J Chin Med Assoc

ORIGINAL ARTICLE

Cementless primary or revision stem in revision hip arthroplasty for aseptic stem loosening with Paprosky type I/II femoral defect?

Fu-Yuan Pai[a,b], Te-Feng Arthur Chou[a,b], Hsuan-Hsiao Ma[a,b], Wei-Lin Chang[a,b], Shang-Wen Tsai[a,b,*], Cheng-Fong Chen[a,b], Po-Kuei Wu[a,b], Wei-Ming Chen[a,b]

[a]Department of Orthopaedics and Traumatology, Taipei Veterans General Hospital, Taipei, Taiwan, ROC; [b]Department of Orthopaedics, School of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan, ROC

Abstract

Background: The use of primary or revision stem during revision total hip arthroplasty (THA) for aseptic stem loosening with Paprosky type I/II femoral defect remains controversial. The aim of this study was to compare the outcomes of patients who underwent revision THA with a primary or revision stem.

Methods: We retrospectively reviewed 78 patients who received revision THA for aseptic stem loosening using primary (N = 28) or revision stems (N = 50). The bone defects were classified as Paprosky type I or II. The mean follow-up duration was 72.3 ± 34.7 months. The primary outcome domains included surgical complications and implant failures. The secondary outcome domains included medical complications, 30- and 90-day readmission, and Harris hip score (HHS).

Results: The use of revision stem was associated with a higher incidence than primary stem of patient complications (60.0% vs. 32.1%, $p = 0.018$), including intraoperative femur fracture (28.0% vs. 7.1%, $p = 0.029$) and greater trochanter fracture (16.0% vs. 0%, $p = 0.045$). The implant survival rate was comparable between groups. HHS at the final follow-up was similar.

Conclusion: With a lower risk of surgical complications and a similar rate of mid-term implant survival, cementless primary stem appears superior to revision stem in revision THA for aseptic stem loosening with Paprosky type I/II femoral defect.

Keywords: Aseptic loosening; Cementless; Femoral stem; Joint Revision; Total hip arthroplasty

1.INTRODUCTION

Total hip arthroplasty (THA) is one of the most successful orthopedic procedures. With an aging population, the demand for THA is estimated to increase by 174% between 2007 and 2030 in the United States.[1] The increasing number of primary THA procedures has led to an increase in revision THA procedures.[1,2] Aseptic loosening is among the most common indications for revision THA.[2] The choice between cemented or cementless stems during the first-time revision THA procedure remains controversial, since both types of stems lead to satisfactory long-term implant survival.[3] When using a cementless femoral stem, primary stability is of paramount importance but can be challenging, owing to varying degrees of bone loss.[4,5] One advantage of using a primary stem during the revision procedure is easier implantation, sparing the diaphysis invasion while preserving the native bone stock.[6,7] In contrast, the benefits of using a longer, revision stem include an increased contact area for osteointegration, which allows bypass of the metaphysis and achieves a more reliable fixation in the diaphysis.[4,7,8]

Most studies of the outcomes using either cementless primary or revision stem procedures have been single-arm case series.[6,9–23] Although the mid-term implant survival of both primary (85.0%-96.2%)[9,12,23] and long stem procedures (86.0%-97.0%)[15–17,19,20] is good to excellent, the incidence of common complications differs between the two, including surgical site infection (0% vs. 0%-7%),[9,12,14,17,23,24] periprosthetic joint infection (PJI; 0.7%-5.2% vs. 0%-14%),[9,11,18,21] intraoperative fracture (0.7%-20.2% vs. 0%-64%),[9,12,14,25] greater trochanter fracture (3.3% vs. 6.0%-19.5%),[10,15,17] periprosthetic fracture (1.4%-2.1% vs. 1%-5%),[6,9,13,16] stem subsidence (0% vs. 3%-19.5%),[9,15,17,23] and dislocation rate (0.7%-6.6% vs. 0%-12%).[9,10,13,19] However, heterogeneity across studies should be considered, such as different indications for revision procedure or the different types of bone defects included in each study. Therefore, a cohort study is necessary to compare the outcomes of cementless primary and revision stems. To our knowledge, the only study to compare outcomes between cementless primary and revision stem procedures was conducted by Wood et al.[26] The authors included 20 patients who underwent revision THA using a cementless primary (N = 10) or revision stem procedure (N = 10), with a mean follow-up of 12 months. The implant failure rate was higher in patients receiving primary stem (10% vs. 0%).[26] However, this study included a mixture of indications for failure,

*Address correspondence. Dr. Shang-Wen Tsai, Department of Orthopaedics and Traumatology, Taipei Veterans General Hospital, 201, Section 2, Shi-Pai Road, Taipei 112, Taiwan, ROC. E-mail address: swtsai.vghtpe@gmail.com (S.-W. Tsai).

Conflicts of interest: Dr. Wei-Ming Chen, an editorial board member at Journal of the Chinese Medical Association, had no role in the peer review process of or decision to publish this article. The other authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

Journal of Chinese Medical Association. (2022) 85: 1068-1075.

Received January 13, 2022; accepted June 30, 2022.

doi: 10.1097/JCMA.0000000000000792.

including aseptic loosening, PJI, and pseudotumor. The study also had a small sample size and a short follow-up duration. Therefore, we conducted this study to compare the outcome of patients who received a revision THA procedure for aseptic stem loosening with Paprosky type I/II femoral defect using primary and revision stems. Our primary outcomes included surgical complications and implant failure rate.

The secondary outcomes were medical complications, operation time, blood loss, transfusions, length of stay, 30- and 90-day readmission, and patient-reported outcomes. We hypothesized that the use of primary stems might be associated with fewer complications, shorter operation time, and less blood loss, with similar mid-term implant survival rates and patient-reported outcomes, compared with the use of revision stems.

