The race for the classification of proximal periprosthetic femoral fractures: Vancouver vs Unified Classification System (UCS) - a systematic review

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Abstract
Background: Periprosthetic femoral fractures (PFFs) represent a major cause for surgical revision after hip arthroplasty with detrimental consequences for patients. The Vancouver classification has been traditionally used since its introduction in 1995. The Unified Classification System (UCS) was described in 2014, to widen the spectrum by aiming for a more comprehensive approach. The UCS also aimed to replace the Vancouver classification by expanding the idea of the Vancouver classification to the whole musculoskeletal apparatus. After introduction of the UCS, the question was raised, whether the UCS found its place in the field of analysing PFFs. Therefore, this systematic review was performed to investigate, the use of the UCS compared to the established Vancouver classification.

Methods: Medline was searched for reports published between 1 January 2016 and 31 November 2020, without language restriction. Included were original articles, irrespective of the level of evidence and case reports reporting on a PFF and using either the Vancouver or the UCS to classify the fractures. Excluded were reviews and systematic reviews.

Results: One hundred forty-six studies were included in the analysis. UCS has not been used in a single registry study, giving a pooled cohort size of 3299 patients, compared to 59,178 patients in studies using the Vancouver classification. Since 2016, one study using UCS was published in a top journal, compared to 37 studies using the Vancouver classification (p=0.29). During the study period, the number of yearly publications remained stagnant (p=0.899).

Conclusions: Despite valuable improvement and expansion of the latter UCS, to date, the Vancouver system clearly leads the field of classifying PFFs in the sense of the common use.

Keywords: Vancouver classification, UCS, Unified Classification System, Periprosthetic fractures

Introduction
Periprosthetic femoral fractures (PFFs) are one of the main causes for revision after hip arthroplasty, with an incidence ranging from 6.6-18% [1–4]. Furthermore, the incidence of periprosthetic femoral fractures is expected to increase by up to 4.6% per decade [1, 5–8] to a cumulative incidence of almost 5% [9]. PFFs can have detrimental consequences for the patient with a mortality rate of up to 11% within 1 year after surgical treatment [10]. They also represent a substantial economic burden [7, 11]. One of the key aspects after the diagnosis of PFF is the classification of the fracture, due to its therapeutic consequence, but also, development of further treatment...
options and comparison between specialized centres dealing with this issue [7].

The Vancouver classification, introduced in 1995 [12], is the first comprehensive approach, that clearly defines injury patterns and treatment options for this injury [13]. The classification encompasses the location of the fracture relative to the implant, the fixation of the implant to the bone after the fracture has occurred and it assesses the bone quality. Basically, this classification distinguishes A, B and C cases. “A” cases describe fractures in the intertrochanteric area, the prosthesis is considered stable. “A” cases can be subdivided into “A1” (lesser) and “A2” (greater) entities depending on whether the lesser or the greater trochanter is involved. “B” cases describe diaphyseal fractures around or just below the prosthesis stem, the prosthesis is considered stable and unstable as well depending on the subtype. “B” cases can be subdivided into “B1” (stable stem), “B2” (loose stem) and “B3” (loose stem and substantial bone loss). “C” cases describe fractures distinct below the prosthesis stem, the prosthesis is considered stable [12]. It has been demonstrated to be valid and reproducible [1, 14]. Finally, it also provides treatment recommendations [13]. However, in concordance with the continuous increase of arthroplasty procedures [7], the occurrence of new fracture patterns came to evidence [3, 15]. As a consequence, the Unified Classification System (UCS) was introduced in 2014, expanding the idea of the well-articulated Vancouver classification to the whole musculoskeletal system [16]. Resting on the basic principle of the Vancouver classification, it additionally contains the description of interprosthetic fractures and it also comprises acetabular fractures. Thus additional modifiers were added to the Vancouver classification. A case “D” describes an interprosthetic fracture, a case “E” describes fractures of two bones supporting one prosthesis and a case “F” a fractured bone that is unreplaced but articulating with a prosthesis [17]. As the name suggests, the Unified classification was introduced to "unify" and therefore replace all eponymous classifications. Since the PPFFs are the most common type of periprosthetic fractures [18] and the UCS covers the same nomenclatural algorithm as the Vancouver classification, the UCS aims to be the most conclusive classification to describe PPFFs. Both classifications, the Vancouver system and the UCS as well, show comparable values of validity and reliability in their use, two important variables when it comes to the usability of a classification system [1, 13, 16, 19, 20]. Despite the overlapping characterizations of these classifications, it was expected that the UCS would find a definitive place in the algorithms of patient care [17].

