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The Early- to Mid-term Outcome of Novel Cementless Modular Femoral Stem in East Asian Patients

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Background: Early firm fixation of the femoral implant is crucial in total hip arthroplasty (THA) with unstable metaphysis or a large degree of femoral bone loss. This study aimed to evaluate the outcomes of THA using a novel cementless modular, fluted, tapered stem in such cases.

Methods: From 2015 to 2020, 105 hips (101 patients) had surgery performed by two surgeons at two tertiary hospitals using a cementless modular, fluted, tapered stem for periprosthetic fractures, massive bone loss, prosthetic joint infection sequelae, or tumorous condition. Clinical outcomes, radiographic results, and survivorship of the implant were evaluated.

Results: The average follow-up period was 2.8 years (range, 1–6.2 years). The Koval grade was 2.7 ± 1.7 preoperatively and maintained at 1.2 ± 0.8 at the latest follow-up. The plain radiograph showed bone ingrowth fixation in 89 hips (84.8%). The average stem subsidence at postoperative 1 year was 1.6 ± 3.2 mm (range, 0–11.0 mm). Five reoperations (4.8%) were needed, including 1 for acute periprosthetic fracture, 1 for recurrent dislocation, and 3 for chronic periprosthetic joint infection. Kaplan-Meier survivorship with reoperation for any reason as the endpoint was 94.1%.

Conclusions: The early- to mid-term results of THA with the novel cementless modular, fluted, tapered THA stem system were satisfactory clinically and radiologically. The shortcomings inherent to its modularity were not identified. This modular femoral system may provide adequate fixation and be a practical option in the setting of complicated THA.

Keywords: *Revision total hip arthroplasty, Femoral revisions, Tapered modular stem*

Total hip arthroplasty (THA) is considered the operation of the century[1] and has been used as the treatment of choice for patients with numerous hip disease entities. However, early THAs with specific types of bearing had their inherent durability problems, ultimately leading to revision total THA.[2] Thus, the incidence of femoral stem revision has been increasing.[3] The achievement of stable and durable fixation of a femoral stem is challenging in cases with femoral bone loss, proximal femoral deformity, and periprosthetic fractures.

Therefore, a long distally fixed cementless stem was introduced to bypass proximal femoral bony deficit. Though comparison between modular and nonmodular revision stems has been recently discussed, still there were several advantages of modular revision stems.[4] They offer the independent optimization of the proximal and distal femur to maximize prosthesis fit. Moreover, individual adjustment of anteversion, leg length, and offset can be achieved.[5]

Every 4 to 5 years, a novel modular revision stem is

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introduced to the market with unique improvements, for example, in surface coating and with resolution or reduction of previous complications. The purpose of this study was to evaluate the clinical and radiological results of a novel cementless modular, fluted, revision stem.

METHODS

This study was approved by the Institutional Review Board of Seoul National University Hospital and Seoul National University Bundang Hospital (No. H-2104-215-1215 and No. B-2205-757-402). Informed consent was waived as the study was performed retrospectively.

This is a retrospective study on patients treated with Arcos modular femoral revision system (Zimmer Biomet, Warsaw, IN, USA) (Fig. 1) by two high-volume hip surgeons (JJY and YKL) at two tertiary institutions between March 2015 and March 2020. Arcos modular femoral stem has several types of proximal and distal components, which a surgeon can choose based on the operative situation. A cone type proximal component assembled with a splined tapered distal stem was used in this study. The cone type proximal component is porous plasma spray-coated and has a length variability from 50 mm to 80 mm with offset option. The splined tapered stem has three distinctive features: splines all around the stem, a grit blast-coated surface, and distally 3° tapered design. Clinical follow-up and radiographic examination were routinely performed at 6 weeks, 6 months, and 1 year after surgery and yearly thereafter. The average follow-up period was 2.8 years (range, 1–6.2 years).

Fig. 1. Arcos modular femoral revision system used in this study (Zimmer Biomet, Warsaw, IN, USA).