2.METHODS

2.1.Cohort selection and ethical approval

This was a retrospective cohort study conducted in a single tertiary referral hospital at Taipei, Taiwan. Ethical approval was granted by the institutional review board of our hospital. Informed consent for participation was obtained from all patients and/or their legal guardians. All procedures were conducted in accordance with the Declaration of Helsinki and performed according to relevant guidelines and regulations. Our study period was from January 2010 to May 2019. We obtained medical records and images from the Taipei Veterans General Hospital Orthopedic database. First, we collected the number of revision hip arthroplasty procedures (including total and partial revision) during this period, according to Taiwan's National Health Insurance procedure codes: PCS-64258B, PCS-64201B. Second, we reviewed patients who underwent surgery for aseptic stem loosening according to the International Classification of Diseases, Tenth Revision, Clinical Modification codes T84.03, T84.030, T84.031, T84.038, or T84.039. We reviewed medical records and images and included patients who fulfilled the following criteria: (1) underwent a revision hip arthroplasty procedure for aseptic stem loosening of primary cementless THA, (2) above 18 years of age, (3) follow-up duration of more than 24 months, (4) bone defect classified as Paprosky type I or II, and (5) revision with either cementless primary or revision stems. We excluded patients who had undergone a revision procedure for (1) revision cup (N = 456) or liner only (N = 71), (2) PJI (N = 100), (3) periprosthetic fracture (N = 89), (4) recurrent dislocation (N = 34), (5) broken stem (N = 7), (6) revision with cemented stem (N = 13), or those with (7) Paprosky type III or IV bone defect (N = 6) (Fig. 1). The reasons to exclude a cemented stem as the first-line treatment option at our institution included bone-cement implantation syndrome during implanting a cemented stem[27] and technical challenges and complications during the rerevision procedure of a well-fixed cemented stem, including massive bone loss, cortical perforation, or fracture.[28,29] Cementless femoral stems were considered first in all revision hip arthroplasty procedures, except for patients with severe osteoporosis. Because of the relatively small sample size (N = 13), we excluded the use of cemented stem from our analysis. Of the 78 patients included in this study, 28 patients had undergone the revision procedure using a cementless primary stem (Fig. 2), while the other 50 patients had a cementless revision stem (Fig. 3). All of the procedures were performed by fellowship-trained orthopedic surgeons. The decision to use a

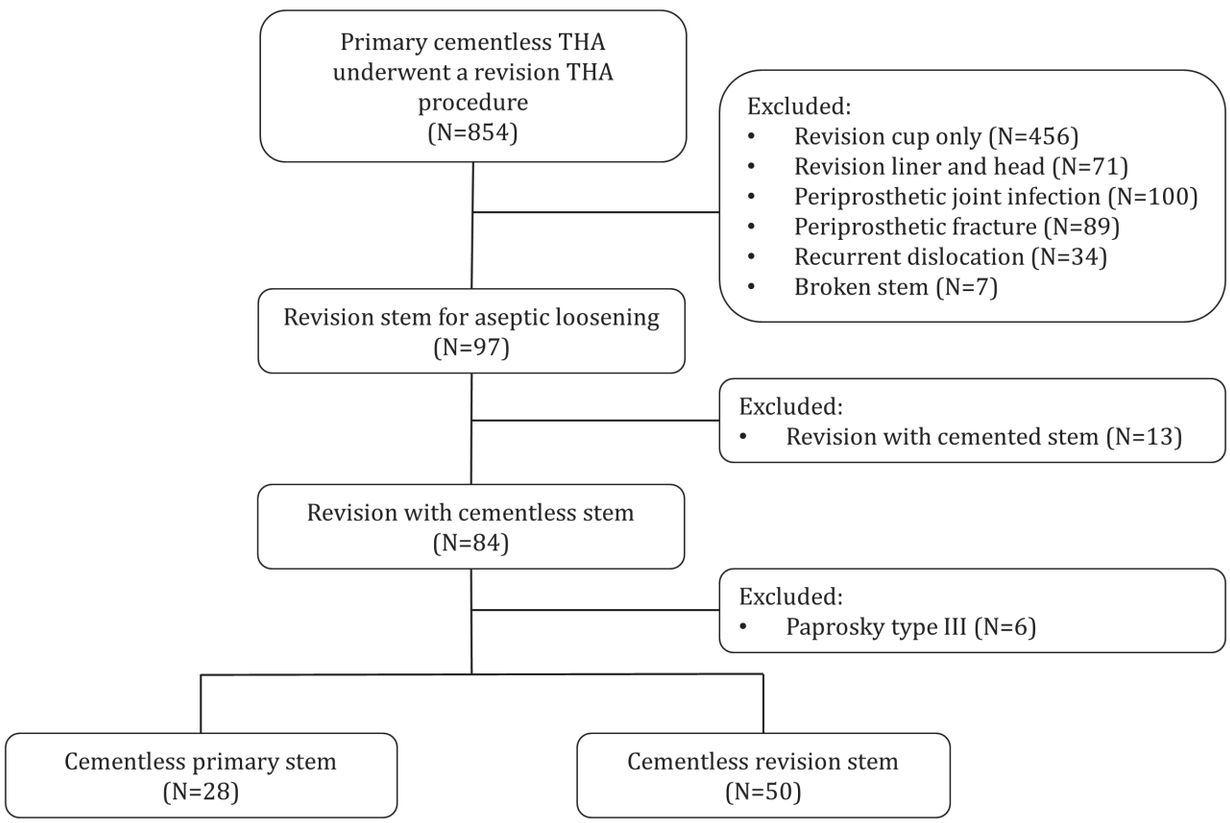

Fig. 1 CONSORT diagram. THA = total hip arthroplasty.

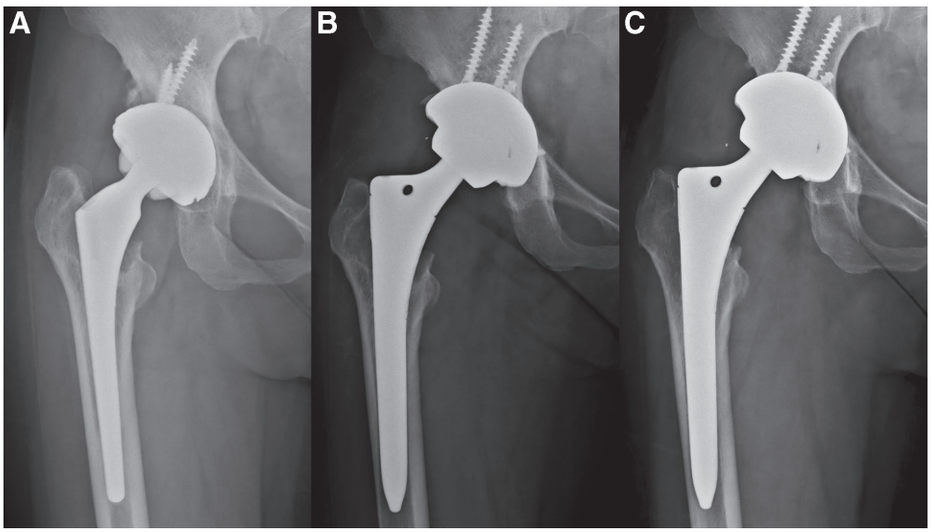

Fig. 2 A 54-year-old female with aseptic stem loosening, Paprosky type II. A, Preoperative radiograph; (B) revision total hip arthroplasty procedure using primary, metaphyseal coated stem, immediate postoperative radiograph; (C) postoperative 24-mo radiograph.

