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# A systematic review of Vancouver B2 and B3 periprosthetic femoral fractures

T. Khan,  
D. Grindlay,  
B. J. Ollivere,  
B. E. Scammell,  
A. R. J. Manktelow,  
R. G. Pearson

*From the University  
of Nottingham,  
Nottingham, United  
Kingdom*

■ T. Khan, MRCS(Eng),  
National Joint Registry/Royal  
College of Surgeons of England  
Research Fellow and Specialty  
Registrar in Trauma and  
Orthopaedic Surgery,  
Department of Academic  
Orthopaedics, Trauma and  
Sports Medicine,  
■ D. Grindlay, PhD,  
Information Specialist,  
Department of Academic  
Orthopaedics, Trauma and  
Sports Medicine,  
■ B. J. Ollivere, MD,  
FRCS(T&O), Associate  
Professor of Trauma Surgery  
and Consultant Trauma and  
Orthopaedic Surgeon,  
Department of Academic  
Orthopaedics, Trauma and  
Sports Medicine,  
■ B. E. Scammell, MD,  
FRCS(T&O), Professor of  
Trauma & Orthopaedic Surgery  
■ R. G. Pearson, PhD, Senior  
Research Fellow, Department of  
Academic Orthopaedics,  
Trauma and Sports Medicine,  
University of Nottingham,  
Nottingham NG7 2NR, UK.

■ A. R. J. Manktelow, BSc,  
MBBS, FRCS(Ed), FRCS(Orth),  
Consultant Trauma and  
Orthopaedic Surgeon,  
Department of Academic  
Orthopaedics, Trauma and  
Sports Medicine,  
Nottingham University  
Hospitals NHS Trust,  
Nottingham, UK.

Correspondence should be sent  
to T. Khan; email:  
tanvirkhan@doctors.org.uk

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## Aims

The aim of this study was to investigate the outcomes of Vancouver type B2 and B3 fractures by performing a systematic review of the methods of surgical treatment which have been reported.

## Materials and Methods

A systematic search was performed in Ovid MEDLINE, Embase and the Cochrane Central Register of Controlled Trials. For inclusion, studies required a minimum of ten patients with a Vancouver type B2 and/or ten patients with a Vancouver type B3 fracture, a minimum mean follow-up of two years and outcomes which were matched to the type of fracture. Studies were also required to report the rate of re-operation as an outcome measure. The protocol was registered in the PROSPERO database.

## Results

A total of 22 studies were included based on the eligibility criteria, including 343 B2 fractures and 167 B3 fractures. The mean follow-up ranged from 32 months to 74 months.

Of 343 Vancouver B2 fractures, the treatment in 298 (86.8%) involved revision arthroplasty and 45 (12.6%) were treated with internal fixation alone. A total of 37 patients (12.4%) treated with revision arthroplasty and six (13.3%) treated by internal fixation only underwent further re-operation.

Of 167 Vancouver B3 fractures, the treatment in 160 (95.8%) involved revision arthroplasty and eight (4.8%) were treated with internal fixation without revision. A total of 23 patients (14.4%) treated with revision arthroplasty and two (28.6%) treated only with internal fixation required re-operation.

## Conclusion

A significant proportion, particularly of B2 fractures, were treated without revision of the stem. These were associated with a higher rate of re-operation. The treatment of B3 fractures without revision of the stem resulted in a high rate of re-operation. This demonstrates the importance of careful evaluation and accurate characterisation of the fracture at the time of presentation to ensure the correct management. There is a need for improvement in the reporting of data in case series recording the outcome of the surgical treatment of periprosthetic fractures. We have suggested a minimum dataset to improve the quality of data in studies dealing with these fractures.

