



Staged Revision of Infected-hip Arthroplasty Using an Antibiotics-loaded Intra-articular Cement Spacer: Impact on Cemented and Cementless Stem Retention

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Purpose: Currently, standard management of a peri-prosthetic infection is a two-stage revision procedure. However, removal of well-fixed cement is technically demanding and associated with numerous potential complications. For these reasons, two-stage revision with preservation of the original femoral stem can be considered and several previous studies have achieved successful results. While most prior studies used cemented stems, the use of cementless stems during arthroplasty has been gradually increasing; this study aims to assess the comparative effectiveness of a two-stage revision of infected hip arthroplasties at preserving cemented and cementless stems.

Materials and Methods: Between December 2001 and February 2017, Inje University Sanggye Paik Hospital treated 45 cases of deep infections following hip arthroplasty with a two stage revisional arthroplasty using antibiotics-loaded cement spacers. This approach was applied in an effort to preserve the previously implanted femoral stem. Of these 45 cases, 20 were followed-up for at least two years and included in this analysis. Peri-operative clinical symptoms, radiological findings, function and complications during insertion of an antibiotics-loaded cement spacer were analyzed in this study.

Results: Peri-prosthetic infections were controlled in 19 of the 20 included cases. Clinical outcomes, as assessed using the Harris hip score, Western Ontario and McMaster University score, also improved. Importantly, similarly improved outcomes were achieved for both cemented and cementless femoral stems.

Conclusion: In cases of deep infection following hip arthroplasty, two-stage revision arthroplasty to preserve the previously implanted femoral stem (cemented or cementless) effectively controls infections and preserves joint function.

Key Words: Infected hip arthroplasty, Femoral stem, Harris hip score, Western Ontario and McMaster University score, Two-stage revision

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INTRODUCTION

Postoperative infections after hip arthroplasty is a serious orthopedic complication that imposes time and economic burdens. Despite the use of antibiotics, peri-prosthetic infections following hip arthroplasties occur in up to 1% of cases. Infections may require several reoperations and long-term treatment, eventually resulting in revisional hip arthroplasty¹⁻³.

Two-staged exchange with delayed reimplantation of a new prosthesis is a preferred method of treatment for deep peri-prosthetic infection after total hip arthroplasty (THA)⁴. It is also generally believed that all components should be removed to eradicate the infection, however, the removal of well-fixed cement is technically demanding and may be associated with complications (e.g., excessive blood loss, bone loss, femoral fracture)^{5,6}. In addition, the osseointegrated cement-bone interface is not part of the effective joint space and is inaccessible to infecting organisms⁷. Also, well-fixed cementless stems should be removed using cutting instruments to divide areas of bone ingrowth or ongrowth. Furthermore, when bone ingrowth involves the diaphyseal area for the cementless femoral stems, extended greater trochanteric osteotomies are required^{8,9}. Lastly, if a circumferential bone ingrowth

of a cementless stem acts as a barrier to intrusion of infected joint fluid and microorganisms, the infection could be treated without the removal of a well-fixed stem, and the risk of recurrent infection and implant failure would be lower¹⁰.

For the reasons outlined above, two-stage revisional hip arthroplasty can be considered in order to preserve the original femoral stem; previous studies outlining outcomes of this approach have reported successful results^{7,8,10-12}. Although most previous studies used cemented stems, the use of cementless stems in arthroplasty has been gradually increasing; this study aimed to assess the effectiveness of two-stage revision surgery to preserve cemented and cementless stems in those with infections following a hip arthroplasty.

MATERIALS AND METHODS

Between December 2001 and February 2017, 20 of 45 cases (7 males and 13 females, 8 bipolar hemiarthroplasty [BHA], and 12 THA) of deep infections following hip arthroplasty were: i) treated via a two-stage revision surgery with an antibiotics-loaded cement spacer (ALCS) designed to preserve the previously implanted femoral stem and ii) observed for more than two years in the Inje University Sanggye Paik Hospital. The previous implants were evenly