primary or revision stem was made based on the surgeon's preference. The primary stems used were Versys (Zimmer Biomet, Warsaw, IN, USA), M/L taper (Zimmer Biomet, Warsaw, IN, USA), U2 (United Orthopedic Corp., New Taipei City, Taiwan), and Secur-fit (Stryker Orthopedics, Mahwah, IN, USA). For revision stems, we included U2 revision (United Orthopedic Corp., New Taipei City, Taiwan), Restoration HA (Stryker Orthopedics, Mahwah, IN, USA), AML (Depuy, Warsaw, IN, USA), and Wagner SL (Zimmer Biomet, Warsaw, IN, USA).

2.2.Cohort characteristics

We reviewed the medical records of each patient and recorded age, sex, height, weight, body mass index (BMI), American Society of Anesthesiologists (ASA) grade, Charlson Comorbidity Index (CCI), type of revision procedure, surgical approach, Paprosky classification, and follow-up duration. The mean age was 62.6 ± 14.1 years. Twenty-three patients were female (29.5%) and 55 were male (70.5%). The mean BMI was 26.9 ± 4.4 kg/m^2. Most of the patients were classified as ASA II (N = 47, 60.3%) or III (N = 23, 29.5%). The distribution of CCI was 0 (N = 13, 16.7%), 1 (N = 15, 19.2%), 2 (N = 15, 19.2%), 3 (N = 9, 11.5%), 4 (N = 11, 14.1%), and 5 or more (N = 15, 19.2%). Thirty-six patients (46.2%) underwent revision procedure for stem only, while the other 42 patients underwent revision THA (53.8%). All patients were classified as having Paprosky type I (N = 67, 85.9%) or II (N = 11, 14.1%) bone defects. The mean follow-up duration after the revision procedure was 72.3 ± 34.7 months (range, 24-132) (Table 1).

All images were examined by two senior authors (S.W.T., F.Y.P.). The diagnosis of aseptic loosening was made based on clinical symptoms; presence of radiolucent lines in three or more Gruen zones and/or stem subsidence greater than 5 mm on plain radiographs[30]; intraoperative findings; and multiple sets of intraoperative cultures. Stem subsidence of greater than 5 mm

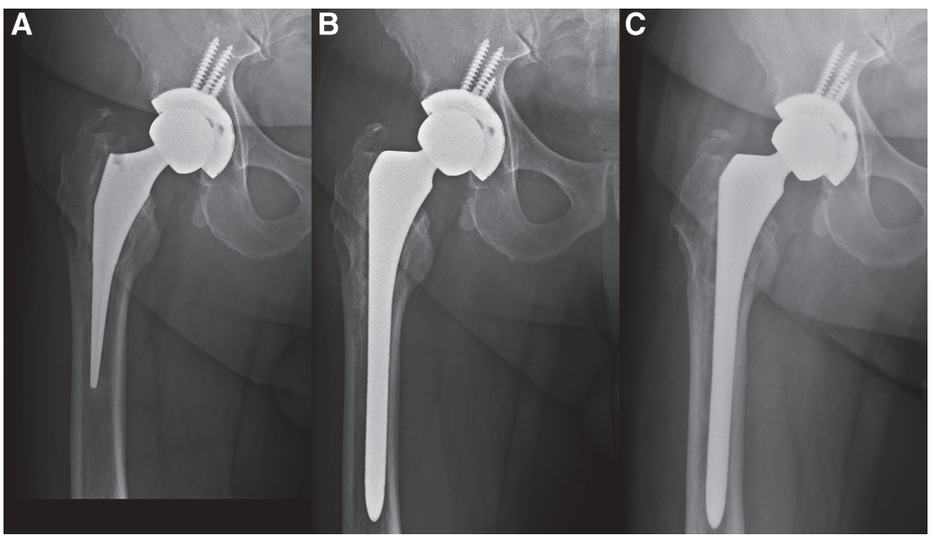

Fig. 3 A 55-year-old male with aseptic stem loosening, Paprosky type II. (A) Preoperative radiograph; (B) revision procedure using extensively coated, diaphyseal filling revision stem, immediate postoperative radiograph; (C) postoperative 24-mo radiograph.

Table 1

Patient demographics

	Overall (N = 78)	Primary stem (N = 28)	Revision stem (N = 50)	*p*
Age, y	62.6 ± 14.1 (40-93)	63.5 ± 13.1 (42-83)	62.1 ± 14.8 (40-93)	0.690
Sex				0.053
Female	23 (29.5%)	12 (42.9%)	11 (22%)	
Male	55 (70.5%)	16 (57.1%)	39 (78%)	
Height, m	1.61 ± 0.09 (1.40-1.80)	1.61 ± 0.09 (1.44-1.80)	1.61 ± 0.09 (1.40-1.79)	0.961
Weight, kg	70.2 ± 14.2 (47.5-115.1)	71.4 ± 13.8 (54.0-115.1)	69.5 ± 14.4 (47.5-111.0)	0.565
Body mass index, kg/m^2	26.9 ± 4.4 (18.2-39.7)	27.3 ± 4.1 (18.2-38.5)	26.6 ± 4.6 (19.4-36.7)	0.494
ASA grade				0.189
1	8 (10.3%)	5 (17.9%)	3 (6.0%)	
2	47 (60.3%)	14 (50.0%)	33 (66.0%)	
3	23 (29.5%)	9 (32.1%)	14 (28.0%)	
Charlson Comorbidity Index				0.534
0	13 (16.7%)	4 (14.3%)	9 (18.0%)	
1	15 (19.2%)	7 (25.0%)	8 (16.0%)	
2	15 (19.2%)	5 (17.9%)	10 (20.0%)	
3	9 (11.5%)	1 (3.6%)	8 (16.0%)	
4	11 (14.1%)	4 (14.3%)	7 (14.0%)	
5+	15 (19.2%)	7 (25.0%)	8 (16.0%)	
Revision procedure				0.054
Revision stem only	36 (46.2%)	17 (60.7%)	19 (38.0%)	
Revision THA	42 (53.8%)	11 (39.3%)	31 (62.0%)	
Surgical approach				0.818
Lateral transgluteal	63 (80.8%)	23 (82.1%)	40 (80.0%)	
Posterolateral	15 (19.2%)	5 (17.9%)	10 (20.0%)	
Paprosky classification				0.186
I	67 (85.9%)	26 (92.9%)	41 (82.0%)	
II	11 (14.1%)	2 (7.1%)	9 (18.0%)	
Follow-up duration, mo	72.3 ± 34.7 (24-132)	75.1 ± 36.6 (24-132)	70.7 ± 33.8 (24-129)	0.589