Clinical outcomes were assessed using Koval grade[6] and the visual analog scale (VAS).[7] Preoperative, postoperative, and follow-up radiographs were analyzed by the orthopedic surgeon who was not involved in the surgery and was blinded to the patient information (HSK). Paprosky classification was used to evaluate preoperative bone defects.[8] Periprosthetic femoral fractures were classified using the Vancouver classification.[9] Stem stability, loosening, subsidence, and healing status of osteotomy site were analyzed in serial postoperative radiographs. Migration of stem was measured from definitive landmarks on the stem to fixed landmarks on the femur.[10] Implant loosening was defined as progressive subsidence or radiolucent lines of > 1 mm around the implant.[11]

The mean age of the patients at the time of surgery was 67.0 years (range, 27–91 years). There were 42 female patients (40.0%). The average body mass index was 24.4 kg/m^2 (range, 15.5–37.5 kg/m^2). The length of hospital stay was 10.0 days on average (range, 3–98 days) (Table 1). The initial operation was performed 12.2 years on average prior to revision surgery. Common indications for surgery were aseptic loosening (59.0%), periprosthetic fractures (19.0%), and the second-stage operation after prosthetic joint infection (9.5%). The Paprosky type IIIa bone defect was most common (35.2%), followed by type II bone defect (32.4%). Most patients (71.4%) had combined spinal and epidural anesthesia since the mean operation time was 197.3 minutes (range, 75–300 minutes). Femoral osteoto-

Table 1. Demographics and Baseline Characteristics of 105 Hips

Parameter	Value
Age (yr)	67.0 ± 12.3
Sex	
Female	42 (40.0)
Male	63 (60.0)
BMI (kg/m^2)	24.4 ± 3.9
Right : left	52 : 53
ASA physical status classification	
1	21 (20.0)
2	63 (60.0)
3	21 (20.0)
Hospital stay (day)	10.0 ± 11.7
Duration of follow-up (yr)	2.8 ± 1.6

Values are presented as mean ± standard deviation or number (%).
BMI: body mass index, ASA: American Society of Anesthesiologists.

Table 2. Surgical Indications and Intraoperative Data of 105 Hips

Variable	Value
Initial replacement to repair time (yr)	12.2 ± 10.6
Indication for surgery	
Aseptic loosening	62 (59.0)
Peri-prosthetic fracture around a primary THA	20 (19.0)
Septic loosening	10 (9.5)
Failed treatment of hip fracture	7 (6.7)
Other (hip infection sequelae, GCT)	6 (5.7)
Type of operation	
Both acetabular cup and femoral stem revised	54 (51.4)
Only femoral stem revised	43 (41.0)
Primary total hip arthroplasty	8 (7.6)
Paprosky classification of femoral defect	
I	17 (16.2)
II	34 (32.4)
IIIa	37 (35.2)
IIIb	17 (16.2)
Anesthesia	
Combined spinal and epidural anesthesia	75 (71.4)
General anesthesia	17 (16.2)
Spinal anesthesia	13 (12.4)
Proximal femoral stem length (mm)	
50	34 (32.4)
60	26 (24.8)
70	29 (27.6)
80	16 (15.2)
Distal femoral stem length (mm)	
150	71 (67.6)
190	31 (29.5)
200	3 (2.9)
Femoral stem diameter (mm)	16.5 ± 4.3
Osteotomy	
Trochanteric osteotomy	8 (7.6)
Extended trochanteric osteotomy	24 (22.9)
Estimated blood loss (mL)	1,134.4 ± 754.5
Operative duration (min)	197.3 ± 54.9

Values are presented as mean ± standard deviation or number (%).
THA: total hip arthroplasty, GCT: giant cell tumor.

my was used in 32 cases: conventional greater trochanteric osteotomy in 8 and extended greater trochanteric osteotomy in 24. The most common femoral stem diameter and length were 14 mm (range, 12 to 24 mm) and 150 mm, respectively (Table 2).

