ORIGINAL ARTICLE
Hip Pelvis 35(4): 217-227, 2023
https://doi.org/10.5371/hp.2023.35.4.217

Print ISSN 2287-3260
Online ISSN 2287-3279
Hip & Pelvis

Open Reduction and Internal Fixation for Vancouver B1 and B2 Periprosthetic Femoral Fractures: A Proportional Meta-Analysis

Byung-Ho Yoon, MD, Seong Gyun Park, MD, Young Hak Roh, MD

Department of Orthopedic Surgery, Ewha Womans University Mokdong Hospital, Ewha Womans University College of Medicine, Seoul, Korea

Purpose: Periprosthetic femoral fracture (PFF) is a common complication after total hip arthroplasty, and open reduction and internal fixation (ORIF) is a common surgical treatment. We conducted a meta-analysis to compare the outcomes of ORIF in patients with different fracture patterns (Vancouver B1 and B2).

Materials and Methods: We conducted a systematic search of PubMed, Embase, Cochrane Library and KoreaMed from inception to August 2022. We conducted a pair-wise meta-analysis (with a fixed-effects model) on the 10 comparative studies and a proportional meta-analysis on the data from the 39 articles to determine a consensus. The outcomes were the incidence of reoperations that included osteosynthesis, irrigation/debridement and revision arthroplasty.

Results: The pair-wise meta-analysis showed similar outcomes between two groups; the risk of reoperation (odds ratio [OR]=0.82, confidence interval [CI] 0.43-1.55, *P*=0.542), nonunion (OR=0.49; CI 0.22-1.10, *P*=0.085) and deep infection (OR=1.89, CI 0.48-7.46, *P*=0.361). In proportion meta-analysis, pooled prevalence of reoperation was 9% (95% CI, 6-12) in B1 and 8% (95% CI, 2-15) in B2 (heterogeneity between two groups (Q), *P*=0.772). The pooled prevalence of nonunion was same as of 4% in B1 and B2 (Q, *P*=0.678), and deep infection was 2% (95% CI, 1-3) in B1 and 4% (95% CI, 2-7) in B2 (Q, *P*=0.130).

Conclusion: ORIF is a feasible treatment for B1 and B2 periprosthetic femoral fractures, with acceptable outcomes in terms of, nonunion and infection. The results of this study would help clinicians and provide baseline data for further studies validating PFF.

Key Words: Femoral fractures, Open fracture reduction, Malunited fractures, Infections, Meta-analysis

Submitted: March 23, 2023 1st revision: May 13, 2023
2nd revision: May 15, 2023 Final acceptance: May 23, 2023
Address reprint request to
Young Hak Roh, MD
(https://orcid.org/0000-0002-7192-4046)
Department of Orthopaedic Surgery, Ewha Womans University Mokdong Hospital, Ewha Womans University College of Medicine, 1071 Anyangcheon-ro, Yangcheon-gu, Seoul 07985, Korea
TEL: +82-2-2650-2639
E-mail: rohyh@ewha.ac.kr

INTRODUCTION

Periprosthetic femoral fracture (PFF) after total hip arthroplasty (THA) is a rare but potentially serious complication associated with high mortality when occurring in frail, elderly patients[1,2]. PFFs are generally classified according to the Vancouver system, which is helpful to clinicians in assessing the severity of the fracture and in making decisions about an appropriate treatment plan[3-5]. Vancouver type is classified as A, B, or C according to the location of the fracture and Vancouver type B is a fracture located around a stem. Vancouver B1 implies a well-fixed stem, B2 a loose stem with good bone stock.

Open reduction and internal fixation (ORIF) is one of the surgical options for treatment of PFF[6-9]. The goal of ORIF is to provide immediate stability to the fracture, promote bone healing, and maintain the patient's mobility[10-12]. However, evidence from comparison of the outcomes of ORIF for B1 and B2 PFFs is limited. B1 PFFs show a stable fracture pattern without significant bone loss, whereas B2 PFFs are unstable and associated with bone loss, which can make ORIF more challenging[13-15].

Previous studies have reported varying outcomes for ORIF in B1 and B2 PFFs. Some studies have suggested that outcomes after ORIF are better for B1 PFFs than for B2 PFFs[4]. Other studies have reported that no significant differences in the outcomes of ORIF were observed between B1 and B2 PFFs[16-18]. However, most of these studies included small sample sizes, were retrospective, and the follow-up periods were limited.

Relevant systematic reviews and meta-analyses are rare due to variations in the method used for measurement and the bone site evaluated. Thus, a meta-analysis was performed by including all eligible cohort studies that evaluated results of surgery for PFF. Our aim was to (1) estimate the pooled rate of nonunion, deep infection, and overall revision nonunion rate after surgery for PFF and (2) compare these outcomes between Vancouver B1 and B2 PFF in patients who were treated using the ORIF technique.

MATERIALS AND METHODS

1. Search Methods for Identification of Studies

A comprehensive search of electronic databases was conducted for identification of studies comparing the outcomes of ORIF between B1 and B2 PFFs published from January 1990 to August 2022 according to the updated guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocols 2020 statement (Supplementary Table 1)[19]. A search of multiple comprehensive databases, including MEDLINE (PubMed), EMBASE, and Cochrane Library databases and KoreaMed for studies was conducted. The search strategy was developed in collaboration with a librarian and an overview of the search strategy is provided in Supplementary Material 1. Articles that met the selection criteria (including prospective and retrospective case-control studies) were included in the meta-analysis. We contacted the authors of articles with insufficient or missing data as an attempt to obtain complete data.

Only a few relevant studies directly comparing Vancouver B1 and B2 were identified in the initial search, thus single cohort studies examining clinical results after ORIF of PFFs were included.

2. Study Selection Criteria

All publications were categorized using EndNote X20 for Windows (Clarivate). Screening pertinent titles and abstracts for studies was performed independently by two reviewers (B.H.Y. and S.G.P.) and a search based on full-text review was then performed. Discrepancies between these two reviewers were resolved by a third reviewer (Y.H.R.). Inclusion criteria were as follows: (1) Published as an original article in English or Korean. (2) The study was a comparative or single-cohort study examining the outcomes for patients treated with ORIF for PFF; defined as Vancouver B1 and B2. (3) At least one of the following main clinical outcomes was reported: the incidence of nonunion and infection.