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As the number of total hip arthroplasties (THA) being performed worldwide continues to increase,<sup>1,2</sup> so does the incidence of periprosthetic femoral fracture. Based on the predictive modelling of National Joint Registry (NJR) data,<sup>2</sup> it has been projected that the numbers of primary and revision THAs in England and Wales will reach 186 893 and 137 056, respectively, by 2030.<sup>2</sup> A higher risk of periprosthetic femoral fracture has been shown in revision THA<sup>3</sup> but also following uncemented femoral fixation,<sup>4</sup> which is

increasingly being used.<sup>1,2,5</sup> The incidence of periprosthetic femoral fractures will therefore continue to rise. The Swedish National Hip Arthroplasty Register,<sup>6</sup> which contains data from 1979 onwards, shows periprosthetic fracture as the second most common reason for revision beyond four years after primary arthroplasty.<sup>7</sup>

The management algorithm surrounding the treatment of periprosthetic femoral fractures is complex. Various factors determine the correct form of treatment. The major influences are

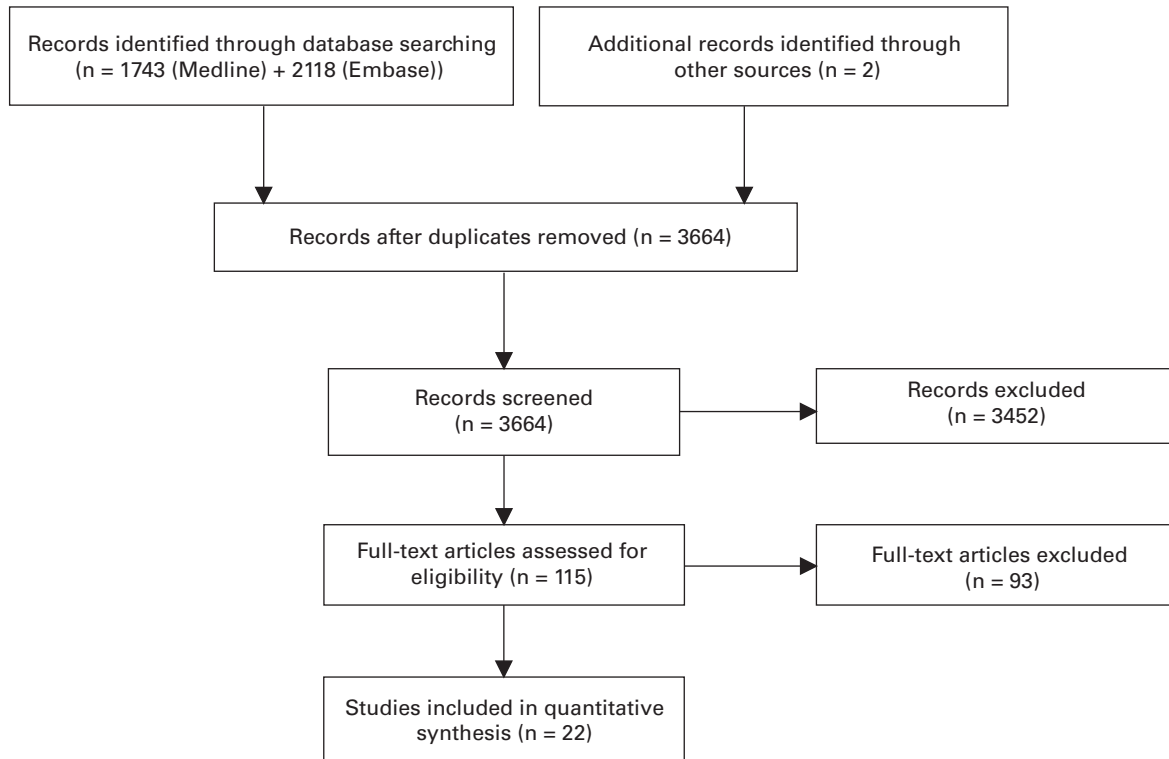


Fig. 1

Prepared Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

the location of the fracture relative to the implant, the state of fixation of the implant and the influence of the quality of the surrounding bone. These three variables are identified in the Vancouver classification and form the basis of the established algorithm of management.<sup>8</sup> B2 fractures may, however, be difficult to identify when implant loosening is not obvious, and the determination of B3 status can be subjective. In this study, one of the objectives was to demonstrate supportive evidence for the importance of attributing an accurate Vancouver classification to the fracture.

A number of studies have indicated a poorer outcome and higher mortality after revision for periprosthetic fracture compared with other indications for revision.<sup>9-11</sup> Drew et al<sup>12</sup> calculated the combined risk of either death or re-operation in the first year after a periprosthetic femoral fracture to be 24%. Furthermore, the costs associated with the treatment of these fractures are significant.<sup>13,14</sup> In today's challenging healthcare environment, only a successful clinical outcome will provide cost effective management.