The purpose of this systematic review was to answer this question performing a comparison, investigating the frequency of these 2 classifications for the description of PPFFs found in the orthopaedic literature.

**Material and methods**

**Search strategy**

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines [21]. Medline was searched for reports published between 1 January 2016 and 31 November 2020, without a language restriction. Although the UCS was proposed in 2014, we decided to exclude papers before 2016, to allow the centres to get familiar with the UCS. We included original articles, irrespective of the level of evidence, and case reports reporting on a PPFF and using either the Vancouver or the UCS to classify the fractures. We excluded reviews and systematic reviews. The search queries were: (periprosthetic) AND (fracture) AND (Vancouver); ((periprosthetic) AND (fracture)) AND (Vancouver); ((periprosthetic) AND (fracture)) AND (unified). The search results were imported into Zotero (George Mason University, Fairfax, VA, U.S.) and duplicates excluded. The titles and abstracts were screened for the inclusion and exclusion criteria. Full texts of the included studies were accessed to retrieve the following information: Author, year of publication, size of the cohort, length of follow-up, study type (clinical, case report, biomechanical, validation, instructional) and the classification used. Finally, we investigated, whether the study has been published in the top 10% of its category in the year of its release according to the Journal Citation Reports (Clarivate Analytics, Philadelphia, PA, U.S.). References of retrieved articles were manually screened. The full list of all included studies is shown in Table 1.

**Data analysis**

Cohort sizes were pooled for each classification and descriptively compared. Changes in the yearly number of publications were compared using the Log-Rank (Mantel Cox) test. The ratio of publications in top 10% of journals was compared using the chi-square analysis. JASP 0.14.1 (University of Amsterdam, the Netherlands) was used for the statistical analysis.