Exclusion criteria were as follows: (1) the study included only distal femur fractures (Vancouver C); (2) the study included inter-prosthetic fractures or osteosynthesis of failed fixation (non-union); (3) the study included periprosthetic fracture after total knee arthroplasty or pathologic fracture; (4) the study used national registry data; and (5) the article was a review, expert opinion, case report, animal study or basic science study.

3. Outcome Measures and Data Extraction

The primary outcome for this meta-analysis was the incidence of reoperations, which was defined as cases requiring at least one reoperation (osteosynthesis, irrigation/debridement and revision arthroplasty)[20]. Performance of osteosynthesis or revision surgery due to failure following osteosynthesis in PFFs was regarded as nonunion. Surgical irrigation and debridement without removal of osteosynthesis was regarded as a deep infection.

For every eligible study, the following data were extracted and entered into a spreadsheet by two reviewers (blinded by the authors): the family name of the first author, year of publication, inclusion period, country, number of patients, type of fracture according to Vancouver classification, fracture pattern (oblique, spiral, transverse, and comminuted), fixation device, use of cortical strut bone graft, surgical technique, mean years after the index operation, sample characteristics (age, sex ratio, body mass index).

4. Quality Assessment and Publication Bias

Independent evaluation of the quality of all studies was performed by two of the authors (B.H.Y. and S.G.P.), using the Newcastle-Ottawa scales for observational studies and discrepancies between these two reviewers were resolved by a third reviewer (Y.H.R.). Begg's funnel plot and Egger's test were used to assess the presence of publication bias.

5. Statistical Analysis

Pair-wise meta-analysis was performed from the articles that examined the outcomes of both Vancouver B1 and B2. The forest plots were generated with odds ratio (OR) and 95% confidence intervals (CIs) using a fixed-effect model in all clinical outcomes.

Second, a proportion meta-analysis of data from all relevant studies that reported the incidence of nonunion and deep infection was performed. All patients included in the selected studies were then divided into two groups, according to Vancouver type (B1/B2), and heterogeneity between the two groups was also calculated. Trials containing zero cells are augmented with addition of 0.5 successes to each arm.

The cortical strut bone graft, which provides better fixation strength and enhances fracture-healing, could be an important covariant to clinical outcomes. Therefore, we attempted to perform an additional analysis by only including studies that used a strut bone graft. However, a cortical allograft augmentation was used where necessary (case by case), thus performance of subgroup analysis was not possible. Fracture pattern can also be regarded as another covariant to union rate. However, the results were classified according to fracture pattern in only two studies, so that performance of subgroup analysis was also not possible.

All analyses were performed using STATA software (ver. 14.0; Stata Corporation). Because published data were used in this study, ethical approval was not required.

RESULTS

1. Description of the Included Studies

The primary search of the databases yielded 871 records.

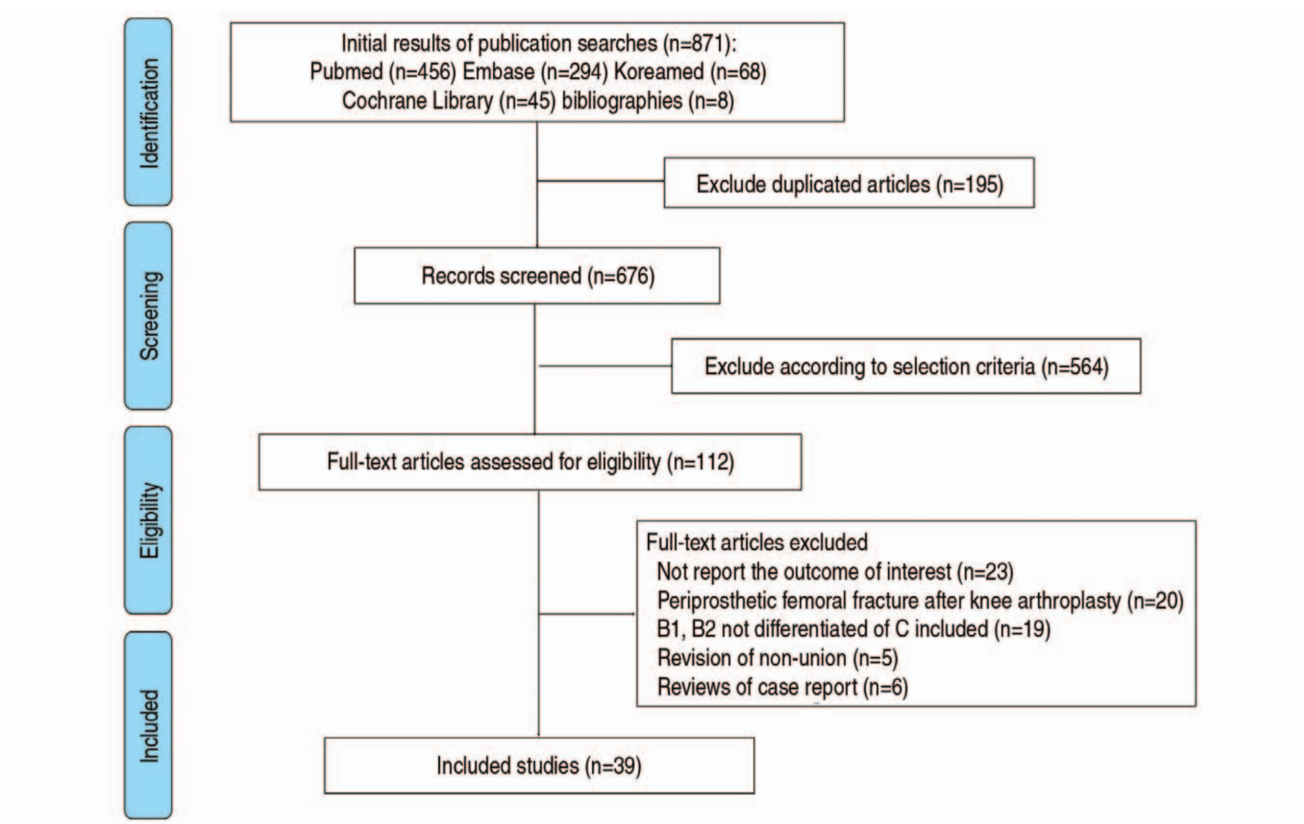

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram detailing the process of selecting relevant clinical studies.