Many of these fractures are Vancouver types B2 or B3.<sup>8,15</sup> Data from the Swedish National Hip Arthroplasty Register, showed that 555 of 1049 (53%) periprosthetic femoral fractures were type B2 and 43 (4.1%) were type B3.<sup>16</sup> Due to the presence of a loose stem with either good (Type B2) or poor bone stock (Type B3), revision surgery is generally recommended.

Joint registries can provide an analysis of revision surgery for periprosthetic femoral fractures, but the breadth of data collected is limited. Much of this is related to the difficulties of collecting appropriate data at the time of an emergency admission for fracture. Similarly, registry data will not identify the entire cohort, specifically will often not identify those treated with fixation alone. With the exception of publications based on the Swedish registry,<sup>16,17</sup> most other reported registry studies do not describe details of the classification of the fracture and the technique of fixation used at revision.<sup>18-21</sup>

The results from observational studies may provide detailed information which can be used collectively to assess the outcome of different forms of treatment for type B2 and B3 fractures. Although systematic reviews have assessed the outcomes of B1<sup>22,23</sup> and C<sup>22</sup> fractures, there are no previous formal systematic reviews assessing the outcomes or comparative outcomes of B2 and B3 fractures.

The primary aim of this study was to perform a systematic review of the methods of surgical treatment and outcomes of Vancouver B2 and B3 fractures. The secondary aim was to compare the outcomes in fractures treated with revision of the stem *versus* those treated with internal fixation without revision of the stem. We hypothesised that the appropriate classification of periprosthetic fractures is critical to avoiding unnecessary further surgery and ensuring a cost effective and successful outcome.

**Table I.** Total numbers and re-operations of Vancouver B2 and B3 fractures by the type of fracture

Fracture type	Revision with or without ORIF			ORIF without revision	Total
	Cemented	Uncemented	Unspecified		
Total Type B2 fractures	82	153	63	45	343
Re-operations Type B2 fractures, n (%)	11 (13.4)	19 (12.4)	7 (11.1)	6 (13.3)	43 (12.5)
Total Type B3 fractures	49	90	21	7	167
Re-operations Type B3 fractures, n (%)	8 (16.3)	12 (13.3)	3 (14.3)	2 (28.6)	25 (15.0)

ORIF, open reduction and internal fixation

## Materials and Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist for systematic reviews.<sup>24</sup> The review was registered on PROSPERO,<sup>25</sup> an international prospective register of systematic reviews.

A comprehensive electronic search of Ovid MEDLINE, Embase, and the Cochrane Central Register of Controlled Trials and Database of Systematic Reviews<sup>26</sup> from the earliest available year of indexing until August 2016 was conducted. As an example, the key terms used in the Ovid MEDLINE search are shown in supplementary material. The electronic search was supplemented with a manual search of the reference lists of all retrieved review articles for any other relevant citations. Abstracts of all citations were screened and full texts of articles were obtained to decide on inclusion of relevant studies. The attrition flowchart is shown in Figure 1.

Observational studies reporting the outcomes of surgical treatment of periprosthetic femoral fractures after THA, were included if: periprosthetic femoral fractures were classified according to the Vancouver system,<sup>15</sup> they included at least ten patients with a type B2 fracture, and/or ten patients with a type B3 fracture. A minimum of two years mean follow-up was required and studies had to report re-operation (including revision arthroplasty) as an outcome measure.

Studies were excluded if the fractures were not classified according to the Vancouver system, or if the methods of treatment and outcomes were not reported separately according to the classification of the fractures.

Two authors (TK, RGP) independently extracted data relating to the design of the study, the country of conduct, the period of study, case selection, the assessment of outcome and the characteristics of the patients. In cases of disagreement on the data which were extracted, a third author (BES) independently extracted the data. Quality assessment was performed independently by two authors using the validated tool specifically designed by Guo et al<sup>27</sup> to assess the quality of case series, and a minimum dataset was designed to improve data reporting specific to periprosthetic femoral fractures.