ASA = American Society of Anesthesiologists; THA = total hip arthroplasty.

on serial plain radiographs was considered clinically relevant.[31] Paprosky classification[32] was used to evaluate proximal femoral bone defects. During the perioperative period, we recorded operation time, intraoperative blood loss, preoperative and postoperative hemoglobin level, estimated blood loss, transfusion rate and amount, length of stay, and 30- and 90-day readmission. After surgery, clinical condition and plain films were evaluated monthly during the first 3 months, then in 3-month intervals for the first year, and annually thereafter. We evaluated the functional outcome of all patients using the Harris hip score (HHS)[33] at the last follow-up visit. We recorded both surgical and medication complications, the number of patients having complications, the reoperation rate, and the implant failure rate. Common surgical complications included surgical site infection, PJI, intraoperative femur fracture, greater trochanter fracture, periprosthetic femur fracture, stem subsidence, aseptic stem loosening, dislocation, and nerve injury. A stem subsidence of more than 5 mm was considered as having clinical relevance.[34] Common medical complications included acute coronary syndrome, congestive heart failure, acute kidney injury, deep vein thrombosis, pulmonary embolism, cerebrovascular disease, urinary tract infection, pneumonia, and gastrointestinal bleeding.

2.3.Statistical analysis

Statistical analyses were performed using SPSS version 22 (IBM Corp., Armonk, NY, USA). Descriptive statistics were generated for all available data. The Student's *t* test was used to compare continuous variables. The chi-square test was used to compare discrete variables. When one or more of the cells in the contingency table had an expected frequency of less than 5, we performed Fisher's exact test. Time-dependent analyses for implant failure were performed using Kaplan-Meier analysis, and differences between group curves were analyzed using the log-rank test. Statistical significance was defined as p-value <0.05.

3.RESULTS

3.1.Baseline demographics

In this study, 28 patients (35.9%) were surgically treated with revision procedure using primary stem and 50 (64.1%) with revision stem. The age, sex, height, weight, BMI, ASA grade, CCI, index procedure, surgical approach, Paprosky classification, and follow-up duration after surgery did not differ between the two groups (Table 1).

3.2.Surgical outcomes

The mean operation time was 168.5 ± 87.2 (range, 55-720) minutes. Mean intraoperative blood loss was 1035 ± 654 (range, 150-3300) mL. The mean preoperative and postoperative hemoglobin levels were 13.1 ± 1.7 (range, 8.6-16.9) and 10.8 ± 1.4 (range, 7.8-14.2) g/dL, respectively. Mean estimated blood loss, calculated using the Gross and Nadler formula,[35,36] was 1422 ± 689 (range, 70-3690) mL. The transfusion rate was 73.1% (N = 57). The mean transfusion amount of pack red blood cells was 4 ± 2.2 (range, 2-10) units. The mean hospital length of stay was 7.4 ± 2.9 (range, 4-18) days. The 30-day readmission rate was 5.1% (N = 4). The reasons for 30-day readmission included dislocation (N = 2), gastrointestinal bleeding (N = 1), and heart failure (N = 1). The 90-day readmission rate was 7.7% (N = 6). The reasons for 90-day readmission included dislocation (N = 3), gastrointestinal bleeding (N = 1), heart failure (N = 1), and deep vein thrombosis in the left leg (N = 1). The mean HHS at the last follow-up visit was 84.6 ± 17.6 (range, 41.8-100).

Table 2

Surgical outcomes in both intervention groups

	Overall (N = 78)	Primary stem (N = 28)	Revision stem (N = 50)	*p*
Operation time, min	168.5 ± 87.2 (55-720)	126.4 ± 46.3 (55-220)	192.1 ± 95.9 (90-720)	0.001
Intraoperative blood loss, mL	1035 ± 654 (150-3300)	700 ± 491 (150-2300)	1223 ± 663 (150-3300)	<0.001
Preoperative hemoglobin level, g/dL	13.1 ± 1.7 (8.6-16.9)	13.0 ± 1.7 (8.6-16.9)	13.1 ± 1.6 (9.4-16.6)	0.825
Postoperative hemoglobin level, g/dL	10.8 ± 1.4 (7.8-14.2)	11.1 ± 1.5 (7.9-14.2)	10.6 ± 1.4 (7.8-13.7)	0.137
Estimated blood loss, mL	1422 ± 689 (70-3690)	1003 ± 456 (70-1790)	1657 ± 690 (260-3690)	<0.001
Transfusion rate (%)	57 (73.1)	14 (50.0)	43 (86.0)	0.001
Transfusion amount, unit	4.0 ± 2.2 (2-10)	3.1 ± 1.6 (2-6)	4.3 ± 2.4 (2-10)	0.098
Length ofstay, d	7.4 ± 2.9 (4-18)	7.2 ± 3.7 (4-18)	7.5 ± 2.3 (4-14)	0.656
30-d readmission (%)[a]	4 (5.1)	0 (0)	4 (8.0)	0.291
90-d readmission (%)[b]	6 (7.7)	1 (3.6)	5 (10.0)	0.411
HHS at the last follow-up	84.6 ± 17.6 (41.8-100)	83.9 ± 17.8 (47.3-100)	85.0 ± 17.7 (41.8-100)	0.816

HHS = Harris hip score.