Table 1. The Outcomes Form Included Studies Which Investigated the Clinical Results of Vancouver Type B1 or B2 Periprosthetic Femoral Fracture

Study	Enrollment period	Vancouver classification	No. of fractures	No. of nonunion	No. of deep infection	No. of revision arthroplasty	Mean age (yr)	Applying strut bone graft
Marino et al.[16] (2022)	2017-2020	Vancouver type B1	17	0 (0)	1 (5.9)	NA	84.4	NA
		Vancouver type B2	12	0 (0)	1 (8.3)	NA		NA
Lv et al.[23] (2022)	2010-2019	Vancouver type B1	17	1 (5.88)	1 (5.9)	0 (0)	67.2	None
Kubik et al.[24] (2022)	2008-2019	Vancouver type B1	31	2 (6.45)	0 (0)	0 (0)	71.3	None
Agostini et al.[17] (2022)	2012-2018	Vancouver type B1	24	1 (4.16)	1 (4.2)	NA	74.3	NA
		Vancouver type B2	14	0 (0)	1 (7.1)	NA		NA
Taha et al.[25] (2021)	2017-2019	Vancouver type B1	24	1 (4.16)	2 (8.3)	0 (0)	77	None
Slullitel et al.[21] (2021)	2010-2018	Vancouver type B1	47	1 (2.12)	0 (0)	0 (0)	83	None
		Vancouver type B2	27	0 (0)	0 (0)	2 (7.4)		None
Roche-Albero et al.[26] (2021)	2014-2017	Vancouver type B1	37	0 (0)	1 (2.7)	0 (0)	80.7	None
Powell-Bowns et al.[6] (2021)	2008-2016	Vancouver type B1	69	6 (8.69)	1 (1.4)	0 (0)	77.9	None
		Vancouver type B2	45	1 (2.22)	0 (0)	0 (0)		None
González-Martín et al.[44] (2021)	2009-2019	Vancouver type B2	39	0 (0)	4 (10.3)	2 (5.1)	78.4	None
Gausden et al.[4] (2021)	2008-2017	Vancouver type B1	47	6 (12.7)	1 (2.1)	3 (6.4)	72	Partial
		Vancouver type B2	125	4 (3.2)	8 (6.4)	3 (2.4)		
Del Chiaro et al.[27] (2021)	2010-2016	Vancouver type B1	32	3 (9.37)	0 (0)	0 (0)	76.7	None
Bhalchandra Londhe et al.[28] (2021)	2015-2018	Vancouver type B1	15	0 (0)	0 (0)	NA	74	None
Zajonz et al.[29] (2020)	2010-2016	Vancouver type B1	20	2 (10)	NA	1 (5)	76	NA
Zheng et al.[1] (2020)	2008-2016	Vancouver type B1	35	2 (5.71)	0 (0)	3 (8.6)	50.1	Partial
Ciriello et al.[30] (2020)	2013-2019	Vancouver type B1	22	1 (4.54)	0 (0)	NA	84.8	None
Min et al.[20] (2020)	2001-2018	Vancouver type B1	63	7 (11.1)	1 (1.6)	2 (3.2)	67.6	None
Smitham et al.[45] (2019)	2002-2014	Vancouver type B2	52	2 (3.84)	NA	0 (0)	82	NA
Park et al.[46] (2019)	-	Vancouver type B2	27	0 (0)	0 (0)	0 (0)	70.8	None
Manara et al.[22] (2019)	2006-2015	Vancouver type B1	16	0 (0)	NA	NA	75.7	Yes
		Vancouver type B2	6	0 (0)	NA	NA		Yes
Min et al.[31] (2018)	2011-2017	Vancouver type B1	37	2 (5.4)	0 (0)	1 (2.7)	70.1	None
Lee et al.[32] (2018)	2014-2016	Vancouver type B1	13	3 (23.07)	NA	NA	75	None
Kim et al.[2] (2017)	1998-2014	Vancouver type B1	25	3 (12)	1 (4)	1 (4)	63	Yes
Ricciardi et al.[7] (2017)	2003-2012	Vancouver type B1	36	2 (5.55)	NA	NA	69	None
		Vancouver type B2	15	0 (0)	NA	NA		None
Yeo et al.[33] (2016)	2009-2014	Vancouver type B1	17	0 (0)	0 (0)	0 (0)	74	Yes
Solomon et al.[47] (2015)	2000-2010	Vancouver type B2	15	0 (0)	NA	NA	79	None
Russo et al.[34] (2015)	2007-2010	Vancouver type B1	14	2 (14.28)	0 (0)	1 (7.1)	-	NA
Lunebourg et al.[8] (2015)	2002-2007	Vancouver type B1	18	0 (0)	0 (0)	0 (0)	79	None
		Vancouver type B2	23	0 (0)	1 (4.3)	1 (4.3)		None
Kinov et al.[35] (2015)	2004-2013	Vancouver type B1	16	1 (6.25)	0 (0)	NA	64.7	None

(Continued to the next page)

Table 1. Continued

Study	Enrollment period	Vancouver classification	No. of fractures	No. of nonunion	No. of deep infection	No. of revision arthroplasty	Mean age (yr)	Applying strut bone graft
Niikura et al.[18] (2014)	2005-2013	Vancouver type B1	19	1 (5.26)	0 (0)	0 (0)	78.5	None
		Vancouver type B2	4	0 (0)	0 (0)	0 (0)		None
Holder et al.[36] (2014)	2004-2009	Vancouver type B1	15	2 (13.33)	NA	NA	78	None
Dargan et al.[37] (2014)	2010-2012	Vancouver type B1	20	0 (0)	1 (5)	0 (0)	74	None
Khashan et al.[38] (2013)	2006-2011	Vancouver type B1	21	5 (23.8)	2 (9.5)	1 (4.8)	80	Partial
Baba et al.[39] (2013)	2004-2009	Vancouver type B1	30	0 (0)	0 (0)	NA	76.1	None
Froberg et al.[5] (2012)	2002-2011	Vancouver type B1	58	3 (5.17)	4 (6.9)	2 (3.4)	78	None
Apivatthakakul et al.[40] (2012)	2007-2008	Vancouver type B1	10	0 (0)	0 (0)	0 (0)	74	None
Pavlou et al.[9] (2011)	1995-2007	Vancouver type B1	6	2 (33.3)	0 (0)	NA	75	NA
		Vancouver type B2	27	15 (55.5)	1 (6.7)	NA		Partial
Ebraheim et al.[41] (2009)	2005-2006	Vancouver type B1	13	0 (0)	1 (7.7)	0 (0)	77	None
Buttaro et al.[42] (2007)	2003-2005	Vancouver type B1	14	1 (7.14)	0 (0)	NA	68	Partial
Old et al.[43] (2006)	1993-2005	Vancouver type B1	19	1 (5.26)	0 (0)	0 (0)	78	None

NA: non-available.