**Results**

After running the search strategy, and exclusion of duplicates, 146 studies were included for the analysis, coming from centres in 29 countries on 6 continents (Fig 1). The Unified Classification was used in 9/145 studies (6.2%). UCS has not been used in a
| Author            | Year | Sample size | Top ten | Follow up (months) |
|-------------------|------|-------------|---------|--------------------|
| Fan MQ [16]       | 2020 | 2412        | no      | 0                  |
| Huang JF [3]      | 2018 | 402         | no      | 216                |
| Huang JF [20]     | 2016 | 228         | no      | 178                |
| Rupp M [22]       | 2019 | 75          | no      | 96                 |
| Gunther T [23]    | 2020 | 75          | no      | 52,9               |
| Nagvadia H [24]   | 2018 | 43          | no      | 16,5               |
| Kim MB [25]       | 2017 | 19          | no      | 16                 |
| Yeo [26]          | 2016 | 17          | yes     | 28                 |
| Manara JR [27]    | 2018 | 28          | no      | 26,4               |
| Diaz-Dilernia F [28] | 2019 | 54         | yes     | 75                 |
| Karam J [29]      | 2020 | 172         | no      | 96                 |
| Smitham [30]      | 2019 | 52          | yes     | 39,6               |
| Stevens [31]      | 2018 | 102         | no      | 0                  |
| Gordon K [32]     | 2016 | 20          | no      | 0                  |
| Joestl J [33]     | 2016 | 36          | no      | 18,3               |
| Lang NW [34]      | 2017 | 42          | no      | 26                 |
| Thaler [35]       | 2019 | 40          | yes     | 50                 |
| Trieb [36]        | 2016 | 34          | no      | 43,2               |
| Ghijsseling S [37] | 2018 | 8          | no      | 60                 |
| Aleem IS [38]     | 2016 | 1           | no      | 0                  |
| Bates BD [14]     | 2018 | 89          | no      | 0                  |
| Herman A [39]     | 2019 | 379         | no      | 68,4               |
| Lochab JL [40]    | 2016 | 18          | no      | 0                  |
| Li D [41]         | 2018 | 33          | no      | 58                 |
| Sun [42]          | 2020 | 83          | no      | 120                |
| Wang [43]         | 2019 | 129         | no      | In-hospital-stay   |
| Wang [44]         | 2019 | 34          | no      | 102                |
| Zhang [45]        | 2016 | 89          | yes     | 12                 |
| Zheng [46]        | 2020 | 97          | yes     | 24                 |
| Pavelka [47]      | 2017 | 83          | no      | min 36             |
| Gromov K [48]     | 2017 | 1441        | yes     | 23,7               |
| Andriamananaivo T [49] | 2020 | 50        | no      | 3                  |
| Bonnevialle P [50] | 2018 | 51        | no      | 27,6               |
| Cohen S [51]      | 2017 | 70          | no      | 43                 |
| Ehlinger L [52]   | 2017 | 1           | no      | 0                  |
| Gavanier B [53]   | 2017 | 45          | no      | 20                 |
| Perrin [54]       | 2018 | 49          | no      | 6                  |
| Bellova P [55]    | 2019 | 481         | no      | 63                 |
| Brand S [56]      | 2016 | 2           | no      | 0                  |
| Fink B [57]       | 2017 | 14          | yes     | 52,2               |
| Hoffmann MF [58]  | 2016 | 27          | no      | 24                 |
| Hoffmann MF [59]  | 2016 | 109         | no      | 25                 |
| Innmann M [60]    | 2017 | 163         | yes     | 264                |
| Klasan A [61]     | 2019 | 16          | no      | 0                  |
| Mülker M [62]     | 2019 | 8           | no      | 34                 |
| Schreiner [63]    | 2020 | 18          | no      | 18,50              |
| WählnerT [64]     | 2020 | 8 pairs     | yes     | /                  |
| WählnerT [65]     | 2017 | 5 pairs     | no      | /                  |
| Zajonz [66]       | 2020 | 80          | no      | 32 and 48          |
| Author                | Year | Sample size | Top ten | Follow up (months) |
|-----------------------|------|-------------|---------|--------------------|
| Zwingmann [67]        | 2016 | 70          | no      | 40                 |
| Walcher [68]          | 2016 | 38          | yes     | /                  |
| Woo [69]              | 2016 | 1           | no      | 26                 |
| Dozsai D [70]         | 2020 | 41          | no      | 96                 |
| Dhason R [71]         | 2020 | 15          | yes     | 0                  |
| Kittanakere SR [72]   | 2018 | 16          | no      | 60                 |
| Baig MN [73]          | 2018 | 1           | no      | 0                  |
| Cassidy JT [74]       | 2018 | 9           | no      | 49,3               |
| Fenelon C [75]        | 2019 | 138         | yes     | 25                 |
| Sheridan [76]         | 2017 | 30          | no      | 12 and 32          |
| Angelini A [77]       | 2016 | 54          | no      | 8,5                |
| Bibiano L [78]        | 2019 | 7           | no      | 50                 |
| Biggi S [79]          | 2018 | 207         | no      | 12                 |
| Caruso G [79]         | 2017 | 73          | no      | 41                 |
| Castelli A [80]       | 2018 | 24          | no      | 36                 |
| Cottino U [81]        | 2019 | 3248        | no      | 72                 |
| Giaretta S [82]       | 2019 | 64          | no      | 23,1               |
| Munegato D [83]       | 2020 | 25          | no      | 29                 |
| Pavone [84]           | 2019 | 38          | no      | 37,2               |
| Randelli [85]         | 2018 | 19          | no      | 73,8               |
| Solarino [86]         | 2019 | 3           | yes     | 178,8              |
| Solarino [87]         | 2018 | 2           | no      | 240                |
| Spina [88]            | 2020 | 121         | no      | 12                 |