[a]30-day readmission: dislocation (N = 2), gastrointestinal bleeding (N = 1), congestive heart failure (N = 1).

[b]90-day readmission: dislocation (N = 3, 1 in primary stem group), gastrointestinal bleeding and pneumonia (N = 1, same patient, two events) (N = 1), congestive heart failure (N = 1), deep vein thrombosis (N = 1).

Table 3

Surgical complications, reoperations, implant failures, and in-hospital medical complications.

	Overall (N = 78)	Primary stem (N = 28)	Revision stem (N = 50)	*p*
Surgical complications (%)				
Surgical site infection	10 (12.8)	1 (3.6)	9 (18.0)	0.086
Periprosthetic joint infection	5 (6.4)	2 (7.1)	3 (6.0)	1.000
Intraoperative femur fracture	16 (20.5)	2 (7.1)	14 (28.0)	0.029
Greater trochanter fracture	8 (10.3)	0	8 (16.0)	0.045
Periprosthetic femur fracture	2 (2.6)	0	2 (4.0)	0.534
Stem subsidence	6 (7.7)	2 (7.1)	4 (8.0)	1.000
Aseptic stem loosening	1 (1.3)	0	1 (2.0)	1.000
Dislocation	7 (9.0)	2 (7.1)	5 (10.0)	1.000
Nerve injury	00	0	0	-
Number of patients having surgical complications	39 (50.0)	9 (32.1)	30 (60.0)	0.018
Reoperation (%)[a]	9 (11.5)	2 (7.1)	7 (14.0)	0.477
Implant failure (%)[b]	4 (5.1)	1 (3.6)	3 (6.0)	1.000

[a]*Reoperation*: periprosthetic joint infection (N = 5, 2 in the primary stem group), periprosthetic femur fracture (N = 2), dislocation (N = 1), stem aseptic loosening (N = 1).

[b]*Implant failure*: periprosthetic joint infection (N = 3, 1 in the primary stem group), stem aseptic loosening (N = 1).

The revision stem group was associated with longer operation time (192.1 ± 95.9 vs. 126.4 ± 46.3 minutes, $p = 0.001$), more intraoperative blood loss (1,223 ± 663 vs. 700 ± 491 mL, $p < 0.001$), more estimated blood loss (1,657 ± 690 vs. 1,003 ± 456 mL, $p < 0.001$), and a higher transfusion rate (86.0% vs. 50.0%, $p = 0.001$) compared with the primary stem group. The preoperative and postoperative hemoglobin levels, transfusion amount, length of stay, 30- and 90-day readmission rate, and HHS at the last follow-up did not differ between the two groups (Table 2).

3.3.Complications and implant failure

Thirty-nine patients (50.0%) had complications. Common surgical complications included intraoperative femur fracture (N = 16, 20.5%), surgical site infection (N = 10, 12.8%), greater trochanter fracture (N = 8, 10.3%), dislocation (N = 7, 9.0%), stem subsidence (N = 6, 7.7%), PJI (N = 5, 6.4%), periprosthetic fracture (N = 2, 2.6%), and aseptic stem loosening (N = 1, 1.3%). The nine (11.5%) reoperation procedures included two-stage exchange arthroplasty (N = 3) and debridement (N = 2) for PJI, fracture fixation for periprosthetic femur fracture (N = 2), open reduction for dislocation (N = 1), and stem revision for aseptic stem loosening (N = 1). There were four (5.1%) implant failure events, including PJI treated with two-stage exchange arthroplasty (N = 3) and aseptic stem loosening treated with stem revision (N = 1).

The revision group was associated with higher rates of intraoperative fracture (28.0% vs. 7.1%, $p = 0.029$), greater trochanter fracture (16.0% vs. 0%, $p = 0.045$), and patient complications (60.0% vs. 32.1%, $p = 0.018$), compared with the primary stem group. The revision stem group also showed a trend toward a higher rate of surgical site infection, compared to the primary stem group (18.0% vs. 3.6%, $p = 0.086$). None of the patients had nerve injury. The rates of reoperation and implant failure also did not differ between the two groups (Table 3). The overall implant survival rates were 97.4% (95% confidence Interval [CI], 93.8%-100%) and 94.0% (95% CI, 88.2%-99.8%) at postoperative years 2 and 5, respectively. (Fig. 4A). In the primary stem group, the implant survival rate at postoperative years 2 and 5 were 100% (95% CI, 100%-100%) and 95.2% (95% CI, 86%-100%), respectively. In the revision stem group, the implant survival rate at postoperative years 2 and 5 were 96.0% (95% CI, 90.4%-100%) and 93.3% (95% CI, 85.7%-100%), respectively. The implant survival rates were comparable between the two groups (log-rank test, $p = 0.629$) (Fig. 4B). There were two instances of in-hospital medical complications, including acute kidney injury (N = 1) and deep vein thrombosis (N = 1). The overall rate was 2.6%. The rate was similar in the two groups (Table 4).