After removal of duplicates, screening of 676 articles by title and abstract was performed. As a result, 112 full-text articles were selected and reviewed for eligibility. A total of 39 studies were finally included in the systematic review (Fig. 1). Among 39 studies, 10 articles compared the results of Vancouver B1 PFFs treated with ORIF with that of B2 PFFs, and were included in a pair-wise meta-analysis[4,6-9,16-18,21,22]. Twenty-five single cohort studies[1,2,5,20,23-43] reported outcomes after surgery for treatment of Vancouver B1 PFFs, and four single cohort studies with Vancouver B2[44-47]. The studies identified for the meta-analysis included 1,348 femurs: 917 Vancouver B1 PFFs, and 431 Vancouver B2 PFFs (Table 1).

2. Pairwise Meta-Analysis of Comparative Studies

From the results of meta-analysis on ten comparative studies, no differences in reoperation rate (OR, 0.82; CI, 0.43-1.55; P=0.542) (Fig. 2A) and nonunion rate (OR, 0.49; CI, 0.22-1.10; P=0.085) (Fig. 2B) were observed between the two groups. Deep infection rate also did not differ between the two groups (OR, 1.89; CI, 0.48-7.46; P=0.361) (Fig. 2C).

3. Incidence of Reoperation

According to the results of proportion meta-analysis, the pooled prevalence of reoperation was 9% (95% CI, 6-12) from all studies; 9% (95% CI, 6-12) in Vancouver B1 PFFs and 8% (95% CI, 2-15) in Vancouver B2 PFFs (Supplementary Fig. 1). No significant difference in reoperation rate was observed between the two groups (heterogeneity between the two groups [Q], P=0.772).

4. Incidence of Nonunion

According to the results of proportion meta-analysis, the pooled prevalence of nonunion was 4% (95% CI, 3-5) from all studies; 4% (95% CI, 3-6) in Vancouver B1 PFFs and 4% (95% CI, 1-6) in Vancouver B2 PFF (Supplementary Fig. 2). No significant difference in nonunion rate was observed between the two groups (Q, P=0.678).

5. Incidence of Deep Infection

According to the results of proportion meta-analysis, the pooled prevalence of deep infection was 3% (95% CI, 2-4) from all studies; 2% (95% CI, 1-3) in Vancouver B1 PFFs and 4% (95% CI, 2-7) in Vancouver B2 PFFs

(Supplementary Fig. 3). No significant difference in deep infection rate was observed between the two groups (Q, *P*=0.130).

6. Quality Assessment and Publication Bias

After evaluation of methodologic quality, the mean value of awarded stars was 6.4 (five stars [1 study], six stars [21 studies], seven stars [17 studies]) (Supplementary Table 2). The Begg's funnel plot was symmetrical, and the *P*-values for bias showed no significance for all outcomes (Fig. 3).

DISCUSSION

Discussion of periprosthetic fractures can include many aspects such as their epidemiology, classification, and treatment. ORIF can be applied as a viable treatment option for both B1 and B2 PFFs; however, there are challenges due to the presence of the prosthesis, which are primarily endured by elderly patients with osteoporosis[26,32]. We examined the outcomes by focusing on the rate of union and deep infection of PFF after THA.

The results of our meta-analysis showed that ORIF can be regarded as an acceptable treatment for B1 and B2 PFFs, and shows satisfactory outcomes in terms of nonunion; 4% (95% CI, 3-6) in Vancouver B1 PFFs and 4% (95% CI, 1-6) in Vancouver B2 PFFs. While B2 fractures are generally regarded as more complex and unstable than B1 fractures, several studies have demonstrated that similar outcomes can be achieved with use of ORIF in both