Rehabilitation

Patients were instructed to limit their ambulation to toe-touch weight-bearing for 6 weeks, followed by progressive weight-bearing over the next 6 weeks. Patients typically were allowed to bear weight as tolerated without a crutch or walker 3 to 6 months postoperatively.

Radiologic Evaluation

Two orthopedic surgeons (HSK and JWP) analyzed all radiographs using a picture archiving and communication system (Infinitt PACS; Infinitt Healthcare, Seoul, Korea). Leg length discrepancy was defined as the perpendicular distance between a horizontal reference line drawn through teardrops and the lesser trochanters on an anteroposterior simple pelvic radiograph. The final radiographs were used in outcome analyses. Stem subsidence was analyzed with the distance change from the tip of the greater trochanter to the stem shoulder.

Statistical Analysis

All data are shown as mean with standard deviation unless otherwise specified. Kaplan-Meier survivorship[12] was calculated using the reoperation of the femoral component for any reason as endpoints. The data were statistically analyzed using IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). For post hoc power analysis, the program G*Power 3.1 was used.

RESULTS

Clinical Outcome and Radiological Evaluation

Clinical follow-up showed that VAS scores improved from an average of 74.5 points (range, 50–90) preoperatively to 21.1 points (range, 0–30) at the latest follow-up. The Koval grade was 2.7 ± 1.7 preoperatively and maintained at 1.2 ± 0.8 at the latest follow-up. The postoperative radiographic examination revealed that 89 femoral stems (84.8%) re-

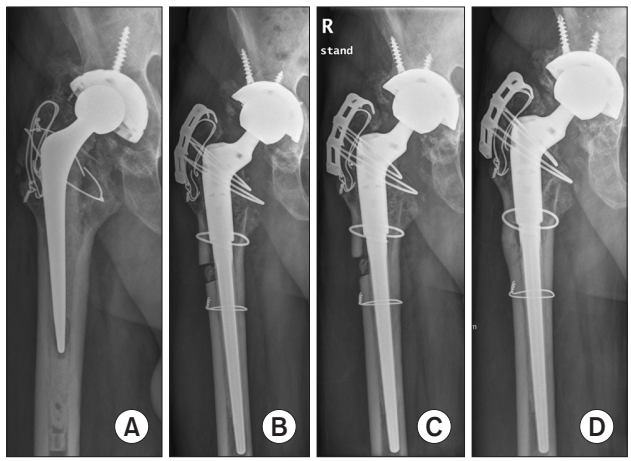

Fig. 2. (A) A 80-year-old man who had cemented total hip arthroplasty 17 years ago due to ankylosis of the right hip had inguinal area pain due to polyethylene wear and osteolysis. (B) He underwent cup and stem revision, and the stem was revised to Arcos modular stem (immediate postoperative radiograph). The anteroposterior radiographs at postoperative 6 months (C) and 4 years (D) showed minimal osteolysis around the stem and negligible subsidence of the stem, with firm fixation of the functioning implant.

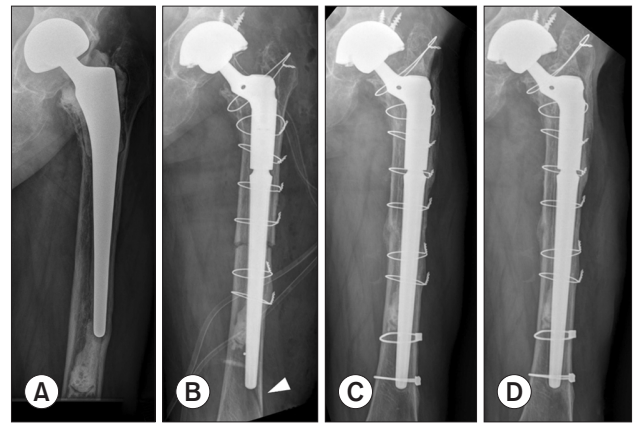

Fig. 3. (A) A 68-year-old man had bipolar hemiarthroplasty 32 years ago due to osteonecrosis of the femoral head. The preoperative radiograph showed a loosened femoral stem due to a radiolucent osteolytic lesion around the stem. (B) The immediate postoperative radiograph showed a crack at the very distal end of the stem (arrowhead). He was treated by open reduction and internal fixation with cerclage wires 3 days after the index operation. The anteroposterior radiographs taken at postoperative 1 year (C) and 2 years (D). He was without any symptoms at the latest follow-up.