**Statistical analysis.** Extracted data were entered onto RevMan Version 5.3 (Cochrane, London, United Kingdom). Treatment was categorised by the type of fracture (Vancouver

B2 or B3) and the type of treatment (revision with or without open reduction and internal fixation (ORIF), ORIF alone). The details of the component used at revision were also recorded. The demographics of the further operations were reported according to the type of fracture and treatment. Risk Ratios (with 95% confidence intervals (CIs)) for re-operation were calculated using the Mantel-Haenszel random effects model<sup>28</sup> to make comparisons between the types of fracture and treatment. Data were represented as Forest plots and two-tailed z tests were used with a level of significance of 5%. Studies which reported treating both types of fracture, or similarly used both revision with or without ORIF and ORIF alone, could be included when calculating Risk Ratios.

## Results

A total of 22 studies fulfilled the inclusion criteria and were included in the review. All were case series.<sup>29-50</sup> Two involved the same patients,<sup>32,50</sup> data were extracted from both separately and then combined for analysis.

A total of 510 Vancouver B2 or B3 fractures treated between 1984 and 2012 were included for analysis. The mean follow-up ranged between 32 months and 74 months. **B2 fractures.** A total of 343 B2 fractures were reported in 14 case series (see supplementary material). Information about the gender was available for 125 patients (64 women; 61 men). Treatment involved revision of the stem with or without internal fixation in 298 patients (87.6%). A total of 45 were treated with fixation without revision of the stem. For those treated with revision THA, cemented stems were used in 82 (27.6%) and uncemented stems in 153 patients (51.3%). The type of stem was not specified in 63 operations (21.1%).

A total of 43 patients (12.8%) required re-operation following treatment. A total of 37 patients (12.4%) who were treated with revision of the stem with or without internal fixation required re-operation and six (13.3%) who were treated with internal fixation alone required re-operation. Table I shows the re-operations by the type of fracture.

Four studies<sup>38,39,45,49</sup> reported the results of treating Vancouver B2 fractures with either revision of the stem with or without ORIF or with ORIF alone. The calculated Risk Ratio of re-operation was 1.74 (95% CI 0.61 to 4.97,  $p = 0.30$ ) in favour of revision with or without ORIF (Fig. 2).

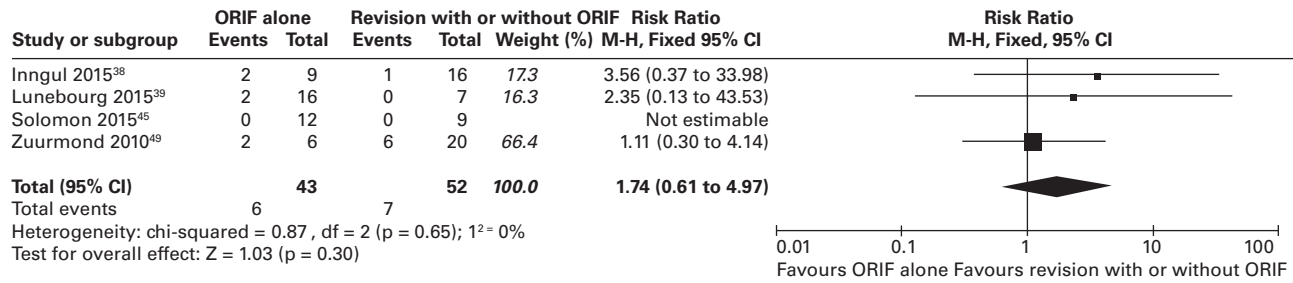


Fig. 2

Forest plot comparing the risk of re-operation for Vancouver B2 fractures treated with revision arthroplasty with or without open reduction and internal fixation (ORIF) versus ORIF alone (M-H, Mantel-Haenszel method; CI, confidence intervals; df, degrees of freedom).