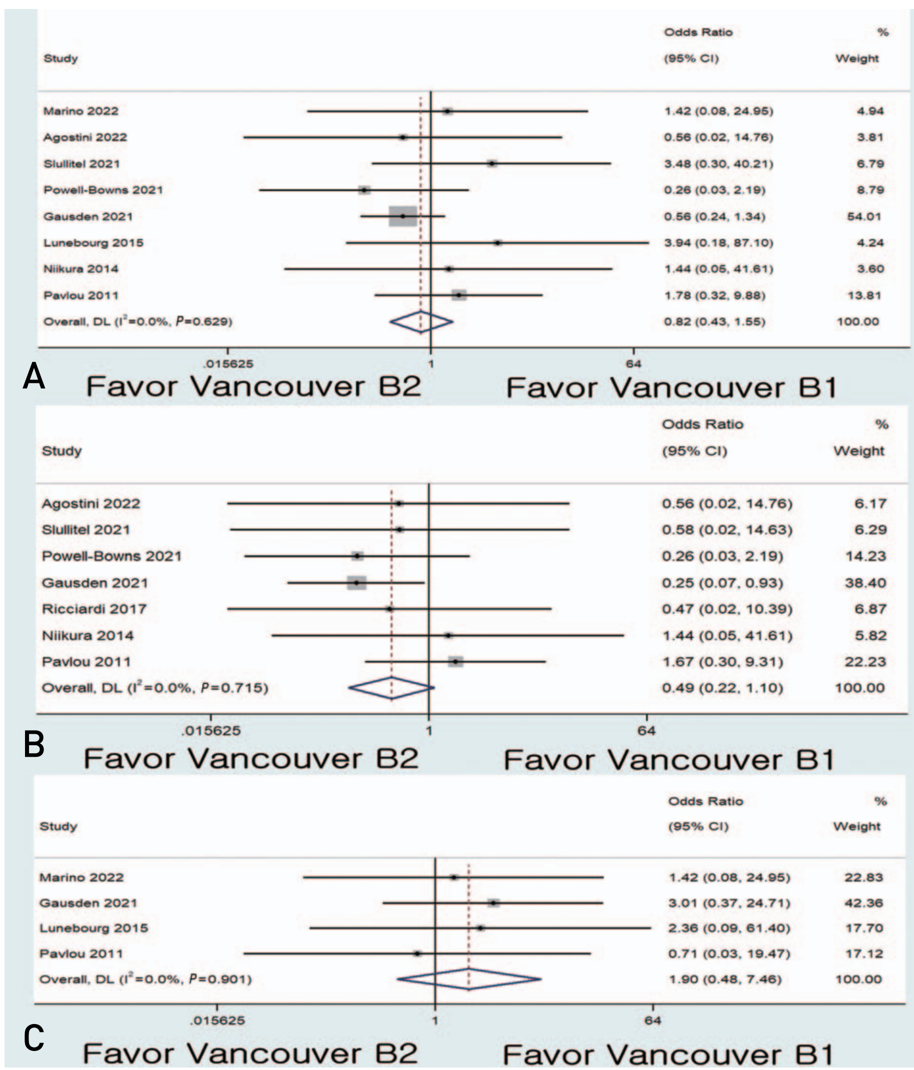

Fig. 2. The risk was calculated as odds ratios in patients who underwent open reduction and internal fixation between Vancouver B1 and B2 fracture. (A) Overall reoperations. (B) Nonunion. (C) Deep infection.

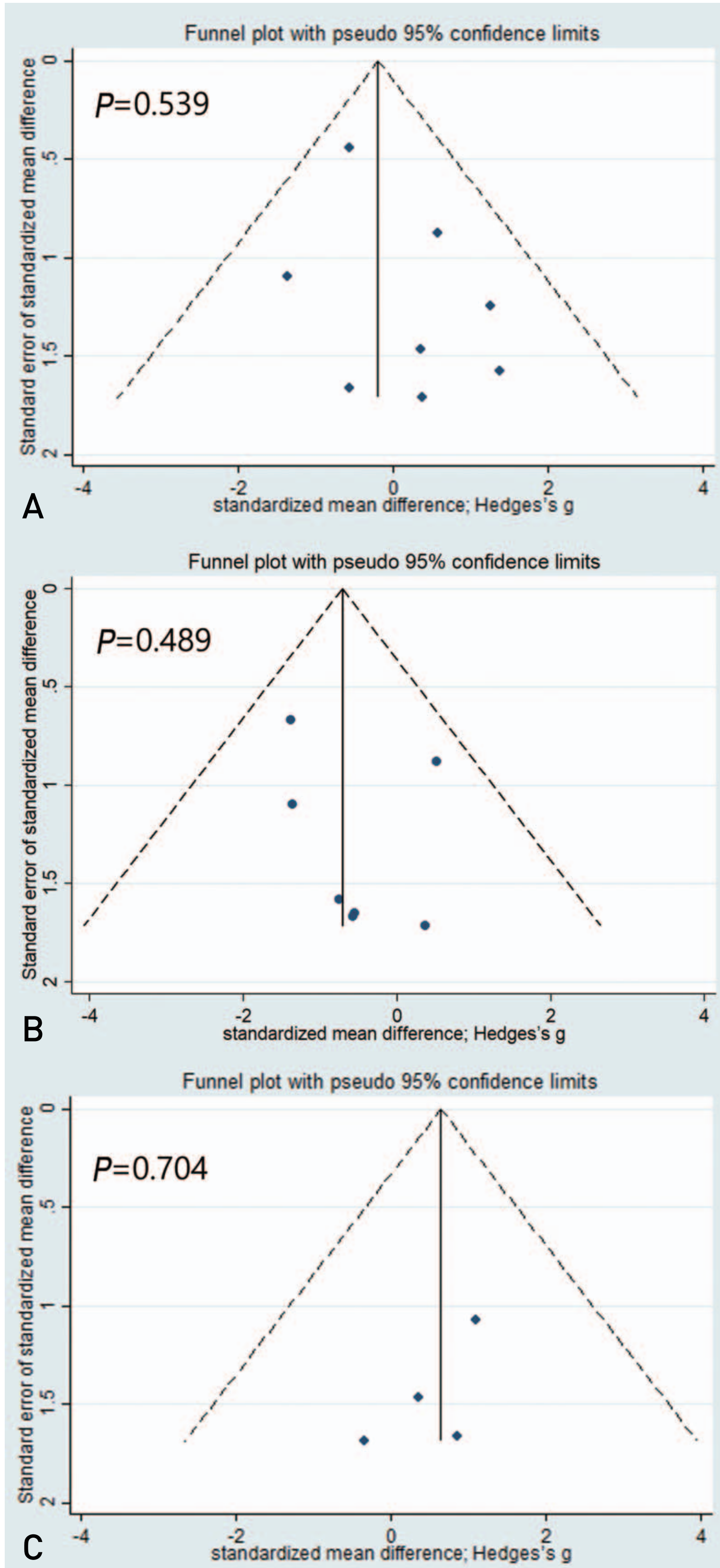

Fig. 3. Begg's funnel plot and *P*-value by Egger's test indicate publication bias. There was asymmetry, but there was no significant publication bias. (**A**) Overall reoperations. (**B**) Nonunion. (**C**) Deep infection.

groups of patients, particularly when using cemented stems. A study by Slullitel et al.[21] comparing the outcomes of ORIF in B1 and B2 PFFs reported that no significant differences in the revision rate, functional outcomes, or complication rates were observed between the two groups. Similarly, a study by Powell-Bowns et al.[6] reported that all Vancouver B fractures located around Exeter stems could be managed with fixation as opposed to revision arthroplasty when the bone-cement interface was intact and the fracture could be reduced. Many studies have reported noninferior outcomes of ORIF for management of B2 PFFs, with the advantage of a shorter operating time, lower blood transfusion rate, and overall fewer complications[26,48]. For example, ORIF, which can preserve the existing implant and provide good functional outcomes, may be preferred in treatment of stable B2 fractures with a good bone stock and minimal implant loosening[49-51]. Thus, there is potential for selection bias in the included studies reporting outcomes of ORIF in Vancouver B2 PFFs[44-46]. We suggest that clinicians interpret the results of individual studies, with a particular focus on the decision to perform ORIF in B2 fractures, which is typically made on a study-by-study basis.

Deep Infection is another potential devastating complication resulting in major morbidity for the patient; the reported risk of infection after PFF ranges from approximately 2% to 10%[52,53]. According to the results of our meta-analysis, pooled prevalence of deep infection was 3% from all studies and no significant difference in the OR of postoperative deep infection was observed between B1 and B2. While use of ORIF in management of B2 fractures may require more extensive dissection and may be associated with a longer recovery time, there is no evidence to suggest that development of a deep infection is more likely when compared with B1 fractures. However, the actual rate of infection may be even higher in certain patient populations, such as those with previous infection or multiple revision surgery; therefore, surgeons have also noted that this risk should be minimized[54,55].

