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# Periprosthetic fractures of the proximal femur: beyond the Vancouver classification

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- 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

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## Introduction

Femoral periprosthetic fractures are serious complications of total hip replacement (THR) with an expected incidence of 0.1–18% after THR.[1–3] 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.[4] Furthermore, the incidence has been increasing in recent years, with a reported up to 2.5-fold increase over the past two decades.[5] This observation may be explained partly by the increasing frequency of primary joint replacement surgeries and the increased life expectancy.[3,5,6] The incidence of periprosthetic femoral fractures has been shown to increase with age.[2] 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.[7,8]

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.[9,10] They also carry a significantly higher mortality risk than primary hip arthroplasties.[11–14] An evidence-based optimal treatment is therefore of great social and economical interest.[15]

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.[16,17] 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.[18–21] 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.[22–24] One of these proposed classification systems is the Vancouver classification by Duncan and Masri,[22] which was later further expanded into the Unified Classification System.[25]

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 al[29] and Ninan et al[23] with our own, and constructed an algorithmic approach to identify loose stems around periprosthetic fractures using patient history, stem design, and plain radiographs.

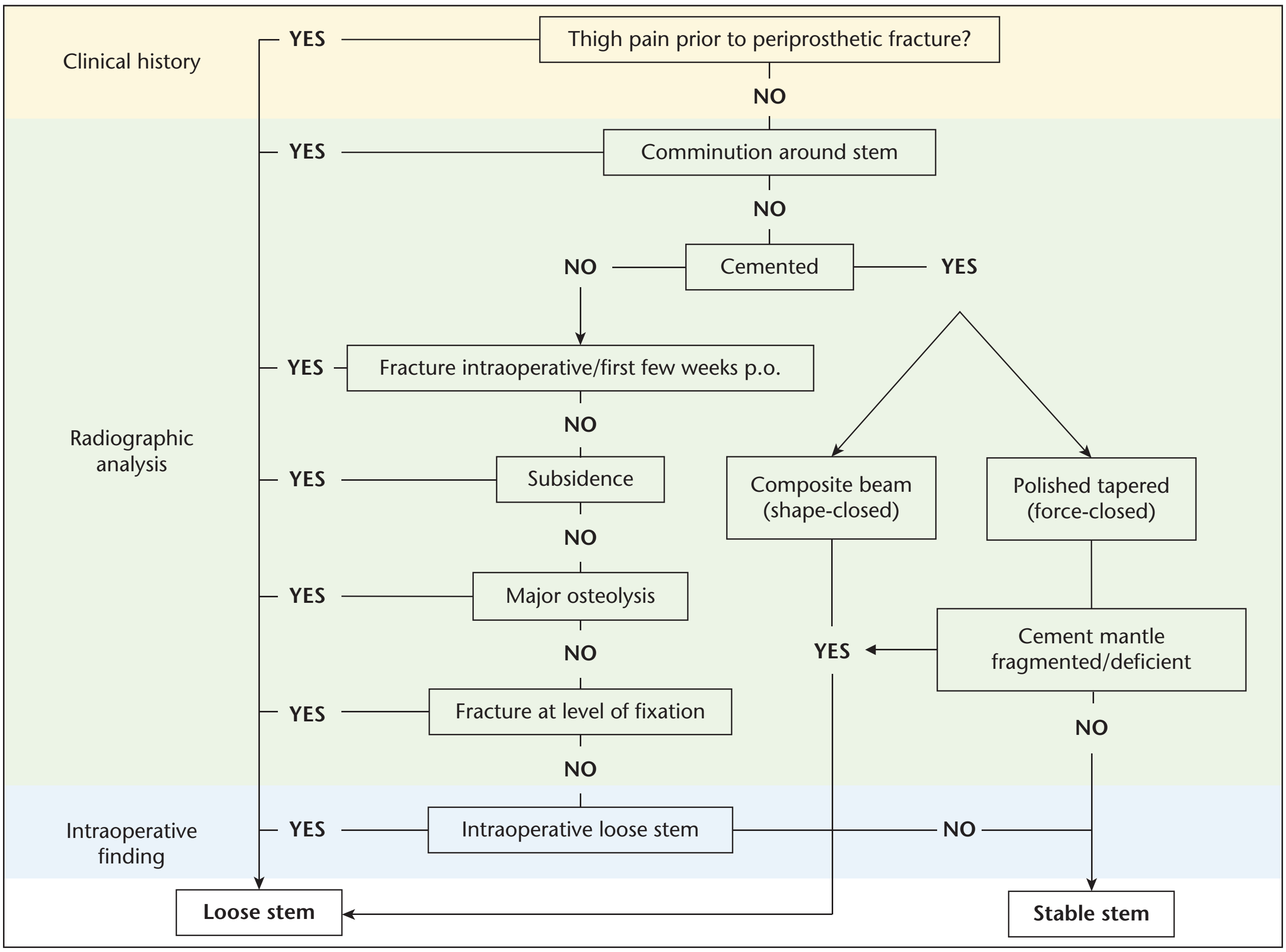


Fig. 1 An algorithm for better identifying loose stems in patients suffering a periprosthetic fracture after total hip replacement (THR). (1) Increasing pain or reduced mobility due to hip problems prior to the fracture could be a sign of stem loosening. (2) Comminution around the stem is a sign of a 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.

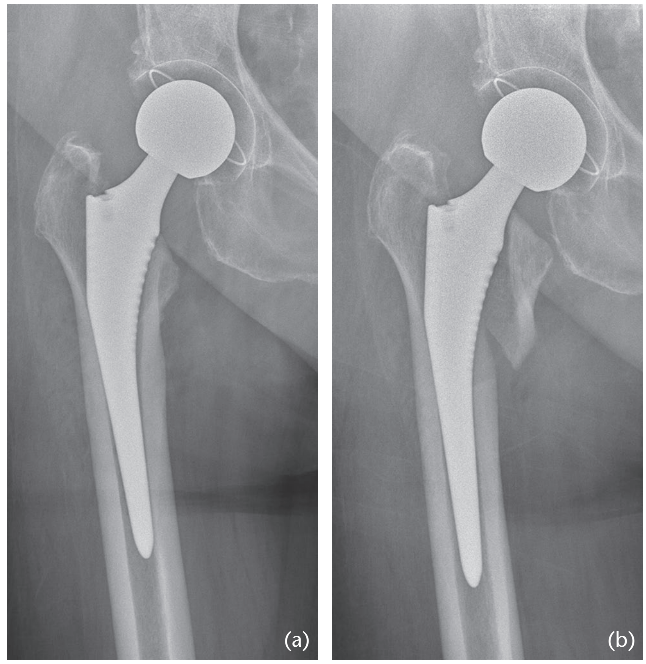


**Fig. 2** A 72-year-old female patient suffered a periprosthetic Vancouver B2 fracture during physical therapy five days after receiving an uncemented primary total hip replacement. When comparing radiographs taken prior to the fracture (a) and after the fracture (b), subsidence was evident, indicating the need for a revision.