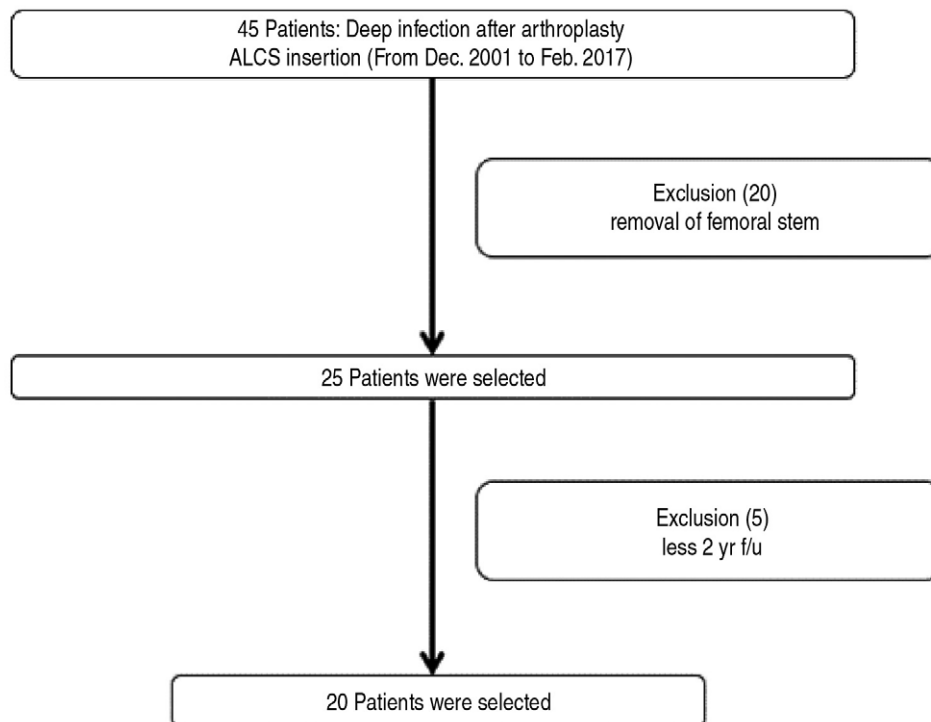


Fig. 1. Flowchart of case selection and analysis.
ALCS: antibiotics-loaded cement spacer, f/u: follow-up.

divided into cemented (n=10) and cementless (n=10) stems. Among the original 45 patients, 20 cases were excluded for total implant removal, including the femoral stem, and five cases were excluded for follow-up durations of less than two years (Fig. 1).

Infections were diagnosed based on the presence of pus drainage, positive aspirated fluid and/or tissue culture histological evidence of infection¹³, and increased levels of inflammatory markers, including C-reactive protein (CRP) >10 mg/L (normal range, 0-5 mg/L) or erythrocyte sedimentation rate (ESR) >30 mm/hr (normal range, 0-15 mm/hr)¹⁴. Preoperative joint aspiration was performed in cases with increased inflammatory marker levels or where doubts persisted regarding the diagnosis of infection. Samples from tissues were remaining infections were suspected were obtained and evaluated by frozen section. Polynuclear white cells were counted by high-field microscopy ($\times 400$) at more than five sites. In some cases, technetium-99 m scans were performed before operations to preserve femoral stems without radioisotope uptake. White blood cell scintigraphy was not performed to diagnose infections. All patients were reviewed clinically and radiologically at six weeks, three months, six months, and every six months thereafter.

While most previous studies assessing the effectiveness of two-stage revision surgeries at preserving previously implanted stems because of post-arthroplasty infections involved cemented stems, the use of cementless stems has been gradually increasing; here, we aimed to compare the effectiveness of this approach at preserving cemented vs. cementless stems.

1. Operative and Postoperative Procedures

In cases well-fixed cemented stems with radioluscent lines involving less than 50% of the cement-bone interface

on the preoperative radiographs, cases were considered to be potential candidates for preservation of the femoral cement¹⁵. The neck of the femur was re-cut to remove 1 mm or more from the proximal surface in order to enable assessment of the integrity of the cement bone interface. The cement was considered well-fixed if a scalpel could not be passed between it and bone⁷.

Also, in cases well-fixed cementless stems with radiographic evidence of bone ingrowth along the entire length of the stem on the preoperative radiographs, stem removal was not attempted. In cases of well-fixed cementless stems without radiographic evidence of bone ingrowth along the entire length of the stem on the preoperative radiographs, stem removal using a thin osteotomes was attempted to create a cleavage between the stem and the proximal femur followed by removal of the stem using the stem extractor. If this procedure was not effective, the stem was not removed¹⁰. Additional magnetic resonance imaging and bone scans were not routinely conducted.