Table 3. List of Early and Late Postoperative Complications

Variable	Value
Preoperative leg length discrepancy (mm)	–10.8 ± 17.9
Postoperative leg length discrepancy (mm)	–32.2 ± 21.1
Subsidence at postoperative 1 year (mm)	1.3 ± 2.4
List of early and late postoperative complications	
No complication	99 (94.3)
Acute peri-prosthetic fracture	1 (1.0)
Dislocation	2 (1.9)
Chronic prosthetic infection	3 (2.9)

Values are presented as mean ± standard deviation or number (%).

mained stable, while 16 stems (15.2%) acquired stable fibrous fixation (Fig. 2). On the range of femoral stem migration, the average subsidence was 1.6 mm (range, 0–11.0 mm) at postoperative 1 year. Afterwards, all migrations were stabilized without further progression. The mean leg length discrepancy was improved from –32.2 mm (range, –55.7 to 5 mm) preoperatively to –10.8 mm (range, –51.8 to 21.2 mm) postoperatively (Table 3).

Complications

We observed 1 periprosthetic fracture when the Arcos stem was inserted (Fig. 3). The level of fracture was at the very end of the distal portion of the stem and was treated by open reduction and internal fixation with cerclage wires in 3 days from the index operation. At postoperative 2 years, the fracture was healed, and the patient was free of symptoms. Two hips were dislocated during the follow-up. One of them was treated with closed reduction, and no more dislocation occurred throughout the follow-up. The other 98-year-old male patient suffered recurrent dislocations and was treated with Girdlestone resection arthroplasty.

Three periprosthetic joint infections occurred during the follow-up. The infections were noted at postoperative 2 weeks, 3 weeks, and 2 years each. Two acute infections were treated with debridement with implant retention and intravenous antibiotics treatment and Girdlestone resection arthroplasty each. After a follow-up of 1 year, there were no signs of infection, and patients did not want further surgical intervention.

Chronic periprosthetic joint infection was successfully treated by debridement and intravenous antibiotics. Conventional culture methods revealed *Klebsiella pneumoniae* as a causative organism of the infection. At 1 year after the surgical debridement, signs and symptoms of remnant or recurrent infection were not observed.

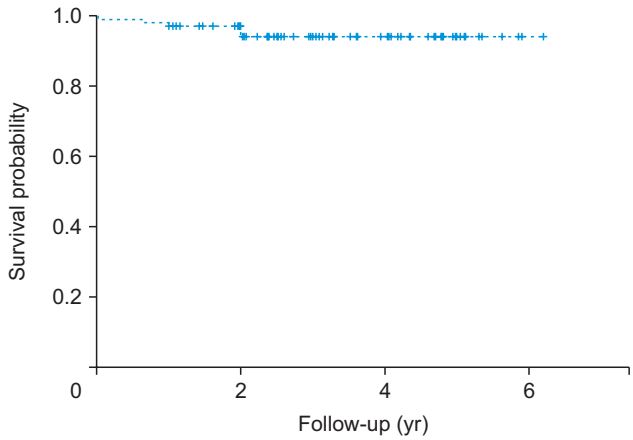

Fig. 4. Kaplan-Meier curve with reoperation for any reason as the endpoint. The tick marks indicate censored data.

Survivorship

Overall, 5 reoperations (4.8%) were needed, including 1 for acute fracture, 1 for recurrent dislocation, and 3 for periprosthetic joint infection (Table 3). There was no observed septic loosening, dislocation, and modular junction fracture in our study. The overall cumulative Kaplan-Meier survivorship with reoperation for any reason as the endpoint was 94.1% (95% confidence interval, 88.8%–99.3%) at postoperative 6.2 years (Fig. 4).