### *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

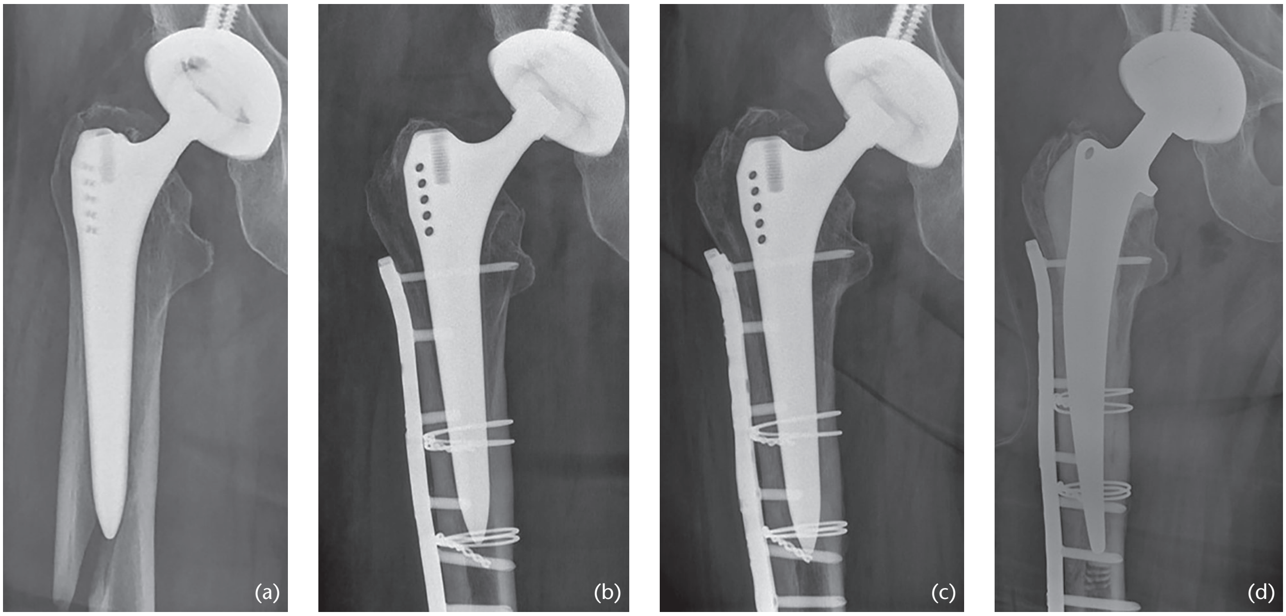


**Fig. 3** A 67-year-old female patient suffered a periprosthetic Vancouver B2 fracture three years after receiving an uncemented primary total hip replacement (a). According to the algorithm, revision of the stem should have been performed. However, in the belief that the implant was well-fixed, femur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

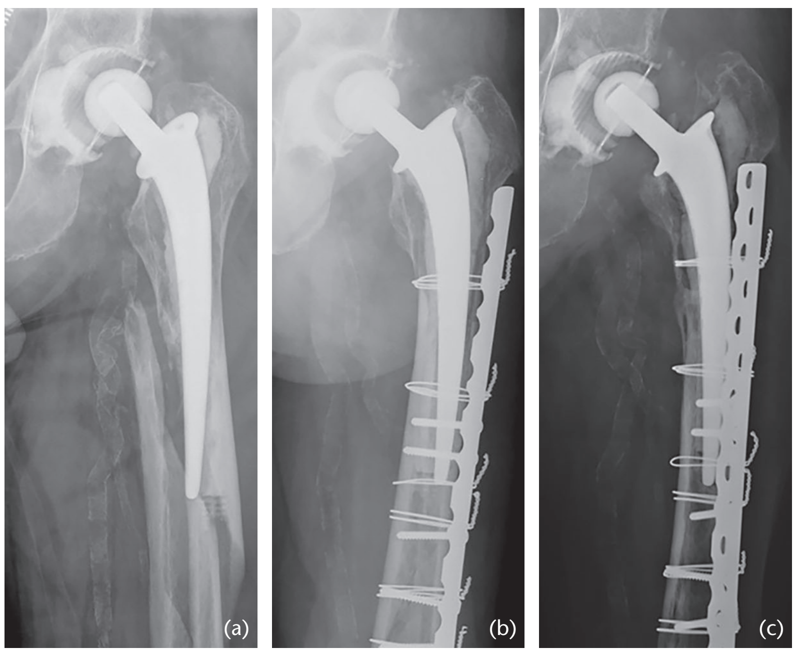


**Fig. 4** An 82-year-old male patient suffered a periprosthetic Vancouver B2 fracture 10 years after receiving a cemented (composite beam) primary total hip replacement (a). Revision surgery should have been performed, instead, femur osteosynthesis was carried out (b). Three months postoperatively, the stem had subsided, indicating revision surgery (c).

within the cement mantle, therefore a bond between the stem and the cement is not needed.[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.[40] Whereas in polished taper stems, failures commonly occur through loosening at the