In cases with well-fixed cemented and cementless femoral stems, the acetabular component and femoral head were removed while: i) the femoral stem was preserved, and ii) debridement of infected soft tissue on the acetabulum was performed.

In the case of previous THAs, acetabular reaming was done to match the previous acetabular cup size. For previous BHA cases, acetabular reaming was performed until one size smaller than the appropriately sized acetabular cup measured preoperatively was achieved.

Cement was constructed with Antibiotic Simplex P (Stryker Orthopaedics, Limerick, Ireland). One Pack of cement contained 0.5 g erythromycin, 3×10^6 IU colistin, and 3 g of either heat-stable vancomycin or cefuroxime (second-generation cephalosporins). The mixed cement was melted into a bipolar shell used for BHA and the prosthetic femoral

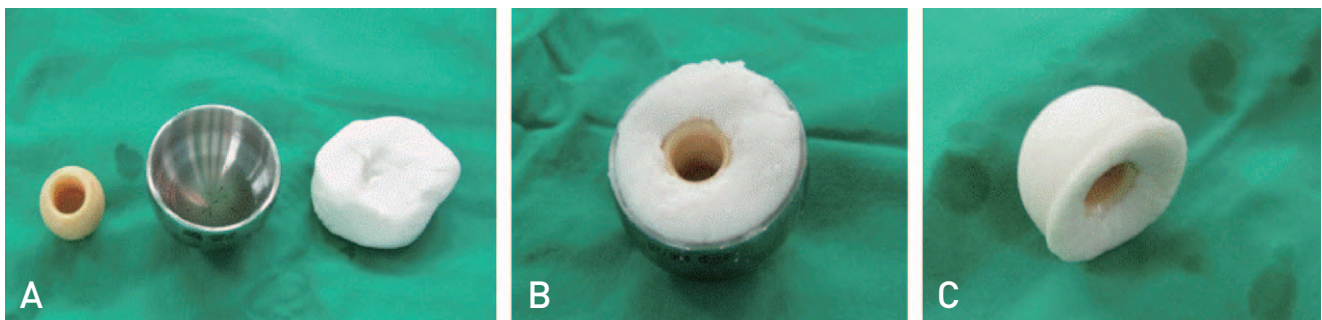


Fig. 2. The cement spacer was molded into the shape of a hemiarthroplasty. **(A)** The spacer consists of a bipolar head, shell, and antibiotics-mixed cement. **(B)** Prosthesis fitted over the sterilized head according to the size of the retrieved acetabular cup. **(C)** The spacer was molded into the required shape.

