is 30%, therefore, conservative treatment should be considered in non-ambulatory patients and patients with severe morbidity and/or low life expectancy.\textsuperscript{11–14} Some studies have documented that ORIF resulted in less intraoperative blood loss and shorter operation time than stem revision;\textsuperscript{18,21} this could also be a reason for a surgeon to favour ORIF over stem revision in patients with poor health and low physical demands, despite stem revision being indicated. These considerations are patient specific and are not incorporated into our algorithm. Thus, although our algorithm may help identify loose stems, the treating surgeons still need to decide which treatment option may result in the best clinical outcome for individual patients. In addition, since there is the possibility that a loose stem may be identified intraoperatively, both trauma and arthroplasty surgeons (or a surgeon with expertise in both fracture fixation and revisional arthroplasty) may need to be present or on stand-by.

Proximal femoral periprosthetic fractures are difficult to treat. Poor results and high mortality rates have been reported.\textsuperscript{13} Accurate initial classification of the fracture is crucial in obtaining successful treatment results. The present algorithm could be a useful tool in treating proximal femoral periprosthetic fractures; further studies on a larger scale will be necessary to validate its application.

**Conclusion**

A correct diagnosis of the stability of the implant is crucial for the optimal treatment of periprosthetic fractures. We have incorporated clinical, radiological, and intraoperative parameters, as well as stem-specific properties into an algorithm that enables surgeons to identify loose stems after periprosthetic femoral fractures. This systematic approach should allow for better preoperative planning and improve outcome.
BEYOND THE VANCOUVER CLASSIFICATION

FUNDING STATEMENT
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OA LICENCE TEXT
©2020 The author(s)
This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

REFERENCES
1. Lindahl H, Malchau H, Herberts P, Garellick G. Periprosthetic femoral fractures classification and demographics of 1049 periprosthetic femoral fractures from the Swedish National Hip Arthroplasty Register. J Arthroplasty 2005;20:857–865.
2. Cook RE, Jenkins PJ, Walmesley PJ, Patton JT, Robinson CM. Risk factors for periprosthetic fractures of the hip: a survivorship analysis. Clin Orthop Relat Res 2008;466:1652–1656.
3. Della Rocca GJ, Leung KS, Pape HC. Periprosthetic fractures: epidemiology and future projections. J Orthop Trauma 2011;25:566–570.
4. AOANJRR. Hip, knee and shoulder arthroplasty: 2018 annual report. Adelaide: AOA, 2018.
5. Frenzel S, Vécsei V, Negrin L. Periprosthetic femoral fractures: incidence, classification problems and the proposal of a modified classification scheme. Int Orthop 2015;39:1909–1920.
6. Lindahl H. Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. Injury 2007;38:651–654.
7. Abdel MP, Houdek MT, Watts CD, Lewallen DG, Berry DJ. Epidemiology of periprosthetic femoral fractures in 5477 revision total hip arthroplasties: a 40-year experience. Bone Joint J 2016;98-B:468–474.
8. Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32,644 primary total hip arthroplasties: a 40-year experience. Bone Joint J 2016;98-B:461–467.
9. Holder N, Papp S, Goffton W, Beaule PE. Outcomes following surgical treatment of periprosthetic femur fractures: a single centre series. Can J Surg 2014;57:209–213.
10. Moreta J, Aguirre U, de Ugarte OS, Jáuregui I, Mozos JL. Functional and radiological outcome of periprosthetic femoral fractures after hip arthroplasty. Injury 2015;46:292–298.
11. Streubel PN. Mortality after periprosthetic femur fractures. J Knee Surg 2013;26:27–30.
12. Lindahl H, Oden A, Garellick G, Malchau H. The excess mortality due to periprosthetic femur fracture: a study from the Swedish national hip arthroplasty register. Bone 2007;40:1294–1298.
13. Young SW, Walker CG, Pittro RP. Functional outcome of femoral peri prosthetic fracture and revision hip arthroplasty: a matched-pair study from the New Zealand Registry. Acta Orthop 2008;79:483–488.
14. Bhattacharyya T, Chang D, Meigs JB, Estok DM II, Malchau H. Mortality after periprosthetic fracture of the femur. J Bone Joint Surg Am 2007;89:2658–2662.
15. Lyons RF, Piggott RP, Curtin W, Murphy CG. Periprosthetic hip fractures: a review of the economic burden based on length of stay. J Orthop 2018;15:118–121.
16. Berry DJ. Management of periprosthetic fractures: the hip. J Arthroplasty 2002;17:11–13.
17. Holley K, Zelken J, Padgett D, Chimento G, Yun A, Buly R. Periprosthetic fractures of the femur after hip arthroplasty: an analysis of 90 patients. JSS 2007;3:190–197.
18. Joestl J, Hofbauer M, Lang N, Tiefenboeck T, Hajdu S. Locking compression plate versus revision-prosthesis for Vancouver type B2 periprosthetic femoral fractures after total hip arthroplasty. Injury 2016;47:939–943.
19. Lunebourg A, Mouhsine E, Cherix S, Ollivier M, Chevalley F, Wettstein M. Treatment of type B periprosthetic femoral fractures with curved non-locking plate with eccentric holes: retrospective study of 43 patients with minimum 1-year follow-up. Orthop Traumatol Surg Res 2015;101:277–282.
20. Spina M, Scalvi A. Vancouver B2 periprosthetic femoral fractures: a comparative study of stem revision versus internal fixation with plate. Eur J Orthop Surg Traumatol 2018;28:733–742.
21. Baum C, Leimbacher M, Kriebling P, Platz A, Cadosch D. Treatment of periprosthetic femoral fractures Vancouver type B2: revision arthroplasty versus open reduction and internal fixation with locking compression plate. Gersat Orthop Surg Rehabil 2019;70:215459319876859.
22. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect 1995;44:293–304.
23. Ninan TM, Costa ML, Krikler SJ. Classification of femoral periprosthetic fractures. Injury 2007;38:661–668.
24. Mont MA, Maar DC. Fractures of the ipsilateral femur after hip arthroplasty: a statistical analysis of outcome based on 487 patients. J Arthroplasty 1994;9:511–519.
25. Duncan CP, Haddad FS. The Unified Classification System (UCS): improving our understanding of periprosthetic fractures. Bone Joint J 2014;96-B:713–716.
26. Brady OH, Garbuz DS, Masri BA, Duncan CP. The reliability and validity of the Vancouver classification of femoral fractures after hip replacement. J Arthroplasty 2000;15:59–62.
27. Naqvi GA, Baig SA, Awan N. Interobserver and intraobserver reliability and validity of the Vancouver classification system of periprosthetic femoral fractures after hip arthroplasty. J Arthroplasty 2012;27:1047–1050.
28. Lauer HL, Wutzler S, Possner S, et al. Outcome after operative treatment of Vancouver type B and C periprosthetic femoral fractures: open reduction and internal fixation versus revision arthroplasty. Arch Orthop Trauma Surg 2011;131:983–989.
29. Baba T, Homma Y, Momomura R, et al. New classification focusing on implant designs useful for setting therapeutic strategy for periprosthetic femoral fractures. Int Orthop 2019;43:7–5.
30. Schwarzkopf R, Oni JK, Marwin SE. Total hip arthroplasty periprosthetic femoral fractures: a review of classification and current treatment. Bull Hosp Jt Dis 2013;71:68–78.
31. Mostofi SB. Fracture classification in clinical practice. Second ed. London: Springer-Verlag, 2012.
32. Campbell D, Mercer G, Nilsson KG, Wells V, Field JR, Callary SA. Early migration characteristics of a hydroxyapatite-coated femoral stem: an RSA study. Int Orthop 2011;35:483–488.
33. Kärrholm J, Borröns E, Löwenhielm G, Snorrason F. Does early micromotion of femoral stem prostheses matter? A 7- to 9-year stereoradiographic follow-up of 84 cemented prostheses. J Bone Joint Surg Br 1994;76:912–917.