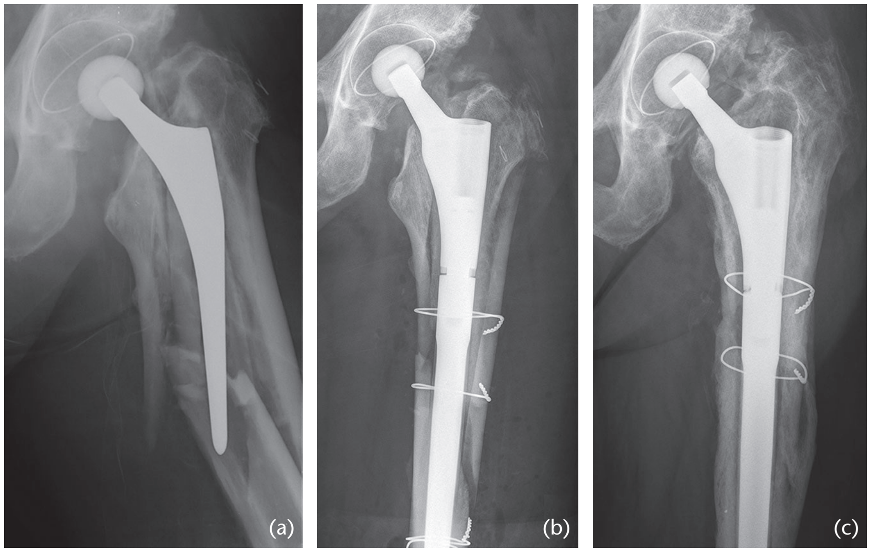


**Fig. 5** An 81-year-old male patient suffered a periprosthetic Vancouver B2 fracture six months after receiving a cemented (polished taper) primary total hip replacement (a). Revision surgery was performed (b). Six years later, the patient is pain free and satisfied (c).

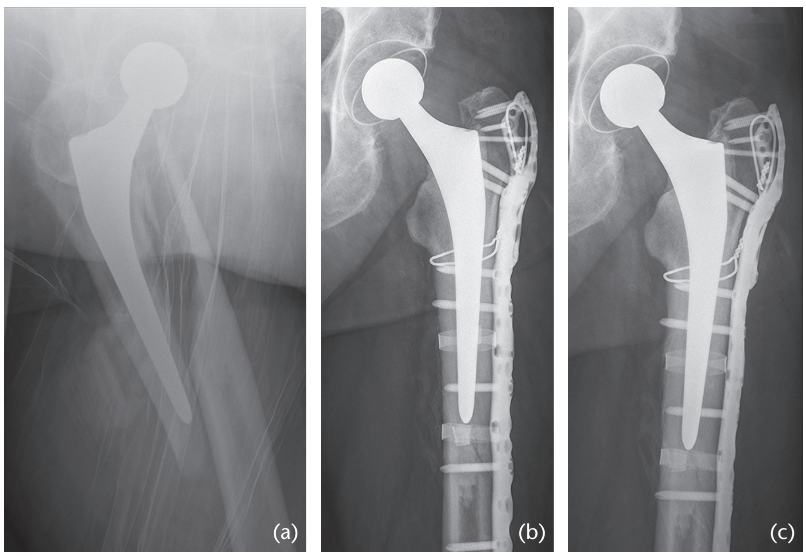


**Fig. 6** A 61-year-old male patient suffered a periprosthetic Vancouver B1 fracture two months after receiving a cemented (polished taper) primary total hip replacement (a). The patient was treated with femur osteosynthesis (b). One year after osteosynthesis, the patient is pain free and satisfied (c).

cement/bone interface and are associated with loss of bone stock, presence of radiolucent lines, and osteolysis.[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.[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).[44] A polished tapered stem can be considered well-fixed if the cement/bone interface is intact as illustrated in Fig. 6A–C.[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.[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.[1,45] It may also explain why significantly higher rates of complications after ORIF treatment have been observed.[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).[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[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.[11–14] Some studies have documented that ORIF resulted in less intraoperative blood loss and shorter operation time than stem revision;[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.[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.

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