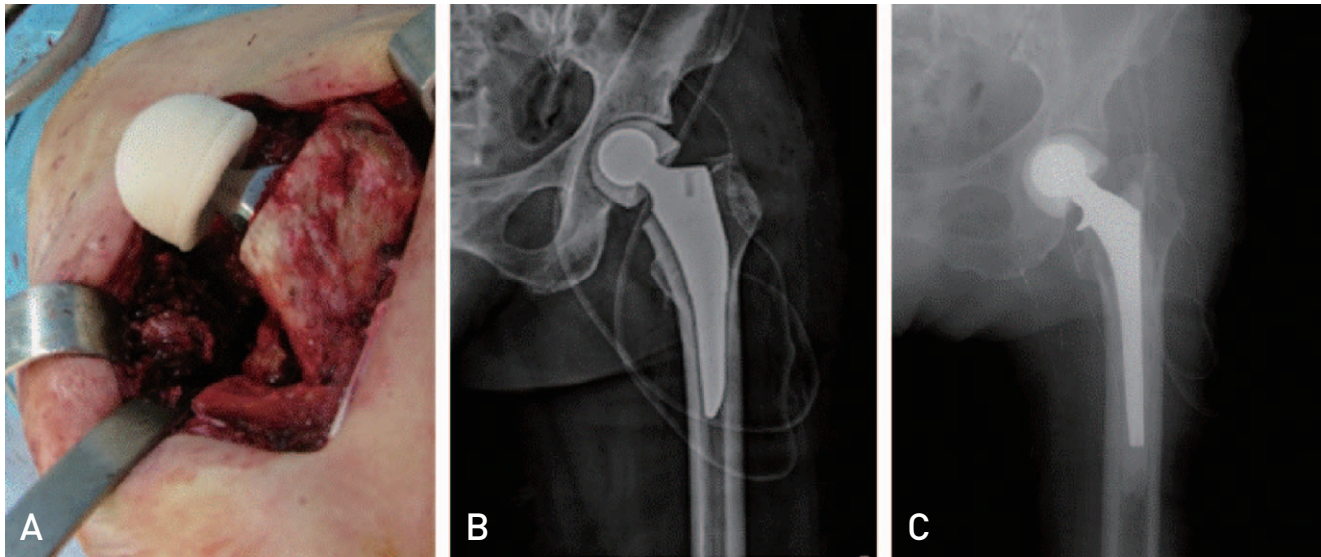


Fig. 3. (A) The molded cement spacer was attached to the retained femoral stem and attached to the trunnion of the femoral neck. (B) An 80-year-old female with an antibiotics-loaded cement spacer inserted into a cementless femoral stem. (C) A 75-year-old female with an antibiotics-loaded cement spacer inserted into a cemented femoral stem.

head was solidified in the center of the cement (Fig. 2, 3). To maintain a high antibiotic concentration, an intra-joint hemo-vac was inserted in most cases. Compressive dressings were used until postoperative day 7 to prevent hematoma when not using a hemo-vac. Patients taking anti-platelets received hemo-vac until the drainage volume was less than 50 mL. Just after drainage removal, partial weight-bearing with crutch ambulation and possible joint range of motion was allowed. Between implant removal with ALCS to the secondary revision, antibiotics to which the cultured organisms were sensitive were injected intravenously for 3-4 weeks and oral antibiotics were administered until CRP levels had normalized. Revisional arthroplasty was performed when evidence of infection was excluded by clinical symptoms and CRP levels had normalized for 1-2 weeks without antibiotics. From the intraoperative field, every tissue suspected of infection was obtained for frozen section biopsy. Cases with average polynuclear white cell counts of five or more in ($\times 400$) high-field microscopy in more than five sites underwent repeated debridement of the infected tissue and another ALCS for infection control. In cases of clumping polynuclear white cells, the number was counted as 10.

2. Outcome Measures

We analyzed perioperative clinical symptoms, radiological findings, and changes in ESR and CRP levels to identify the recurrence of postoperative infections.

Clinical outcomes were assessed using the Harris hip score (HHS)¹⁶⁾ and Western Ontario and McMaster University score (WOMAC score)¹⁷⁾ at the last follow-up; these values were compared with scores at diagnosis of the first postoperative infection and after ALCS insertion.

3. Statistical Analysis

The Mann-Whitney *U*-test was used to analyze between groups (i.e., cement and cementless). The Fisher's exact test was used to analyze nominal variables. IBM SPSS Statistics ver. 23 (IBM Corp., Armonk, NY, USA) was used to perform statistical analyses. A $P < 0.05$ was considered statistically significant.

4. Ethics Statement

The study protocol was approved by the Institutional Review Board of Inje University Sanggye Paik Hospital (IRB No. 2019-10-018).

RESULTS

The average age at arthroplasty was 68.5 years (range, 50-83 years) and the average follow-up duration was 38 months (range, 24-85 months). The previous diagnoses for the first hip arthroplasty included: i) femur neck fracture (n=10), ii) femoral head avascular necrosis (n=8), and iii) developmental dysplasia (n=2). Infected arthroplasties

occurred following BHA (n=9) and THA (n=11).

The average duration from primary arthroplasty to infection diagnosis was 25 months (range, 1 month-10 years). The average duration from infection diagnosis to revisional arthroplasty was 73 days (range: 40 days-5 months).

According to Fitzgerald classification, type I acute fulminating infection was that which occurred within three months of the arthroplasty, type II was delayed infection progressively occurring within two years after surgery, and type III late hematogenous infection was that which occurred after two years with other systemic infection transferred by blood supply. In this study, nine (45.0%), three (15.0%), and eight (40.0%) cases were type I, II, and III, respectively.