Table II. Indications for re-operation by type of fracture

Indication for re-operation	B2 fractures	B3 fractures
Refracture	9	2
Infection	3	3
Subsidence	6	3
Stem loosening (aseptic)	4	1
Nonunion	4	0
Dislocation	4	2
Wound infection/superficial haematoma	4	3
Implant breakage	1	1
Not specified	8	10
<b>Total</b>	<b>43</b>	<b>25</b>

Table III. Revision femoral stem designs used in the treatment of B2 and B3 fractures by the design of the implant

Stem design	Type B2 fractures	Type B3 fractures	Total
Tapered, collarless polished (cemented)	24	3	27
Tapered, polished, collared (cemented)	7	0	7
Non-tapered, collared, rough finish (cemented)	23	0	23
Matte finish (cemented)	0	25	25
Tapered fluted (uncemented)	114	58	172
Distal locking (uncemented)	15	24	39
Proximal femoral replacement (cemented)	0	21	21
Unspecified cemented	28	0	28
Unspecified uncemented	46	8	54
Unspecified	41	21	62
<b>Total</b>	<b>298</b>	<b>160</b>	<b>458</b>

Table II summarises the indications for re-operation by the type of fracture.

**B3 fractures.** There were 167 Vancouver B3 fractures in the studies which were included (see supplementary material). Information about the gender was available for 99 patients (59 women, 40 men). In 160 cases (95.2%) treatment involved revision of the stem with or without internal fixation. A total of eight patients (4.8%) were treated with internal fixation alone. Of the 160 patients who underwent revision THA, 90 (53.9%) involved uncemented stems, 28 (16.8) involved a cemented stem and 21 (12.6%) were treated with a cemented stem. Revision prostheses were not specified for 21 patients (12.6%). Table III shows the stem designs which were used for revision in patients with both Vancouver B2 and B3 fractures.

There were a total of 25 re-operations (15.0%) (Table I), 23 (14.4%) in patients who were treated with revision of the stem with or without ORIF, including two who had further surgery for a wound infection in B3 fractures treated with a cemented stem. There were two re-operations (28.6%) for patients treated with ORIF alone, one for a further periprosthetic fracture and one for aseptic loosening of the stem. In two studies,<sup>42,46</sup> the results of those treated with both revision of the stem with or without ORIF or ORIF alone were reported. The Risk Ratio based on these two studies was 1.38 (95% CI 0.38 to 5.01, p = 0.63) in favour of revision of the stem with or without ORIF (Fig. 3).

**B2 versus B3 fractures.** Four studies<sup>33,40,42,43</sup> reported the outcome of sufficient numbers (> 10) of both B2 and B3

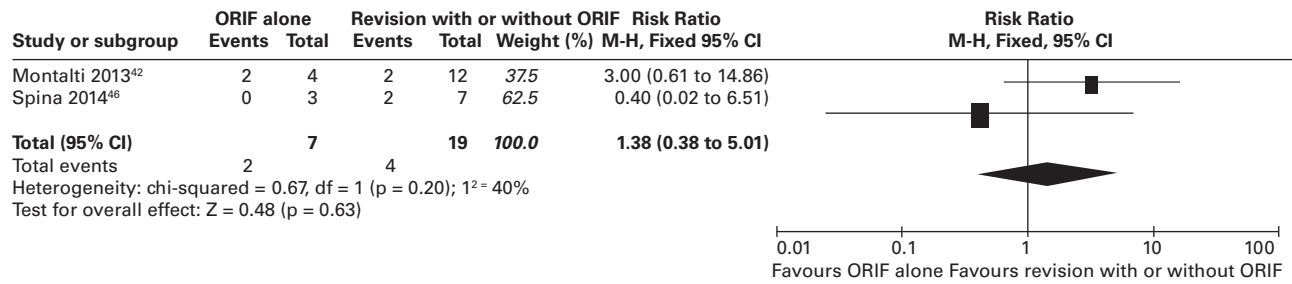


Fig. 3

Forest plot comparing the risk of re-operation for Vancouver B3 fractures treated with revision arthroplasty with or without open reduction and internal fixation (ORIF) versus ORIF alone (M-H, Mantel-Haenszel method; CI, confidence intervals; df, degrees of freedom).<sup>42,46</sup>