In past years, PFFs after hip arthroplasty, particularly in elderly patients, were associated with extremely high rates of mortality and morbidity. This may be due to a combination of factors, including the age and frailty of the patient, and the potential for reoperation such as infection or nonunion. According to the results of our meta-analysis, the pooled prevalence of reoperation was 9% (95% CI, 6-12) from all studies, which is in agreement with promising results from recent studies[48,56]. In recent decades, there have been significant advancements in orthopedic surgery techniques and implants including management of PFF for elderly patients[5,25,28,33]. Thus, because treatment of PFFs can be challenging, it is important for the surgeon to approach the procedure with confidence and diligence.

The current study has several limitations. First, outcomes can be influenced by other factors including quality of the bone stock, use of cerclage cables or wires, and the surgical skill and experience of the treating surgeon; however, we were not able to adjust for all covariables. Second, the heterogeneities of the pre-implants, follow-up period, enrollment time after fracture, and variable outcomes were also limitations of this meta-analysis. Third, evaluation of other outcomes such as functional scores or mortality was not performed in this meta-analysis. Fourth, there is a difference in the number of included studies between the two groups.

CONCLUSION

In conclusion, ORIF is an acceptable treatment for B1 and B2 PFFs, and satisfactory outcomes have been achieved in terms of nonunion, infection, and reoperation. The results of this study would be helpful to clinicians and provide baseline data for use in conduct of additional studies for validation of PFF.

FUNDING

This work was supported by the 2021 Hip and Pelvis Research grant funded by the Korean Hip Society.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Byung-Ho Yoon (https://orcid.org/0000-0001-8518-6331)
Seong Gyun Park (https://orcid.org/0000-0002-7835-6731)
Young Hak Roh (https://orcid.org/0000-0002-7192-4046)

SUPPLEMENTARY MATERIALS

Supplementary data is available at https://hipandpelvis.or.kr/.

REFERENCES

1. Zheng H, Gu H, Shao H, et al. *Treatment and outcomes of*

Vancouver type B periprosthetic femoral fractures. Bone Joint J. 2020;102-B:293-300. https://doi.org/10.1302/0301-620X.102B3.BJJ-2019-0935.R1

2. Kim YH, Mansukhani SA, Kim JS, Park JW. *Use of locking plate and strut onlay allografts for periprosthetic fracture around well-fixed femoral components. J Arthroplasty. 2017;32:166-70. https://doi.org/10.1016/j.arth.2016.05.064*
3. Schopper C, Luger M, Hipmair G, Schauer B, Gotterbarm T, Klasan A. *The race for the classification of proximal periprosthetic femoral fractures: Vancouver vs Unified Classification System (UCS) - a systematic review. BMC Musculoskelet Disord. 2022;23:280. https://doi.org/10.1186/s12891-022-05240-w*
4. Gausden EB, Beiene ZA, Blevins JL, et al. *Periprosthetic femur fractures after total hip arthroplasty: does the mode of failure correlate with classification? J Arthroplasty. 2021;36:2597-602. https://doi.org/10.1016/j.arth.2021.02.048*
5. Froberg L, Troelsen A, Brix M. *Periprosthetic Vancouver type B1 and C fractures treated by locking-plate osteosynthesis: fracture union and reoperations in 60 consecutive fractures. Acta Orthop. 2012;83:648-52. https://doi.org/10.3109/17453674.2012.747925*
6. Powell-Bowns MFR, Oag E, Ng N, et al. *Vancouver B periprosthetic fractures involving the Exeter cemented stem. Bone Joint J. 2021;103-B:309-20. https://doi.org/10.1302/0301-620X.103B2.BJJ-2020-0695.R1*
7. Ricciardi BF, Nodzo SR, Oi K, Lee YY, Westrich GH. *Radiographic outcomes of cable-plate versus cable-grip fixation in periprosthetic fractures of the proximal femur. Hip Int. 2017;27:584-8. https://doi.org/10.5301/hipint.5000496*
8. Lunebourg A, Mouhsine E, Cherix S, Ollivier M, Chevalley F, Wettstein M. *Treatment of type B periprosthetic femur 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;101:277-82. https://doi.org/10.1016/j.otsr.2015.01.015*
9. Pavlou G, Panteliadis P, Macdonald D, et al. *A review of 202 periprosthetic fractures--stem revision and allograft improves outcome for type B fractures. Hip Int. 2011;21:21-9. https://doi.org/10.5301/hip.2011.6301*