Before revisional arthroplasty, 19 of the 20 cases that received antibiotics-loaded cement space insertion designed to help preserve the previously implanted femoral stems had positive bacterial cultures. The detected bacteria included methicillin-resistant *Staphylococcus aureus* (MRSA) (n=7;

35.0%), methicillin-resistant coagulase-negative *Staphylococcus* (MRCNS) (n=5; 25.0%), methicillin-resistant *S. lugdunensis* (n=2; 10.0%), methicillin-resistant *S. haemolyticus* (n=2; 10.0%), methicillin-sensitive *S. epidermidis* (n=1; 5.0%), *Candida albicans* (n=1; 5.0%), and both MRSA and MRCNS (n=1; 5.0%). Revisional arthroplasty was performed after ALCS insertion at an average of 73 days (range, 40-167 days). Three cases (Case Nos. 1, 7, and 10) had more than six more polynuclear white cells (range, 6-15) in intraoperative ($\times 400$) frozen sections of suspected infected tissue, leading to soft tissue debridement and ALCS exchange. There were no cases requiring additional procedures due to acetabular defects during the second-stage surgery.

For complications, dislocation occurred during ALCS insertion, however, it was resolved by manual reduction. Subsequent deep infections were successfully controlled and secondary revisions were possible.

In one case (Case No. 4 who was in poor general condition),

Table 1. Summary of Cases

Case No.	Age (yr) /Sex	Diagnosis	Medical status	ESR (mm/hr) /CRP (mg/L)	Casative organism	Interval between revision (day)	Cemented/ Non-cemented
1	67/Female	Infected BHA	Healthy	67/6.4	MRSA, MRCNS	101 (55+46)	Cemented
2	57/Male	Infected THRA	DM, HTN	87/5.4	MRCNS	46	Cemented
3	50/Female	Infected THRA	Healthy	100/8.3	MRCNS	51	Non-cemented
4	57/Female	Infected THRA	DM, HTN	41/6.2	MRCNS	Failure	Cemented
5	57/Female	Infected THRA	Healthy	59/1.4	MRSA	43	Cemented
6	58/Male	Infected THRA	Healthy	35/2.8	MRSA	47	Non-cemented
7	80/Female	Infected BHA	DM, HTN	85/14.3	MRSA	97 (52+45)	Non-cemented
8	72/Male	Infected BHA	Healthy	91/1.6	MSSE	40	Cemented
9	77/Female	Infected BHA	DM, HTN	53/1.2	MRCNS	48	Cemented
10	69/Male	Infected BHA	DM, HTN	84/10.7	MRSA	152 (67+85)	Non-cemented
11	75/Female	Infected BHA	Dementia	32/5.0	MRSA	52	Cemented
12	65/Male	Infected THRA	Healthy	76/6.4	MRSA	52	Non-cemented
13	76/Female	Infected BHA	DM, HTN, CVA, dementia	31/0.9	<i>Candida albicans</i>	41	Non-cemented
14	83/Female	Infected BHA	DM	75/1.8	MRCNS	62	Non-cemented
15	69/Female	Infected THRA	RA	94/5.4	NG	92	Non-cemented
16	67/Female	Infected THRA	HTN	52/1.0	MRSH	167	Cemented
17	75/Female	Infected THRA	DM, HTN	14/1.8	MRSL	62	Cemented
18	61/Male	Infected THRA	DM	11/2.7	MRSA	62	Cemented
19	83/Male	Infected THRA	HTN, AMI	32/5.1	MRSL	59	Non-cemented
20	73/Female	Infected THRA	DM, HTN, CKD	16/0.8	MRSH	129	Non-cemented

ESR: erythrocyte sedimentation rate, CRP: C-reactive protein, BHA: bipolar hemiarthroplasty, THRA: total hip replacement arthroplasty, DM: diabetes mellitus, HTN: hypertension, CVA: cardiovascular accident, RA: rheumatic arthritis, AMI: acute myocardial infarction, CKD: chronic kidney disease, MRSA: methicillin-resistant *Staphylococcus aureus*, MRCNS: methicillin-resistant coagulase-negative *Staphylococcus*, MSSE: methicillin-sensitive *Staphylococcus epidermidis*, NG: no growth, MRSH: methicillin-resistant *Staphylococcus haemolyticus*, MRSL: methicillin-resistant *Staphylococcus lugdunensis*.

we changed ALCS twice due to continuous infection; however, the infection was not controlled. Transparent shadowing was also observed surrounding the femoral stem in radiological imaging; therefore, the total femoral stem was removed and an ALCS was placed in the empty space. Revisional arthroplasty was performed after this procedure.