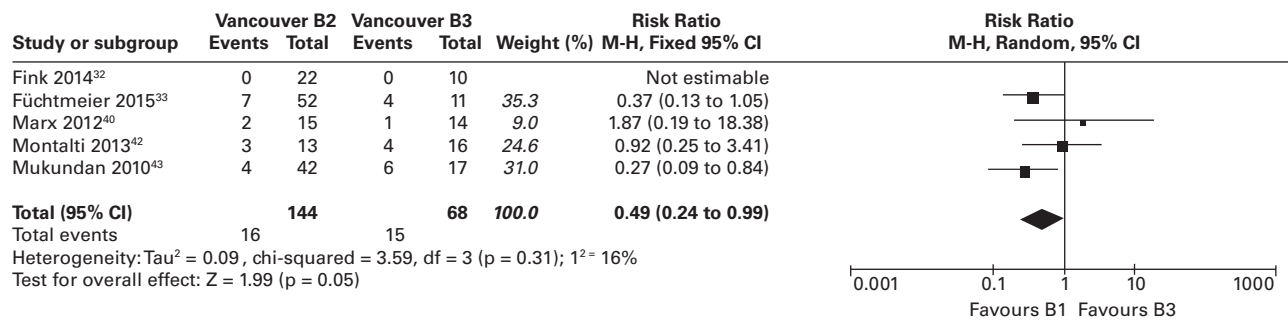


Fig. 4

Forest plot comparing the risk of re-operation for Vancouver B2 and B3 fractures (M-H, Mantel-Haenszel method; CI, confidence intervals; df, degrees of freedom).

fractures for a total of 180 periprosthetic fractures. The Risk Ratio of re-operation regardless of the form of treatment was 0.49 (95% CI 0.24 to 0.99, p = 0.31) in favour of B2 fractures (Fig. 4). The Risk Ratio when excluding patients treated with ORIF alone was 0.52 (95% CI 0.28 to 0.98, p = 0.23) in favour of B2 fractures.

**Uncemented tapered fluted stems.** Uncemented tapered fluted stems were used for revision in 114 B2 fractures (33.2%) and 58 B3 fractures (34.7%). The overall percentage rate of re-operation was 14/114 for B2 (12.3%) and 9/58 for B3 fractures (15.5%). The indications for re-operation included refracture (three), dislocation (three), aseptic loosening (three), wound complications (three) and stem breakage (one). Stem subsidence was reported in 9/172 patients (5.2%), although only three (1.7%) of these required revision. The indication for re-operation was not specified for seven patients.

**Quality assessment.** The mean quality score was 11.5/18 (standard deviation 2.39). Only two studies<sup>34,49</sup> reported detailed individual case-by-case data including demographic details, diagnosis, treatment and outcomes, both adopting a table format with a row per patient. Only five studies<sup>35,40,41,45,47</sup> had a mean follow-up of more than five years. A total of 14 studies<sup>29-33,37,39-46</sup> included either the names of the specific prostheses or details of the design of the stem which was used for revision. No study reported data to allow analysis of survival.

**Discussion**

This systematic review shows that as per consensus, most Vancouver B2 and B3 fractures which are reported in the literature are treated with revision THA with or without internal fixation. However, for B2 fractures particularly, a significant proportion (13.1% in this review) were treated with internal fixation alone. This might reflect difficulties in determining whether or not the stem was loose pre-operatively from the available imaging. However, this determination is important. Often the differentiation between a Vancouver B1 and B2 fracture is straightforward. However, there are fractures, initially felt to be around well-fixed stems, in which only a careful review of previous radiographs or a thorough history identifying pre-existing thigh pain, will raise the suspicion of associated loosening of the stem. Similarly, there are specific patterns and locations of fractures, such as a relatively transverse fracture through an area of lysis below an apparently well-fixed stem, that should alert the surgeon to the likelihood that the stem is failing and should be revised. We found that for both types of fracture, treatment with internal fixation alone was associated with a higher percentage of re-operations, but the difference in relative risk did not reach statistical significance. Almost a third of B3 fractures treated with internal fixation alone required re-operation. This trend is supported by national data from the Swedish

National Hip Arthroplasty Register,<sup>17</sup> which indicates a higher percentage of re-operations for B2 fractures treated with ORIF without revision of the stem (32%), than with those treated with revision alone (10%) or revision combined with internal fixation (23%). The overall proportion of patients undergoing a re-operation was higher than reported in this review which may be a reflection of the longer follow-up of registry data as opposed to published observational series. Another possible explanation is that there is bias in the selection of patients which surgeons/centres treat with internal fixation alone, which may be related to the fitness of the patients for a longer more physiologically demanding revision procedure, non-ambulatory patients, or in those with a limited life expectancy. Some authors have also reported good results at five-year follow-up of treating selected B2 fractures around polished, tapered, collarless stems in which anatomical reduction can be achieved, with internal fixation alone.<sup>45</sup> The information available for this systematic review limits our ability to address the question of which, if any, patients sustaining Vancouver B2 or B3 fractures, would be suitable for treatment with internal fixation alone.