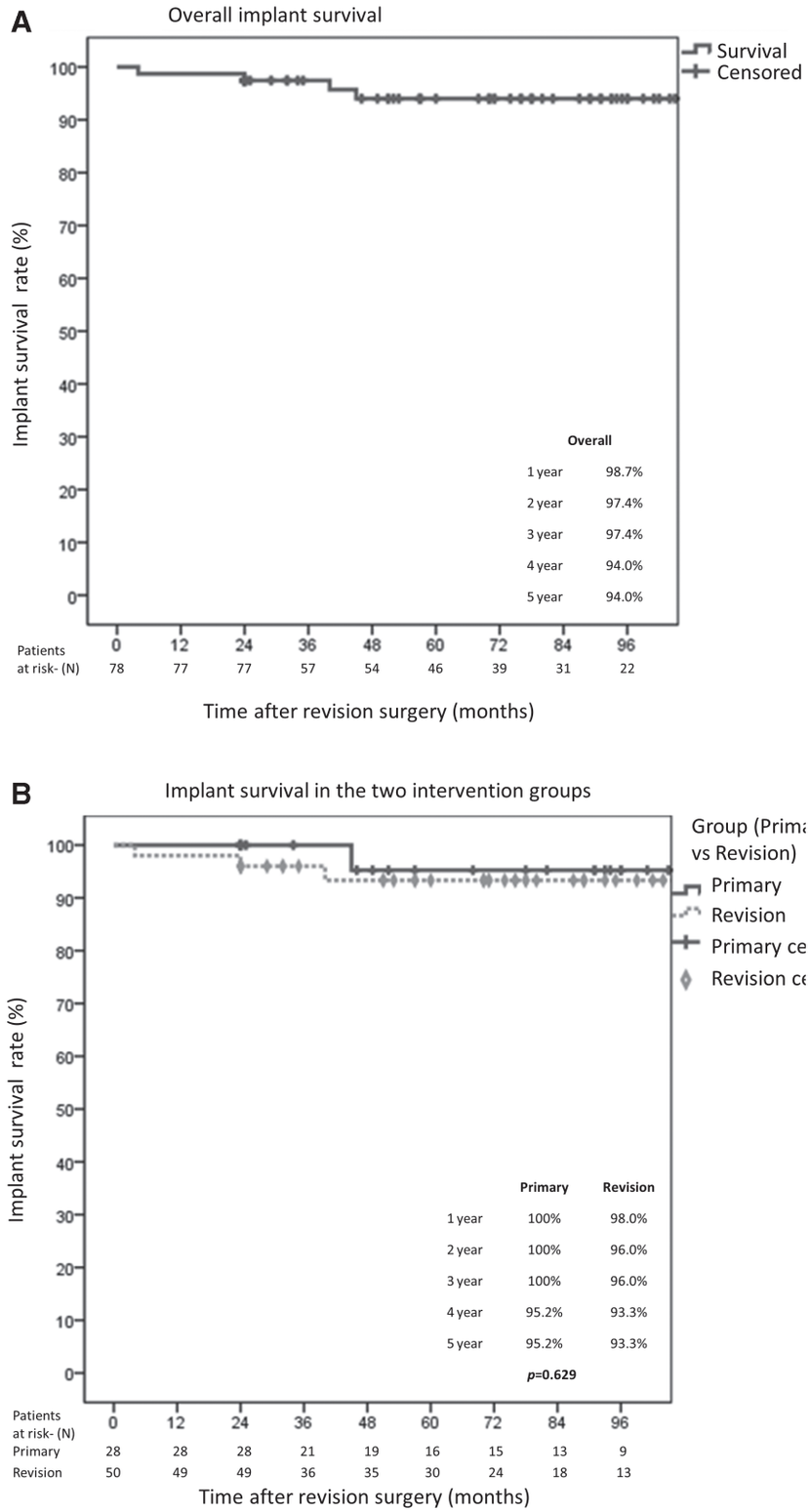

Fig. 4 Survival curves obtained using Kaplan-Meier analysis. A, Overall implant survival rate: 97.4% (95% confidence Interval [CI], 93.8%-100%) and 94.0% (95% CI, 88.2%-99.8%) at postoperative years 2 and 5, respectively. (B) Implant survival rate (primary stem): 100% and 95.2% (95% CI, 86%-100%) at postoperative years 2 and 5, respectively. Implant survival rate (revision stem): 96.0% (95% CI, 90.4%-100%) and 93.3% (95% CI, 85.7%-100%) at postoperative years 2 and 5, respectively.

Table 4

In-hospital medical complications

	Overall (N = 78)	Primary stem (N = 28)	Revision stem (N = 50)	*p*
Medical complications (%)				
Acute coronary syndrome	0	0	0	—
Congestive heart failure	0	0	0	—
Acute kidney injury	1 (1.3)	0	1 (2.0)	1.000
Deep vein thrombosis	1 (1.3)	1 (3.6)	0	0.359
Pulmonary embolism	0	0	0	—
Cerebrovascular disease	0	0	0	—
Urinary tract infection	0	0	0	—
Pneumonia	0	0	0	—
Gastrointestinal bleeding	0	0	0	—
Number of patients having complications	2 (2.6)	1 (3.6)	1 (2.0)	1.000

4.DISCUSSION

In this study, we validated that during the revision hip arthroplasty procedure for aseptic stem loosening with Paprosky type I/II femoral defect, the use of a primary stem can lead to a similar, satisfactory mid-term implant survival rate and a lower incidence of overall surgical complications, intraoperative femur fractures, and greater trochanter fractures, compared with the use of revision stem.

In our study, the overall incidence of patient complications was higher in the revision stem group than in the primary stem group (60.0% vs. 32.1%, $p = 0.018$). Notably, the incidence of intraoperative femur fracture (28.0% vs. 7.1%, $p = 0.029$) and greater trochanter fracture (16.0% vs. 0%, $p = 0.045$) were also higher. The use of a cementless long stem with a large diameter during a revision hip procedure has been validated as having a higher risk of intraoperative fracture.[37,38] Moreover, the increased magnitude of sagittal and coronal femoral bowing in the Asian population may further increase the risk of breach over the distal cortex in this population.[39,40] The reported incidence of intraoperative fracture or greater trochanter fracture varies.[9,10,12,14,15,17,25] However, using revision stem rather than primary stem tends to result in a higher rate of intraoperative fracture (0%-64% vs. 0.7%-20.2%)[9,12,14,25] or greater trochanter fracture (6%-19.5% vs. 3.3%)[10,15,17] Using additional fixation procedures for a greater trochanter or femur fracture may lead to longer operation time, which might increase the risk of short-term complications, including surgical site infection.[41,42]

In our study, the revision group tended to have a higher rate of surgical site infection than the primary group (18.0% vs. 3.6%, $p = 0.086$). Notably, none of these patients developed PJI or underwent reoperation. In our study, PJI was the most common reason for both reoperation (N = 5 of 9, 55.6%) and implant failure (N = 3 of 4, 75.0%). The PJI rate was similar in the primary (7.1%) and revision stem (6.0%) groups; these rates were comparable with reported PJI rates associated with the use of primary (0.7%-10%)[9,11,12,26] or revision stem (0%-14%).[14,17,18,21]