Eight of the remaining 19 cases had crutch ambulation, while the remaining 11 used wheelchair ambulation during the ALCS inserted period. Most cases were pain-free after revision (Table 1).

Nineteen of 20 cases with ALCS insertion had HHS improvement from 42 to 74 before revisional arthroplasty. The WOMAC score also improved from 52 to 28. After revisional arthroplasty, further improvement was observed

for both HHS and WOMAC scores, to 86 and 13, respectively (Fig. 4). After two-stage revisional arthroplasty, the average ESR among patients with cemented femoral stems improved from 50.7 to 21.3 mm/hr and the average CRP decreased from 3.2 to 0.5 mg/L.

We performed subgroup analysis to compare between cemented and cementless stem groups. The average ages of patients in the cemented and cementless stem groups were 67.4 years (n=9, except for one failure) and 69.6 years (n=10), respectively (P=0.280). Women comprised 70% and 60% of the cemented and cementless groups, respectively (P=1.000). The average body mass index (BMI) was 21.5 and 22.6 kg/m² in the cemented and cementless groups, respectively (P=0.605). Prior hip surgery included BHA (n=4) and THA (n=6) in the cemented group and the same in the cementless group (P=1.000). The average mean times from ALCS insertion to revisional arthroplasty were 65.6 days (range, 41-152 days) and 80.7 days (range, 40-167 days) for the cemented and cementless groups, respectively (P=0.315). The failure rate was 10.0% in the cemented group and 0% in the cementless group (P=1.000) (Table 2). The HHS improved from 43 to 79 after ALCS insertion in the cemented femoral stem group and the WOMAC score improved from 51 to 26. After revisional arthroplasty, the HHS in the cemented femoral group further improved to 89; the WOMAC score also improved, to 11. In the cementless femoral stem group, the HHS improved from 41 to 69 after ALCS insertion, while the WOMAC score improved from 54 to 31. After revisional arthroplasty in the cementless femoral stem group, the HHS and WOMAC score further improved to 83 and 13, respectively, demonstrating effective results (Fig. 5, 6).

After revisional arthroplasty, no evidence of infection

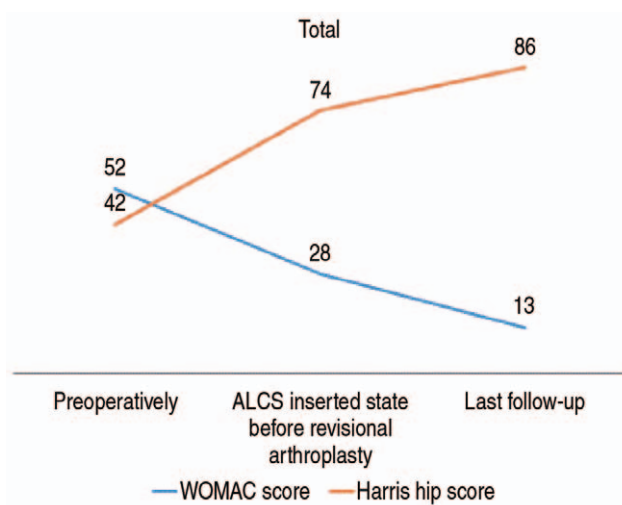


Fig. 4. Harris hip and WOMAC scores; Interval changes of Harris hip and WOMAC score in all patients. WOMAC score: Western Ontario and McMaster University score, ALCS: antibiotics-loaded cement spacer.

Table 2. Comparisons between the Cemented Stem and Non-cemented Stem Groups

Variable	Cemented (n=10)	Non-cemented (n=10)	P-value
Mean age (yr)	67.4	69.6	0.280
Sex (female)	7 (70.0)	6 (60.0)	>0.990
BMI (kg/m ²)	21.5	22.6	0.605
No. of prior hip surgery	4 BHA, 6 THRA	4 BHA, 6 THRA	>0.990
Mean time from ALCS insertion to revisional arthroplasty (day)	65.6 [41-152]*	80.7 [40-167]	0.315
Failure	1 (10.0)	0 (0)	>0.990

Values are presented as mean only, number (%), number only, or median (range).

BMI: body mass index, ALCS: antibiotics-loaded intra-articular cement spacer, BHA: bipolar hemiarthroplasty, THRA: total hip replacement arthroplasty.

* Subject number=9; except 1 failure.