The analysis of included studies with sufficient data available for comparison, indicates a higher relative risk of re-operation for B3 fractures compared with B2 fractures, even when comparing those treated with revision of the stem with or without fixation. Anecdotally, this has been appreciated by surgeons experienced in the management of these fractures, but there is little previous information, to quantify this difference into risk of failure. It is important to remember that compromise in the surrounding bone stock, that determines the differentiation of B2 and B3 fractures, is potentially representative of other factors which may contribute to a higher risk of failure, such as multiple previous operations on the hip, previous infection or fracture, severe lysis or osteopenia and other comorbidities, which have not been accounted for as confounders in this analysis.

Uncemented stems were found to be more commonly used for the management of both B2 and B3 fractures. A significant proportion of these were tapered fluted titanium stems with the non-modular Wagner SL stem (Zimmer Biomet, Warsaw, Indiana) being used in almost a quarter of all patients requiring revision of the stem. Tapered fluted titanium stems provide reliable and versatile distal diaphyseal fixation, which overcomes concerns about proximal stress shielding and the difficulties associated with advanced proximal bone loss.<sup>51</sup> These systems facilitate an accurate restoration of biomechanics of the hip with options to re-establish length and version independently, with modular proximal components. Good results have been reported after femoral revision for aseptic loosening.<sup>52-57</sup> Encouraging results with these technologies have also been reported in the management of periprosthetic fractures.<sup>51,58-60</sup> However, in many studies, the results are reported as part of larger observational cohorts, with their use in B2 and B3 fractures as only one of a number of other

indications for femoral revision. This is likely to have been under-reported in our review as the papers did not satisfy our inclusion criteria.

In this systematic review, the percentage of patients requiring re-operation using tapered fluted stems for both B2 (12.3%) and B3 (16.7%) fractures was comparable with those in the Swedish National Hip Arthroplasty register for the rate of re-operation for B2 and B3 fractures treated with revision of the stem with or without ORIF, which were 18.5% and 15.5% respectively.<sup>17</sup> One of the complications of these stems is subsidence of the stem. This can be a particular concern in the presence of poor bone quality. The rates and magnitude of subsidence differ in different systems. While significant rates of subsidence have been reported with the 2° taper angle of the Wagner SL stem,<sup>61,62</sup> more aggressive angles of taper available in some systems have shown lower rates of subsidence.<sup>63</sup> The overall proportion of subsidence in the stems used for Vancouver B2 and B3 fractures appears relatively low in this review. Most studies had a follow-up of less than five years and it is likely that significant subsidence would have occurred before that time. It is also important to appreciate that there was variation in the threshold for what could be deemed 'clinically significant' subsidence.

This review has limitations. There is a lack of large prospective studies in this field of study. Hence, the studies which were included were all retrospective case series. A total of 115 studies were assessed for inclusion based on the full-text, of which only 22 were finally included. Many were excluded either due to small numbers of periprosthetic fractures or a lack of matched outcomes by classification of the type of fracture. Only two studies reported individual case-by-case details.<sup>34,49</sup> Specifics such as the details of the original implant, whether the fracture occurred after primary or revision THA, the strategies used for fixation and the details of the implants for each patient would have allowed a more detailed analysis. Furthermore, the time to re-operation or death was not reported in any studies, and comparative analysis of survival was not possible.

Similar to the data from the Swedish National Hip Arthroplasty Register, Cook et al<sup>64</sup> reported 52% B2 and 10% B3 fractures in their study of periprosthetic fractures following 6458 primary THAs. Recent results from the Mayo clinic<sup>4</sup> described 557 periprosthetic femoral fractures from their institutional registry of 32 644 primary THAs, of which 24.5% were B2 and 9.2% were B3. As the incidence of Vancouver B2 and B3 femoral fractures continues to rise so will the requirement for complex reconstructive surgery with high morbidity and resulting high costs in financial and clinical resources.