DISCUSSION

The ultimate goal of arthroplasty using a modular stem is to allow patients to have normal activity of daily living. Precise estimation of bone defect and appropriate stem selection are crucial. However, a thorough radiological examination sometimes cannot predict the extent of bone deformity and defect. Therefore, implants that allow several combinations are useful. One of the strengths of this study is the implantation of the same stem in a relatively short period of time. In this study, results of Arcos modular stem were promising with a comparable extraction rate.

Despite several improvements in the current modular stem, previously known complications of the modular stem were also observed in this study. Subsidence after modular stem implantation was reported in several studies. Amanatullah et al.[13] reported 7% of Link MP stem (Waldemar Link, Hamburg, Germany) subsided more than 5 mm, and 2 of them needed revision surgery. Kwong et al.[14] reported the average migration of 2.1 mm at postoperative 3.3 years with the same stem. With the PFM stem (Protek, Sulzer Orthopedics, Switzerland), McInnis et al.[15] found that subsidence occurred in 84% with the average length of 9.9 mm in 2006. Recently, subsidence of 2.1% in surgery using Revitan stems (Zimmer, Warsaw, IN, USA) had been reported by Jang et al.[16] The average migration in our cohorts was 1.6 mm at postoperative 1 year, and 7.8% of them showed more than 5 mm migration. Neither further migration nor any related complication, however, was observed in these patients. We believed that, unlike other previous modular stems, the Arcos stem was 360° splined with tapered distal portion and this feature might have resisted the rotational force and compression force, which prevented further subsidence.

In most cases, periprosthetic fracture was the cause of surgery, in which it might be more challenging to achieve firm fixation than in any other cases. Stable fixation at 4–5 cm above the isthmus is considered to be important. Compared to other modular stems, Arcos stem had the splined tapered design around the stem shaft and grit blast coating to the distal tip of the stem, which seemed to provide the long-term stability through bone fixation and resist further migration.

The intraoperative periprosthetic fractures are another important risk in surgery using a fluted distally fixed modular stem. In previous studies, the prevalence of intraoperative fracture ranged from 3% to 18%.[14,17-20] There was only 1 acute periprosthetic fracture (1.0%) that occurred in our study, and it occurred at the very distal part of the stem. A plausible mechanism for the fracture was the sudden increase in pressure applied on the relatively narrow diaphysis during reaming or prosthetic insertion. Another possible reason would be the use of straight stem in a bowed femur. If the patient's height was short with a relatively short femur, a curved type distal stem such as interlocking type or extended trochanteric osteotomy type might be appropriate to avoid iatrogenic fractures. The treatment of periprosthetic fractures is usually taxing with a high rate of prosthetic migration, mechanical failure, and subsequent instability. Therefore, strenuous efforts should be devoted to prevent this complication. Extended trochanteric osteotomy would usually help to position the femoral stem appropriately, but it was limited due to its own morbidity. Routine fluoroscopy check would also be practical to avoid the risk of intraoperative fracture.

The survival rate of Arcos stem in this study was 94.1% with 95% confidence interval from 88.8% to 99.3%. This is comparable with the data in previously reported literature (Table 4).[13,14,16,17,21-30] Shah et al.[28] reported 86.3% of survival rate with Arcos modular stem, while Dyreborg et al.[29] showed 96% of 5-year survival rate. Though there are no other data using Arcos modular stem from Asian countries, our data were consistent with previous studies.