Data were analyzed using Mann-Whitney U-test and Fisher's exact test.

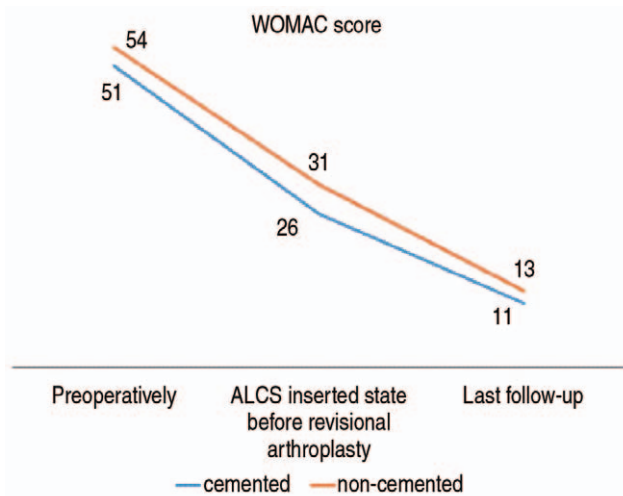


Fig. 5. Comparing interval changes of WOMAC scores in cemented and cementless stem groups. WOMAC score: Western Ontario and McMaster University score, ALCS: antibiotics-loaded cement spacer.

recurrence in radiologic findings, dissociation, displacement, or osteolysis was observed. Effective infection control was achieved in 19 of 20 cases (95.0%).

DISCUSSION

The principle of treatment for deep infection after hip arthroplasty is implant replacement after complete inflammation control. Inflammation control may require debridement of infected tissue including the femoral head. In cases of inserted implants, total removal of the implant (i.e., cement, infected tissue, foreign bodies), is required. Replacement of the implants can be performed as one- or two-stage revision.

Staged revisional arthroplasty has been successful in up to 77% cases, and up to 90% cases using ALCSs¹⁸. Callaghan et al.¹⁹ reported recurrent infection within 10 years in up to 8.3% of immunologically stable patients undergoing one-stage revisional arthroplasty. One-stage revisional arthroplasty is contraindicated for immunologically unstable patients, patients with resistant gram-negative or methicillin-resistant bacterial infections, and in patients for whom primary repair is impossible or with serious soft tissue or bone defects leading to implant fixation failure.

Two-stage revisional arthroplasty is a more effective procedure for complete infection control. In the first stage, the implant and infected tissue are removed and antibiotics are administered based on the sensitivity of specimens obtained during implant removal. For increased efficacy, an

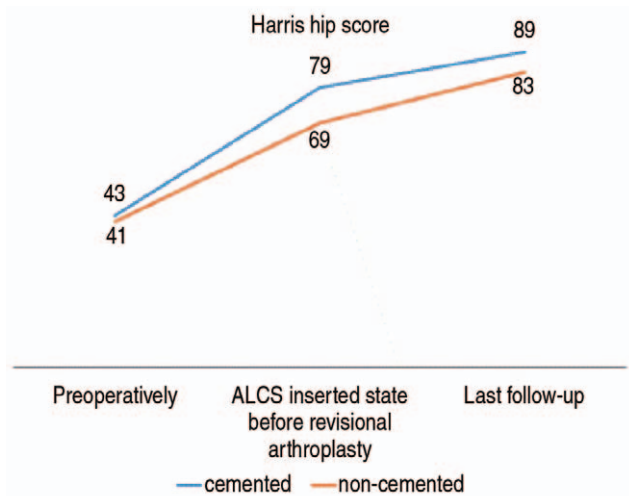


Fig. 6. Comparing interval changes of Harris hip scores in cemented and cementless stem groups. ALCS: antibiotics-loaded cement spacer.

ALCS is used in the procedure. The second stage is the reimplantation of the arthroplasty following complete infection control. Between the first and second stages, infection control is determined by measuring CRP and ESR levels while administering intravenous antibiotics. If the infection is not controlled, revisional arthroplasty cannot be performed; infected soft tissue debridement can be performed repeatedly if necessary.

The traditional two-stage revision was the Girdlestone procedure (excision arthroplasty) and involved the removal of the total implant and infected tissue, leaving an empty space while waiting for infection control²⁰. After infection control, revision arthroplasty was performed. This approach was known as an effective procedure for infection treatment, however, patients experience pain, joint contracture, limited motion, and antibiotic injections from the time of implant removal until revisional arthroplasty. Two-stage revisional arthroplasty had been widely performed due to its high infection control rate, even though it had other disadvantages; two-stage revisional arthroplasty with ALCS was devised to help overcome these disadvantages²⁰⁻²⁴.