In our study, the mid-term implant survival rates of both the primary and revision stem groups were satisfactory. The 5-year implant survival rates of the primary and revision stem group were 95.2% and 93.3%, respectively, rates similar to those of other studies.[9,11,12,14,16,21] The mid-term survival rates of using primary and revision stem in revision THA procedure ranged 95% to 100%[9,11,12] and 86% to 94%,[14,16,21] respectively. The leading causes of failure following a revision THA procedure included aseptic loosening, instability, and PJI.[43,44] In our study, we observed reliable osteointegration with low rates of aseptic stem loosening in both the primary (0%) and revision (N = 1, 2.0%) stem groups, rates similar to those of other studies that reported mid-term results following revision THA with primary stem (0%-5.2%)[9,11] and revision stem (0%-5%)[15,16,19] In addition, the incidence of stem subsidence in the primary (7.1%) and revision stem groups (8.0%) was similar to that reported in other studies (0%-19.5%).[9,15,17,23] Before implanting a cementless primary stem, the femoral canal should be carefully prepared to avoid subsequent stem subsidence or loosening. We removed the loosened stem, performed adequate intraoperative debridement of the soft tissue membrane, and drilled through the distal pedestal, if present. A rasp and burr were used to remove and refresh the sclerotic host bone until punctate bleeding was observed. After serial broaching and/or reaming, we determined an appropriate stem size to achieve maximal metaphyseal fill. If the cavitary defect of the metaphysis was inadequately filled, a morselized allograft was then used to achieve an optimal filling-effect and to provide additional primary stability. Of the 84 patients who had the first-time revision for aseptic stem loosening, 78 (92.9%) had small bone defects (Paprosky type I or II) (Fig. 1). As a result, we hypothesized and validated a potential role for a cementless primary stem during the revision THA procedure. The potential advantages of using cementless primary stem included preservation of the diaphyseal bone stock and less stress-shielding effect compared with the longer, extensively coated revision stem, in which the long-term incidence of stress-shielding around a revision stem can be up to 30%.[20,25,45] A cohort study with long-term follow-up is necessary to further validate these benefits.

There are some limitations of this study. First, the retrospective design of this study could have led to potential biases, including (1) surgeries performed by multiple surgeons; (2) decision to use primary or revision stem based on surgeon's preference; (3) mixed use of primary and revision implant brands; and (4) not a prospective, randomized design. Second, we did not routinely check bone mineral density on every patient, although osteoporosis may impact the rate of complications such as intraoperative femur fractures.[38] Although we did not record osteoporotic fracture (e.g., femoral neck fracture) in our older patients, the age in our cohort ranged from 40 to 93 years. Osteoporosis in some of our patients should be considered an important confounding factor. Third, based on the limited number of subjects in this study, it may be underpowered to detect differences in events with a lower incidence, such as medical complications.

In conclusion, for patients who underwent a revision hip arthroplasty procedure for aseptic stem loosening with Paprosky type I/II femoral defect, cementless primary stem may be a better alternative than revision stem, with a lower risk of overall surgical complications or intraoperative fracture and a similar, satisfactory mid-term implant survival rate.

ACKNOWLEDGMENTS

This work was kindly financially supported by Dr. Morris Chang and Ms. Sophie Chang. The funding sources had no involvement or conflicts of interests with this study.

REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007;**89**:780–5.
2. Schwartz AM, Farley KX, Guild GN, Bradbury TL Jr. Projections and epidemiology of revision hip and knee arthroplasty in the United States to 2030. *J Arthroplasty* 2020;**35**(6S):79–85.
3. Tyson Y, Rolfson O, Kärrholm J, Hailer NP, Mohaddes M. Uncemented or cemented revision stems? Analysis of 2,296 first-time hip revision arthroplasties performed due to aseptic loosening, reported to the Swedish Hip Arthroplasty Register. *Acta Orthop* 2019;**90**:421–6.