| Spina [89]            | 2018 | 34          | no      | 12                 |
| Kamo K [90]           | 2019 | 194         | no      | 10                 |
| Kurinomaru N [91]     | 2019 | 1           | no      | 4                  |
| Ochi [92]             | 2019 | 1           | no      | 24                 |
| Okudera [93]          | 2020 | 51          | no      | /                  |
| Abarquero-Diezhandino A [94] | 2020 | 1 | no | 0 |
| Negrete-Corona [95]   | 2018 | 1           | no      | 12                 |
| Bulatovic N [96]      | 2017 | 23          | no      | 14,5               |
| Karabila MA [97]      | 2016 | 1           | no      | 0                  |
| Duijnisveld BJ [98]   | 2020 | 52          | no      | 12                 |
| van Rijn [99]         | 2020 | 1           | yes     | 12                 |
| Legosz P [100]        | 2019 | 64          | no      | 56,4               |
| Lorkowski C J [101]   | 2020 | 18          | no      | 0                  |
| Kim SM [102]          | 2018 | 897         | no      | 61,2               |
| Kim YH [103]          | 2016 | 24          | yes     | 44,4               |
| Lee JM [104]          | 2018 | 37          | no      | 25                 |
| Lee YK [105]          | 2017 | 19          | yes     | 3,2                |
| Min BW [106]          | 2020 | 63          | no      | 5,9                |
| Min BW [107]          | 2018 | 21          | no      | 33,8               |
| Park [108]            | 2018 | 5           | no      | 103,2              |
| Park [109]            | 2019 | 37          | no      | 12                 |
| Shin [110]            | 2017 | 24          | no      | 24                 |
| Won [111]             | 2020 | 10          | no      | 4,4                |
| Yoo [112]             | 2017 | 1           | yes     | 2                  |
| Yoon [8]              | 2016 | 37          | yes     | 44                 |
| Lizaur-Utrilla A [113] | 2019 | 46          | yes    | 39,6               |
| Author            | Year | Sample size | Top ten | Follow up (months) |
|-------------------|------|-------------|---------|--------------------|
| Moreta J [114]    | 2018 | 43          | no      | 60                 |
| Peiro [115]       | 2020 | 5           | no      | 8.2                |
| Valle Cruz [116]  | 2016 | 44          | no      | 0                  |
| Chatziagorou [117]| 2019 | 1381        | yes     | 24                 |
| Chatziagorou G [118]| 2018 | 1751        | no      | 131                |
| Chatziagorou G [119]| 2019 | 465         | no      | 67.2               |
| Chatziagorou G [120]| 2019 | 639         | no      | 39.6               |
| Mellner C [121]   | 2019 | 2528        | no      | 47                 |
| Mukka S [122]     | 2016 | 979         | yes     | 20                 |
| Baum C [123]      | 2019 | 16          | no      | 120                |
| Kabellitz M [124] | 2018 | 109         | no      | 1.5                |
| Kraus MJ [125]    | 2017 | 1           | no      | 43                 |
| Ladurner A [126]  | 2017 | 43          | yes     | 40                 |
| Lenz M [127]      | 2016 | 12          | no      | 0                  |
| Lenz M [128]      | 2016 | 12          | no      | 0                  |
| Lenz M [129]      | 2020 | 14          | no      | 0                  |
| Tsai [130]        | 2018 | 40          | no      | 67.7               |
| Yang [131]        | 2019 | 50          | no      | 12                 |
| Sariyilmaz [132]  | 2016 | 15          | no      | /                  |
| Aslam-Pervez N [133]| 2018 | 427        | no      | 36                 |
| Chakrabarti D [134]| 2019 | 32         | no      | 21                 |
| El-Bakoury A [135]| 2016 | 20         | yes     | 44.6               |
| Finlayson [136]   | 2018 | 189         | no      | 108                |
| Goudie [137]      | 2017 | 80          | no      | 27                 |
| Johnson-Lynn Sarah [138]| 2015 | 82       | no      | 12                 |
| Jones AR [139]    | 2015 | 90          | no      | 1.4                |
| Moazen M [140]    | 2016 | 12          | yes    | 0                  |
| Abdel MP [141]    | 2016 | 5417        | yes    | 72                 |
| Abdel MP [4]      | 2016 | 32644       | yes    | 96                 |
| Birch CE [142]    | 2017 | 6           | no      | 18.6               |
| Butler BA [143]   | 2019 | 1           | no      | 0                  |
| Chalmers BP [144] | 2018 | 11          | yes    | 60                 |
| Christensen KS [145]| 2019 | 1150      | yes    | 3                  |
| Drew [146]        | 2016 | 188         | yes    | 12                 |
| Gitajn IL [147]   | 2017 | 203         | no      | 38.8               |
| Griffiths S [148] | 2019 | 49          | yes    | 84                 |
| Johnson AJ [138]  | 2020 | 22          | yes    | 0                  |
| Khan S [149]      | 2019 | 1           | no      | 0                  |
| Lee S [150]       | 2019 | 53          | yes    | 0                  |
| Marshall [151]    | 2017 | /           | no      | /                  |
| O'Connell [152]   | 2018 | 30          | no      | /                  |
| Otero [153]       | 2020 | 129         | yes    | 3.75               |
| Parry JA [154]    | 2018 | 61          | yes    | 54                 |
| Rodriguez [155]   | 2017 | /           | no      | /                  |
| Scott [156]       | 2017 | 7           | yes    | 21 and 21.7        |
| Tibbo [157]       | 2019 | /           | yes    | /                  |
| Waligora [158]    | 2017 | 10 pairs    | yes    | /                  |
single registry study, giving a pooled cohort size of 3299 patients, compared to 59,178 patients in the studies using the Vancouver classification. Since 2016, one study using UCS was published in a top journal, compared to 37 studies using the Vancouver classification \((p=0.29)\). During the study period, the number of yearly publications remained stagnant, \((p=0.899)\) (Fig 2).