455
34. Johanson PE, Antonsson M, Shareghi B, Karrholm J. Early subsidence predicts failure of a cemented femoral stem with minor design changes. Clin Orthop Relat Res 2016;474:2221–2229.

35. Streit MR, Haeussler D, Bruckner T, et al. Early migration predicts aseptic loosening of cementless femoral stems: a long-term study. Clin Orthop Relat Res 2016;474:1697–1706.

36. Krismer M, Biedermann R, Stöckl B, Fischer M, Bauer R, Haid C. The prediction of failure of the stem in THA by measurement of early migration using EBRA-FCA. Einzel-Bild-Roentgen-Analyse-femoral component analysis. J Bone Joint Surg Br 1999;81:273–280.

37. Marsland D, Mears SC. A review of periprosthetic femoral fractures associated with total hip arthroplasty. Geriatr Orthop Surg Rehabil 2012;3:107–120.

38. Berry DJ. Periprosthetic fractures associated with osteolysis: a problem on the rise. J Arthroplasty 2003;18:107–111.

39. Lohmann CH, Rampal S, Lohrengel M, Singh G. Imaging in peri-prosthetic assessment: an orthopaedic perspective. EFORT Open Rev 2017;2:117–125.

40. Shen G. Femoral stem fixation: an engineering interpretation of the long-term outcome of Charnley and Exeter stems. J Bone Joint Surg Br 1998;80:754–756.

41. Verdonschot N, Huiskes R. Surface roughness of debonded straight-tapered stems in cemented THA reduces subsidence but not cement damage. Biomaterials 1998;19:1773–1779.

42. Solomon LB, Hussenbocus SM, Carbone TA, Callary SA, Howie DW. Is internal fixation alone advantageous in selected B2 periprosthetic fractures? ANZ J Surg 2015;85:169–173.

43. Howell JR HM, Ling R. The well-cemented total hip arthroplasty: theory and practice. Berlin, Heidelberg: Springer Medizin Verlag, 2005.

44. Quah C, Porteous M, Stephen A. Principles of managing Vancouver type B periprosthetic fractures around cemented polished tapered femoral stems. Eur J Orthop Surg Traumatol 2017;27:477–482.

45. Lindahl H, Garellick G, Regnér H, Herberts P, Malchau H. Three hundred and twenty-one periprosthetic femoral fractures. J Bone Joint Surg Am 2006;88:1215–1222.