10. Yoon BH, Kim KC. *Does teriparatide improve fracture union?: a systematic review. J Bone Metab. 2020;27:167-74. https://doi.org/10.11005/jbm.2020.27.3.167*
11. Zelle BA, Salazar LM, Howard SL, Parikh K, Pape HC. *Surgical treatment options for femoral neck fractures in the elderly. Int Orthop. 2022;46:1111-22. https://doi.org/10.1007/s00264-022-05314-3*
12. Tsai MH, Chen CC, Chang CH, Chang Y, Hsieh PH, Hu CC. *Revision total hip arthroplasty with primary stem or full-porous-coated long stem for aseptic femoral component loosening: a matched-pair study. Orthop Res Rev. 2022;14:25-33. https://doi.org/10.2147/ORR.S346891*
13. Asa'ad F, Thomsen P, Kunrath MF. *The role of titanium particles and ions in the pathogenesis of peri-implantitis. J Bone Metab. 2022;29:145-54. https://doi.org/10.11005/jbm.2022.29.3.145*
14. Van Rysselberghe NL, DeBaun MR, Sanchez M, et al. *Drilling the cement mantle in well-fixed periprosthetic femur fractures is not associated with arthroplasty-related complications. Eur J Orthop Surg Traumatol. Published online July 5, 2022; https://doi.org/10.1007/s00590-022-03308-w*
15. Moon JK, Lee H, Yoon PW, Park KC, Chang JS, Kim JW. *Total hip arthroplasty for failed acetabular fracture: a double-center comparative study on failed proximal femur fracture. Eur J Trauma Emerg Surg. 2022;48:2319-29. https://doi.org/10.1007/s00068-021-01744-7*
16. Marino S, Giuliani A, De Mauro D, et al. *Treatment options for proximal periprosthetic femoral fractures in Total Hip Arthroplasty: a single center experience. Eur Rev Med Pharmacol Sci. 2022;26(1 Suppl):113-8. https://doi.org/10.26355/eurrev_202211_30290*
17. Agostini G, Angelini I, Citarelli C, et al. *Clinical and radiographical outcome after surgical treatment of periprosthetic type B proximal femur fractures: a retrospective study. Musculoskelet Surg. 2022;106:83-7. https://doi.org/10.1007/s12306-020-00676-6*
18. Niikura T, Sakurai A, Oe K, et al. *Clinical and radiological results of locking plate fixation for periprosthetic femoral fractures around hip arthroplasties: a retrospective multi-center study. J Orthop Sci. 2014;19:984-90. https://doi.org/10.1007/s00776-014-0622-3*
19. Page MJ, McKenzie JE, Bossuyt PM, et al. *The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. https://doi.org/10.1136/bmj.n71*
20. Min BW, Lee KJ, Cho CH, Lee IG, Kim BS. *High failure rates of locking compression plate osteosynthesis with transverse fracture around a well-fixed stem tip for periprosthetic femoral fracture. J Clin Med. 2020;9:3758. https://doi.org/10.3390/jcm9113758*
21. Slullitel PA, Garcia-Barreiro GG, Oñativia JI, et al. *Selected Vancouver B2 periprosthetic femoral fractures around cemented polished femoral components can be safely treated with osteosynthesis. Bone Joint J. 2021;103-B:1222-30. https://doi.org/10.1302/0301-620X.103B7.BJJ-2020-1809.R1*
22. Manara JR, Mathews JA, Sandhu HS. *Cable plating with a single strut allograft in the treatment of periprosthetic fractures of the femur. Hip Int. 2019;29:58-64. https://doi.org/10.1177/1120700018761519*
23. Lv H, Guo X, Wang YH, et al. *Open reduction and locked compression plate fixation, with or without allograft strut, for periprosthetic fractures in patients who had a well-fixed femoral stem: a retrospective study with an average 2-year follow-up. BMC Musculoskelet Disord. 2022;23:69. https://doi.org/10.1186/s12891-022-05008-2*
24. Kubik JF, Bornes TD, Gausden EB, Klinger CE, Wellman DS, Helfet DL. *Surgical outcomes of dual-plate fixation for periprosthetic femur fractures around a stable hip arthroplasty stem. Arch Orthop Trauma Surg. 2022;142:3605-11. https://doi.org/10.1007/s00402-021-03950-9*
25. Taha A, ElZaher EH, ElGanzoury I, Ashoub M, Khairy A. *Osteosynthesis and outcomes of traumatic periprosthetic femoral fractures after total hip arthroplasty. Arthroplasty. 2021;3:31. https://doi.org/10.1186/s42836-021-00089-1*
26. Roche-Albero A, Mateo-Agudo J, Martín-Hernández C, Arnaudas-Casanueva M, Gil-Albarova J. *Osteosynthesis in Vancouver type B1 periprosthetic fractures. Injury. 2021;52:2451-8. https://doi.org/10.1016/j.injury.2021.03.023*
27. Del Chiaro A, Piolanti N, Bonicoli E, Pd P, Marchetti S, Scaglione M. *Treatment of Vancouver B1 periprosthetic femoral fractures using Intrauma Iron Lady® locking plate: a retro-*