ALCSs have biological effects by acting directly on the infected lesion, preserving joint mobility and stability, and preventing soft tissue contracture, resulting in favorable clinical outcomes^{25,26}. Kendall et al.²⁷ reported the effectiveness of Prosthesis of Antibiotic-Loaded Acrylic Cement for revision. Garvin and Hanssen²⁸ reported a success rate of up to 91% for two-stage revisional arthroplasty—an approach that was more effective than one-stage revisional arthroplasty. Sanchez-Sotelo et al.²⁹ reported the results of a long-term

follow-up of 121 cases that received ALCSs. In their population, 7.1% of the 121 cases underwent reoperation due to infection recurrence, 7.7% had reoperation due to non-bacterial dissociation and osteolysis, and 87% had successful infection control for 10 years.

Infection eradication is generally believed to require the removal of all components, however, the removal of well-fixed cement is technically demanding and may be associated with complications (e.g., excessive blood loss, bone loss, femoral fracture)^{5,6}. Moreover, an extended trochanteric osteotomy or cortical window is often required to remove a well-fixed femoral stem, thus necessitating extensive soft tissue dissection that devascularizes the proximal femur, possibly leading to the formation of sequestrum, causing infection recurrence¹⁰. In the second-stage procedure to reimplant a cemented prosthesis from which cement has been removed, techniques such as impaction grafting may be required to treat bone loss, further adding to the complexity and risks of the revision³⁰. In addition, some have argued that the osseointegrated cement-bone interface is not part of the effective joint space and is inaccessible to infecting organisms⁷.

Our study involved cases where ALCSs were inserted to match the femoral head morphology and preserve joint function after implant removal and to preserve the previously implanted femoral stem. Spacer insertion was performed only after radiologically excluding infection and osteolysis. This method has advantages (e.g., preserving joint stability, mobility, and soft tissue contracture, avoiding challenging implant removal); furthermore, it is functionally and economically effective. Cordero et al.³¹ reported the possibility of stem preservation in radiologically stable cases with firmly fixed femoral stems. Struhl et al.³² reported effective results for ALCS with original femoral stem preservation in cases of infection following BHA. Yoon et al.³³ reported the successful control of infection after THA in four cases using only a change of femoral head cup with ALCS and femoral stem preservation.

In a recent long-term study of femoral stem preservation in revisional arthroplasty, Morley et al.⁷ reported only one case of recurrent infection among 15 cement stems in an average 82-month observation (minimum 5 years). Lee et al.¹⁰ reported effective results for cementless stems, with two of 17 cases developing recurrent infection within an average follow-up duration of four years. Ekpo et al.⁸ reported two cases of recurrent infection among 19 cementless stems in an average 40-month observation.

In our study, three cases had more than six polynuclear

white cells in frozen sections from the field of revisional arthroplasty, which resulted in soft tissue debridement and ALCS change. Importantly, only one case of definite recurrent infection among 20 cement stems within an average 38-month follow-up (minimum of two years) were observed. This corresponds to a success rate of 95%, which is superior to previous studies compared to 93.3%, 88.2%, and 89.5%; the shorter follow-up period may have affected these comparative results.

The remaining implants cannot exclude infection recurrence, especially in peri-implant infections, in which treatment is challenging due to the difficulty for antibiotics to penetrate biofilms, membranous structures surrounding bacterial colonies around the implant surface³⁴. Therefore, even though evidence of infection is rare before revisional arthroplasty, clinical changes, laboratory examination, and radiological evaluation may be required after revision.

The present study has several limitations including the relatively short average follow-up (three years) compared with other studies. Additionally, there were no control groups to facilitate comparisons with other treatment options and/or well-fixed femoral stems. Therefore, it can not be excluded that this study may have yielded relatively better results than previous studies, because low-grade femoral infection cases were also included herein. The small cohort analysis and lack of randomization or blinding should also be considered limitations.

CONCLUSION

In cases with deep infection following hip arthroplasty, two-stage revisional arthroplasty preserving the femoral stem is efficient for infection control and joint function preservation.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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