It is important to appreciate that a significant number of Vancouver B2 fractures may be misclassified as B1 and treated with internal fixation without revision of the stem. These would not have been captured in this study. Therefore, the true re-operation rate for B2 fractures is likely to be higher than we have recorded.



**Table IV.** Suggested minimum dataset for case series reporting results of periprosthetic fractures

Age at primary (yrs)	Gender	Fracture: post-primary THA, revision, hemiarthroplasty	Yr of primary Implants	Primary Implants	Time to fracture (mths)	Fracture type (Vancouver)	ASA grade + comorbidities	Treatment: stem revision only, ORIF, ORIF only, stem revision + socket revision, cement-in-cement revision	Revision implants	ORIF implants (including strut allograft if used)	Impaction grafting (Y/N)	Reoperation/died/No re-operation (R/D/NR) If re-operation, give indication. E.g. infection, dislocation, fracture, stem failure, subsidence, aseptic loosening	Re-operation details e.g. washout, stem revision	Time to re-operation/ death	Date of last follow-up/death	Other outcomes: patient-reported outcome measures subsidence complications
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ORIF, open reduction and internal fixation; ASA, American Society of Anesthesiologists; THA, total hip arthroplasty

The Vancouver classification has good intra- and inter-observer reliability<sup>15,65-67</sup> and is a useful tool in guiding decision-making. It can, however, be difficult to classify some fractures accurately. Previous authors have suggested algorithms based on various strategies for treatment which are available and which often depend on the design of the existing femoral stem, the location of the fracture and its precise configuration.<sup>68</sup> This systematic review highlights both the variability in the treatment of B2 and B3 fractures, but also the significance of choosing the correct management strategy to avoid an increased risk of re-operation. We also found that although there are established guidelines for the principles of management, there is a shortage of high quality reporting of outcomes. Comparison of such studies would allow refinement in an algorithmic approach to management.

Currently, the National Joint Registry, the largest arthroplasty register in the world, records all primary THAs performed in England and Wales with matched revision procedures by indication. However, as a large population-based database, the breadth of data on each specific indication for revision is limited. For periprosthetic fractures, only those undergoing revision arthroplasty are entered. Therefore, those treated by internal fixation alone, although a relatively small number in the case of B2 and B3 fractures, are not recorded. The classification of these fractures and the details of any use of additional forms of internal fixation are also not recorded. There is therefore a necessary reliance on detailed observational studies to bridge this gap in information. There are reporting recommendations for case series in colorectal,<sup>69</sup> and more recently plastic surgery.<sup>70</sup> On this basis, we have designed a suggested minimum dataset to aid reporting of case series describing the outcome of periprosthetic fractures (Table IV).

In conclusion, this study is the only systematic review of Vancouver B2 and B3 femoral fractures. A proportion of both types of fracture are treated by internal fixation alone and have a higher rate of re-operation. Despite a large number of case series recording the treatment of B2 and B3 fractures, the breadth and detail of data limited the quantitative comparisons of specific forms of treatment. We have suggested a minimum dataset to be used for case series describing the management of these fractures.



### Take home message:

- Vancouver B2 & B3 fractures treated with internal fixation are associated with poorer outcomes.

- Improved reporting of periprosthetic fracture case series will allow better evaluation of treatment modalities in specific patient groups, as well as to allow robust analysis of implants used for revision arthroplasty.

### Supplementary material



A table showing the Ovid MEDLINE search strategy, as well as a data extraction chart, is available alongside the online version of this article at [www.bjj.boneandjoint.org.uk](http://www.bjj.boneandjoint.org.uk)

### Author contributions:

T. Khan: Study design, Data extraction, Analysis and preparation of manuscript.  
D. Grindlay: Study design, Manuscript preparation.  
B. J. Ollivere: Study design, Manuscript preparation.  
B. E. Scammell: Study design, Manuscript preparation.  
A. R. J. Manktelow: Study design, Analysis, Manuscript preparation.  
R. G. Pearson: Study design, Data extraction, Data analysis, Manuscript preparation.

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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.

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