spective study on 32 patients. Injury. 2021;52:2459-62. https://doi.org/10.1016/j.injury.2021.02.089

28. Bhalchandra Londhe S, Churhe S, Omprakash Agrawal P, Shirishkar R, Malcolm Pestonji J, Antao N. *Early experience with the use of trochanteric reattachment plate for the treatment of Vancouver type B 1 periprosthetic hip fractures. J Clin Orthop Trauma. 2021;23:101644. https://doi.org/10.1016/j.jcot.2021.101644*
29. Zajonz D, Pönick C, Edel M, et al. *Results after surgical treatment of periprosthetic proximal femoral fractures. Osteosynthesis with prosthesis preservation vs. prosthesis change. GMS Interdiscip Plast Reconstr Surg DGPW. 2020;9:Doc02. https://doi.org/10.3205/iprs000146*
30. Ciriello V, Chiarpenello R, Tomarchio A, Marra F, Egidio AC, Piovani L. *The management of Vancouver B1 and C periprosthetic fractures: radiographic and clinic outcomes of a monocentric consecutive series. Hip Int. 2020;30(2_suppl):94-100. https://doi.org/10.1177/1120700020971727*
31. Min BW, Cho CH, Son ES, Lee KJ, Lee SW, Min KK. *Minimally invasive plate osteosynthesis with locking compression plate in patients with Vancouver type B1 periprosthetic femoral fractures. Injury. 2018;49:1336-40. https://doi.org/10.1016/j.injury.2018.05.020*
32. Lee JM, Kim TS, Kim TH. *Treatment of periprosthetic femoral fractures following hip arthroplasty. Hip Pelvis. 2018;30:78-85. https://doi.org/10.5371/hp.2018.30.2.78*
33. Yeo I, Rhyu KH, Kim SM, Park YS, Lim SJ. *High union rates of locking compression plating with cortical strut allograft for type B1 periprosthetic femoral fractures. Int Orthop. 2016;40:2365-71. https://doi.org/10.1007/s00264-015-3107-x*
34. Russo M, Malekzadeh AS, Hampton C, Hymes R, Schwartzbach C, Schulman J. *Reversed contralateral LISS plate for Vancouver B1 periprosthetic femoral shaft fractures. Orthopedics. 2015;38:e467-72. https://doi.org/10.3928/01477447-20150603-53*
35. Kinov P, Volpin G, Sevi R, Tanchev PP, Antonov B, Hakim G. *Surgical treatment of periprosthetic femoral fractures following hip arthroplasty: our institutional experience. Injury. 2015;46:1945-50. https://doi.org/10.1016/j.injury.2015.06.017*
36. Holder N, Papp S, Gofton W, Beaulé PE. *Outcomes following surgical treatment of periprosthetic femur fractures: a single centre series. Can J Surg. 2014;57:209-13. https://doi.org/10.1503/cjs.014813*
37. Dargan D, Jenkinson MJ, Acton JD. *A retrospective review of the Dall-Miles plate for periprosthetic femoral fractures: twenty-seven cases and a review of the literature. Injury. 2014;45:1958-63. https://doi.org/10.1016/j.injury.2014.08.034*
38. Khashan M, Amar E, Drexler M, Chechik O, Cohen Z, Steinberg EL. *Superior outcome of strut allograft-augmented plate fixation for the treatment of periprosthetic fractures around a stable femoral stem. Injury. 2013;44:1556-60. https://doi.org/10.1016/j.injury.2013.04.025*
39. Baba T, Kaneko K, Shitoto K, Futamura K, Maruyama Y. *Comparison of therapeutic outcomes of periprosthetic femoral fracture between treatments employing locking and conventional plates. Eur J Orthop Surg Traumatol. 2013;23:437-41. https://doi.org/10.1007/s00590-012-1005-0*
40. Apivatthakakul T, Phornphutkul C, Bunmaprasert T, Sananpanich K, Fernandez Dell'Oca A. *Percutaneous cerclage wiring and minimally invasive plate osteosynthesis (MIPO): a percutaneous reduction technique in the treatment of Vancouver type B1 periprosthetic femoral shaft fractures. Arch Orthop Trauma Surg. 2012;132:813-22. https://doi.org/10.1007/s00402-012-1489-4*
41. Ebraheim NA, Gomez C, Ramineni SK, Liu J. *Fixation of periprosthetic femoral shaft fractures adjacent to a well-fixed femoral stem with reversed distal femoral locking plate. J Trauma. 2009;66:1152-7. https://doi.org/10.1097/TA.0b013e318182561f*
42. Buttaro MA, Farfalli G, Paredes Núñez M, Comba F, Piccaluga F. *Locking compression plate fixation of Vancouver type-B1 periprosthetic femoral fractures. J Bone Joint Surg Am. 2007;89:1964-9. https://doi.org/10.2106/JBJS.F.01224*
43. Old AB, McGrory BJ, White RR, Babikian GM. *Fixation of Vancouver B1 peri-prosthetic fractures by broad metal plates without the application of strut allografts. J Bone Joint Surg Br. 2006;88:1425-9. https://doi.org/10.1302/0301-620X.88B11.17749*
44. González-Martín D, Pais-Brito JL, González-Casamayor S, Guerra-Ferraz A, Martín-Vélez P, Herrera-Pérez M. *Periprosthetic hip fractures with a loose stem: open reduction and internal fixation versus stem revision. J Arthroplasty. 2021;36:3318-25. https://doi.org/10.1016/j.arth.2021.05.003*
45. Smitham PJ, Carbone TA, Bolam SM, et al. *Vancouver B2 peri-prosthetic fractures in cemented femoral implants can be treated with open reduction and internal fixation alone without revision. J Arthroplasty. 2019;34:1430-4. https://doi.org/10.1016/j.arth.2019.03.003*
46. Park JS, Hong S, Nho JH, Kang D, Choi HS, Suh YS. *Radiologic outcomes of open reduction and internal fixation for cementless stems in Vancouver B2 periprosthetic fractures. Acta Orthop Traumatol Turc. 2019;53:24-9. https://doi.org/10.1016/j.aott.2018.10.003*
47. Solomon LB, Hussenbocus SM, Carbone TA, Callary SA, Howie DW. *Is internal fixation alone advantageous in selected B2 periprosthetic fractures? ANZ J Surg. 2015;85:169-73. https://doi.org/10.1111/ans.12884*
48. Lewis DP, Tarrant SM, Cornford L, Balogh ZJ. *Management of Vancouver B2 periprosthetic femoral fractures, revision total hip arthroplasty versus open reduction and internal fixation: a systematic review and meta-analysis. J Orthop Trauma. 2022;36:7-16. https://doi.org/10.1097/BOT.0000000000002148*
49. Vialla T, Tran-Minh D, Barbotte F, et al. *Comparison of the functional outcomes after treatment of periprosthetic hip fractures with femoral stem loosening: locking plate fixation with or without femoral stem revision. Orthop Traumatol Surg Res. 2022;108:103300. https://doi.org/10.1016/j.otsr.2022.103300*
50. Scalici G, Boncinelli D, Zanna L, et al. *Periprosthetic femoral fractures in Total Hip Arthroplasty (THA): a comparison between osteosynthesis and revision in a retrospective cohort study. BMC Musculoskelet Disord. 2022;23:200. https://doi.org/10.1186/s12891-022-05159-2*
51. Pflüger P, Bolierakis E, Wurm M, Horst K, Hildebrand F, Biberthaler P. *Revision rate is higher in patients with periprosthetic femur fractures following revision arthroplasty in comparison with ORIF following our algorithm: a two-center 1 analysis of 129 patients. Eur J Trauma Emerg Surg. 2022;48:1913-8. https://doi.org/10.1007/s00068-021-01832-8*
52. Yoon BH, Seo JG, Koo KH. *Comparison of postoperative infec-*

tion-related complications between cemented and cementless hemiarthroplasty in elderly patients: a meta-analysis. Clin Orthop Surg. 2017;9:145-52. https://doi.org/10.4055/cios.2017.9.2.145

53. Yoon BH, Ha YC, Lee YK, Koo KH. *Postoperative deep infection after cemented versus cementless total hip arthroplasty: a meta-analysis. J Arthroplasty. 2015;30:1823-7. https://doi.org/10.1016/j.arth.2015.04.041*
54. Schmidutz F, Schreiner AJ, Ahrend MD, et al. *Risk of periprosthetic joint infection after posttraumatic hip arthroplasty following acetabular fractures. Z Orthop Unfall. Published online May 23, 2022; https://doi.org/10.1055/a-1810-7379*
55. Keller DM, Pizzo RA, Patel JN, Viola A, Yoon RS, Liporace FA. *Use of antibiotic-cement coated locking plates in the setting of periprosthetic infection and infected nonunion. Injury. 2022;53:2567-72. https://doi.org/10.1016/j.injury.2022.03.040*
56. González-Martín D, Hernández-Castillejo LE, Herrera-Pérez M, Pais-Brito JL, González-Casamayor S, Garrido-Miguel M. *Osteosynthesis versus revision arthroplasty in Vancouver B2 periprosthetic hip fractures: a systematic review and meta-analysis. Eur J Trauma Emerg Surg. 2023;49:87-106. https://doi.org/10.1007/s00068-022-02032-8*