Discussion

This systematic review investigating the usage of PPFF classifications in the orthopaedic literature demonstrates that in the majority of the studies (93.8\%) published since 2016 the Vancouver classification was used. Furthermore, a tendency of relevant change could not be found.

The UCS found a place in the treatment algorithms but for the most common periprosthetic fracture—the proximal femoral periprosthetic fracture—the Vancouver system remains the standard reporting classification. Although the difference is found literally in the name only and both the Vancouver and the UCS show comparable values of reliability and validity [1, 13, 16, 19, 20], it remains unclear whether the orthopaedic community is unaware of the UCS or simply “sticks” with the longer known system.

The UCS has been claimed to have had replaced the historic classifications of periprosthetic fractures [159]. This study demonstrates that this is not the case for the most common periprosthetic fracture, the PPFF. The Vancouver classification, introduced in 1995, was the first classification system to comprehensively describe periprosthetic femoral fractures including the location of the fracture with respect to the prosthesis, the bone quality of the involved bone and the information about the bony anchorage of the prosthesis [12]. The UCS aims to utilize these usable features for the whole extremity skeleton, but it still doesn’t keep up with the Vancouver classification regarding the quantitatively most important issue of the periprosthetic femoral fractures, as the latter is the most commonly used classification for the description of periprosthetic femoral fractures up to now [7].