4. Cavagnaro L, Formica M, Basso M, Zanirato A, Divano S, Felli L. Femoral revision with primary cementless stems: a systematic review of the literature. *Musculoskelet Surg* 2018;**102**:1–9.
5. Ma HH, Chou TA, Tsai SW, Chen CF, Wu PK, Chen WM. Is there a role for cementless primary stem in hip arthroplasty for early or late fixation failures of intertrochanteric fractures? *BMC Musculoskelet Disord* 2022;**23**:266.
6. Tetreault MW, Shukla SK, Yi PH, Sporer SM, Della Valle CJ. Are short fully coated stems adequate for "simple" femoral revisions? *Clin Orthop Relat Res* 2014;**472**:577–83.
7. Sheth NP, Nelson CL, Paprosky WG. Femoral bone loss in revision total hip arthroplasty: evaluation and management. *J Am Acad Orthop Surg* 2013;**21**:601–12.
8. Tsai SW, Chen CF, Wu PK, Chen CM, Chen WM. Cement augmentation in the proximal femur to prevent stem subsidence in revision hip arthroplasty with Paprosky type II/IIIa defects. *J Chin Med Assoc* 2018;**81**:571–6.
9. Romagnoli S, Marullo M, Corbella M, Zero E, Parente A, Bargagliotti M. Conical primary cementless stem in revision hip arthroplasty: 94 consecutive implantations at a mean follow-up of 12.7 years. *J Arthroplasty* 2021;**36**:1080–6.
10. Barakat A, Quayle J, Stott P, Gibbs J, Edmondson M. Results of hydroxyapatite ceramic coated primary femoral stem in revision total hip replacement. *Int Orthop* 2020;**44**:1655–60.
11. Khanuja HS, Issa K, Naziri Q, Banerjee S, Delanois RE, Mont MA. Results of a tapered proximally-coated primary cementless stem for revision hip surgery. *J Arthroplasty* 2014;**29**:225–8.
12. Thorey F, Lerch M, Kiel H, Von Lewinski G, Stukenborg-Colsman C,Windhagen H. Revision total hip arthroplasty with an uncemented primary stem in 79 patients. *Arch Orthop Trauma Surg* 2008;**128**:673–8.
13. Yacovelli S, Ottaway J, Banerjee S, Courtney PM. Modern revision femoral stem designs have no difference in rates of subsidence. *J Arthroplasty* 2021;**36**:268–73.
14. Uriarte I, Moreta J, Cortés L, Bernuy L, Aguirre U, Martínez de Los Mozos JL. Revision hip arthroplasty with a rectangular tapered cementless stem: a retrospective study of the SLR-Plus stem at a mean follow-up of 4.1 years. *Eur J Orthop Surg Traumatol* 2020;**30**:281–9.
15. Herry Y, Viste A, Bothorel H, Desmarchelier R, Fessy MH. Long-term survivorship of a monoblock long cementless stem in revision total hip arthroplasty. *Int Orthop* 2019;**43**:2279–84.
16. Huddleston JI 3rd, Tetreault MW, Yu M, Bedair H, Hansen VJ, Choi HR, et al. Is there a benefit to modularity in 'simpler' femoral revisions? *Clin Orthop Relat Res* 2016;**474**:415–20.
17. Regis D, Sandri A, Bonetti I, Braggion M, Bartolozzi P. Femoral revision with the Wagner tapered stem: a ten- to 15-year follow-up study. *J Bone Joint Surg Br* 2011;**93**:1320–6.
18. Smith MA, Deakin AH, Allen D, Baines J. Midterm outcomes of revision total hip arthroplasty using a modular revision hip system. *J Arthroplasty* 2016;**31**:446–50.
19. Wirtz DC, Gravius S, Ascherl R, Thorweihe M, Forst R, Noeth U, et al. Uncemented femoral revision arthroplasty using a modular tapered, fluted titanium stem: 5- to 16-year results of 163 cases. *Acta Orthop* 2014;**85**:562–9.
20. Imbuldeniya AM, Walter WK, Zicat BA, Walter WL. The S-ROM hydroxyapatite proximally-coated modular femoral stem in revision hip replacement: results of 397 hips at a minimum ten-year follow-up. *Bone Joint J* 2014;**96-B**:730–6.
21. Jibodh SR, Schwarzkopf R, Anthony SG, Malchau H, Dempsey KE, Estok DM 2nd. Revision hip arthroplasty with a modular cementless stem: mid-term follow up. *J Arthroplasty* 2013;**28**:1167–72.
22. Pattyn C, Mulliez A, Verdonk R, Audenaert E. Revision hip arthroplasty using a cementless modular tapered stem. *Int Orthop* 2012;**36**:35–41.
23. Gastaud O, Cambas PM, Tabutin J. Femoral revision with a primary cementless stem. *Orthop Traumatol Surg Res* 2016;**102**:149–53.
24. Hashem A, Al-Azzawi A, Riyadh H, Mukka S, Sayed-Noor A. Cementless, modular, distally fixed stem in hip revision arthroplasty: a single-center study of 132 consecutive hips. *Eur J Orthop Surg Traumatol* 2018;**28**:45–50.
25. Tsukeoka T, Lee TH, Tsuruoka H, Murata T, Suzuki M. Results of revision total hip arthroplasty with Anatomic BR stem: 10-year minimum follow-up. *Mod Rheumatol* 2011;**21**:482–7.
26. Wood TJ, Alzahrani M, Marsh 'D, Somerville LE, Vasarhelyi EM, Lanting BA. Use of the Corail stem for revision total hip arthroplasty: evaluation of clinical outcomes and cost. *Can J Surg* 2019;**62**:78–82.
27. Donaldson AJ, Thomson HE, Harper NJ, Kenny NW. Bone cement implantation syndrome. *Br J Anaesth* 2009;**102**:12–22.
28. Duncan WW, Hubble MJ, Howell JR, Whitehouse SL, Timperley AJ, Gie GA. Revision of the cemented femoral stem using a cement-in-cement technique: a five- to 15-year review. *J Bone Joint Surg Br* 2009;**91**:577–82.
29. Wang L, Lei P, Xie J, Li K, Dai Z, Hu Y. Medium-term outcomes of cemented prostheses and cementless modular prostheses in revision total hip arthroplasty. *Sci Rep* 2013;**3**:2796.
30. Engh CA, Massin P, Suthers KE. Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. *Clin Orthop Relat Res* 1990:107–28.
31. Ries C, Boese CK, Dietrich F, Miehlke W, Heisel C. Femoral stem subsidence in cementless total hip arthroplasty: a retrospective single-centre study. *Int Orthop* 2019;**43**:307–14.
32. Paprosky WG, Perona PG, Lawrence JM. Acetabular defect classification and surgical reconstruction in revision arthroplasty. A 6-year follow-up evaluation. *J Arthroplasty* 1994;**9**:33–44.
33. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am* 1969;**51**:737–55.
34. Callaghan JJ, Salvati EA, Pellicci PM, Wilson PD Jr, Ranawat CS. Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982. A two to five-year follow-up. *J Bone Joint Surg Am* 1985;**67**:1074–85.
35. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. *Surgery* 1962;**51**:224–32.
36. Gross JB. Estimating allowable blood loss: corrected for dilution. *Anesthesiology* 1983;**58**:277–80.
37. Meek RM, Garbuz DS, Masri BA, Greidanus NV, Duncan CP. Intraoperative fracture of the femur in revision total hip arthroplasty with a diaphyseal fitting stem. *J Bone Joint Surg Am* 2004;**86**:480–5.
38. Davidson D, Pike J, Garbuz D, Duncan CP, Masri BA. Intraoperative periprosthetic fractures during total hip arthroplasty. Evaluation and management. *J Bone Joint Surg Am* 2008;**90**:2000–12.
39. Abdelaal AH, Yamamoto N, Hayashi K, Takeuchi A, Morsy AF, Miwa S, et al. Radiological assessment of the femoral bowing in Japanese population. *SICOT J* 2016;**2**:2.
40. Su XY, Zhao Z, Zhao JX, Zhang LC, Long AH, Zhang LH, et al. Three-dimensional analysis of the curvature of the femoral canal in 426 chinese femurs. *Biomed Res Int* 2015;**2015**:318391.
41. Wang Q, Goswami K, Shohat N, Aalirezaie A, Manrique J, Parvizi J. Longer operative time results in a higher rate of subsequent periprosthetic joint infection in patients undergoing primary joint arthroplasty. *J Arthroplasty* 2019;**34**:947–53.
42. Surace P, Sultan AA, George J, Samuel LT, Khlopas A, Molloy RM, et al. The association between operative time and short-term complications in total hip arthroplasty: an analysis of 89,802 surgeries. *J Arthroplasty* 2019;**34**:426–32.
43. Kenney C, Dick S, Lea J, Liu J, Ebraheim NA. A systematic review of the causes of failure of revision total hip arthroplasty. *J Orthop* 2019;**16**:393–5.
44. Springer BD, Fehring TK, Griffin WL, Odum SM, Masonis JL. Why revision total hip arthroplasty fails. *Clin Orthop Relat Res* 2009;**467**:166–73.
45. Sumner DR. Long-term implant fixation and stress-shielding in total hip replacement. *J Biomech* 2015;**48**:797–800.