Another reason why the UCS has been not seeing the expected usage in the literature lies to our minds in the fact that it also covers fractures of higher complexity like the description of interprosthetic fractures. Revealingly the expanded nomenclature offered by the UCS was used in only 9.6\% of the clinical cases reported in our work.
The incidence of the more complex PPFF cases- UCS E, D and F- is low. Since the expansion to more complex cases are the only difference to the Vancouver classification as far as the femur is concerned, this can be interpreted as an additional hindrance for the use of the UCS.

A very interesting aspect about the UCS is found in its expansion dealing with the recently added B2 type fractures involving the greater and the lesser trochanter introduced by Huang et al. These patterns were initially described by Mallory et al in 1989 [3, 15, 29, 160–162]. This expansion of the classification allows the user to more comprehensively describe the patterns involving the medial cortical wall in the case of a lesser trochanteric avulsion fracture around an implant. The stability of the medial cortical wall can be therefore classified, possibly leading to a therapeutic consequence. The modified version of the UCS also shows a higher grade of validity compared to the original classification, reaching a value of 89.8% compared to 79.7% [16]. This expansion was introduced, as the authors experienced a lack of ability to clearly distinguish between stable and unstable UCS type B fractures. The update aims to clarify the differentiation between stable and unstable cases [3], an attempt, that we doubt, as the decision still remains experience and user dependent.

The Vancouver classification on the other hand, was initially introduced for description of periprosthetic femoral fractures around a cemented stem [12]. Indeed, this classification shows high values of inter- and intraobserver reliability, but in some cases, it remains unclear, whether a cemented or cementless stem was used [13, 163, 164]. In contrast to validity values of up to 80% [13, 150, 163, 164], 25% of Vancouver type B fractures radiologically classified as stable (B1), appeared unstable intraoperatively (B2) [164]. The works of Corten et al and Lee et al also indicate that the utilization of the Vancouver classification tendential leads to misinterpretation of unstable type B cases as supposed stable findings. Both works showed a failure rate of 20% (9 out of 45 in both studies), when radiologically determined, supposed stable cases came to evidence as unstable cases intraoperatively [150, 165]. Additional works proof this tendency [166, 167]. In connection with the UCS, the ambiguity regarding the use of cemented or cementless stems becomes apparent as well [17, 19]. Some authors see potential for improvement for both classifications in this regard [150]. The authors in fact raise a doubt on the reliability of a radiologic classification used as a tool for stability assessment of a cementless, femoral stem in case of a periprosthetic femoral fracture [150]. We agree with this observation.

Furthermore, it has to be mentioned, that, although the UCS comprises an expansion of the Vancouver system, some authors still discover findings in a collective of periprosthetic femoral fractures, that are not classifiable under the use of the UCS [3]. In addition, this classification is claimed to be largely dependent on the subjective judgement of the user, especially regarding the implant stability and estimation of bone loss as well [3]. Classifying a fracture as B1 or B2 has led to a development of an algorithm, that should help with the decision of the integrity of the cement mantle and the resulting, therapeutic consequence [168].

Conclusion
Despite valuable improvements and expansion added by the Unified Classification System to date the Vancouver classification remains the leading classification for reporting of proximal periprosthetic femoral fractures in the orthopaedic literature. Both classifications have their weaknesses due to the dependence on user experience, subjectivity or vagueness, especially when it comes to the differentiated assessment of cemented and cementless procedures.

Supplementary Information
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Authors’ contributions
C. Schopper: Wrote the manuscript, performed the statistical analysis, designed the study, acquisition of data, interpretation of the data. M. Luger: Co-wrote the manuscript, acquisition of data, interpretation of the data. G. Hipmair: Revised the manuscript, interpretation of the data. T. Gotterbarm: Revised the manuscript. A. Klasan: Jointly conceived the study, performed statistical analysis, edited the manuscript, interpretation of the data. The author(s) read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations
Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
Clemens Schopper: No conflict of interest/no competing interest.
Matthias Luger: No conflict of interest/no competing interest.
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