Table 4. Previously Reported Survival Rates of the Modular Fluted Tapered Stems

Study	Product name	No. of hips	Mean follow-up (yr)	Survival rate (%)*
Chandler et al. (1994)[21]	S-ROM	52	3	84
Wirtz et al. (2000)[22]	MRP-Titan	142	2.3	95.8
Cameron et al. (2002)[23]	S-ROM	211	7	94
Kwong et al. (2003)[14]	Link MP	143	3.3	97.2
Schuh et al. (2004)[17]	MRP-Titan	79	4	96.2
Tamvakopoulos et al. (2007)[24]	Link MP	40	5.6	92.5
Weiss et al. (2011)[25]	Link MP	90	Minimum 5	90
Fink et al. (2014)[26]	Revitan	116	7.5	95.7
Amanatullah et al. (2015)[13]	Link MP	92	6.4	96
Jang et al. (2015)[16]	Revitan	47	4.5	86
Hoberg et al. (2015)[27]	MRP-Titan	136	4.6	85.6
Shah et al. (2019)[28]	Arcos	51	2	86.3
Dyreborg et al. (2020)[29]	Arcos	116	4	96
Zheng et al. (2021)[30]	Link MP	34	9.1	95
This study	Arcos	105	2.8	94.1

*The reported percentages are either actual percentages of intact implants or based on Kaplan-Meier survivorship analyses. Thus, the average follow-up periods may not equal the survivorship percentages shown.

There are some limitations of our study. First, our study was a retrospective study without a control group. Future large scale, prospective, randomized controlled trials are needed. Second, the number of patients included was small, which might have decreased the type and incidence of complications. The post hoc power analysis for complications indicates a lack of power. Despite the lack of power, this study demonstrated that the novel stem provided fair clinical and radiological outcomes. Future research with a larger cohort would be warranted. In addition, detailed clinical data such as patient outcome or satisfaction scores were absent. Finally, this study was performed in two tertiary referral centers with two hip surgeons, which might not be suitable for generalization of this result.

In conclusion, the early- to mid-term results of revision THA with the cementless Arcos modular fluted tapered stem were encouraging with comparable survival and complication even in the East Asian population. Further prospective and larger cohort research would be warranted.

CONFLICT OF INTEREST

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

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REFERENCES

1. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370(9597):1508-19.
2. Lachiewicz PF, Kleeman LT, Seyler T. Bearing surfaces for total hip arthroplasty. J Am Acad Orthop Surg. 2018;26(2):45-57.
3. 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(4):780-5.
4. Feng S, Zhang Y, Bao YH, Yang Z, Zha GC, Chen XY. Comparison of modular and nonmodular tapered fluted titanium stems in femoral revision hip arthroplasty: a minimum 6-year follow-up study. Sci Rep. 2020;10(1):13692.
5. Srinivasan A, Jung E, Levine BR. Modularity of the femoral component in total hip arthroplasty. J Am Acad Orthop Surg. 2012;20(4):214-22.
6. Koval KJ, Skovron ML, Aharonoff GB, Meadows SE, Zuckerman JD. Ambulatory ability after hip fracture: a prospective study in geriatric patients. Clin Orthop Relat Res. 1995;(310):150-9.
7. Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. Ann Rheum Dis. 1978;37(4):378-81.
8. Krishnamurthy AB, MacDonald SJ, Paprosky WG. 5- to 13-year follow-up study on cementless femoral components in revision surgery. J Arthroplasty. 1997;12(8):839-47.
9. Duncan CP, Masri BA. Fractures of the femur after hip replacement. Instr Course Lect. 1995;44:293-304.
10. Abdel MP. CORR Insights(®): high survivorship with cementless stems and cortical strut allografts for large femoral bone defects in revision THA. Clin Orthop Relat Res. 2015;473(9):3001-2.
11. Park MS, Lim YJ, Chung WC, Ham DH, Lee SH. Management of periprosthetic femur fractures treated with distal fixation using a modular femoral stem using an anterolateral approach. J Arthroplasty. 2009;24(8):1270-6.
12. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc. 1958;53(282):457-81.
13. Amanatullah DF, Howard JL, Siman H, Trousdale RT, Mabry TM, Berry DJ. Revision total hip arthroplasty in patients with extensive proximal femoral bone loss using a fluted tapered modular femoral component. Bone Joint J. 2015;97(3):312-7.
14. Kwong LM, Miller AJ, Lubinus P. A modular distal fixation option for proximal bone loss in revision total hip arthroplasty: a 2- to 6-year follow-up study. J Arthroplasty. 2003;18(3 Suppl 1):94-7.
15. McInnis DP, Horne G, Devane PA. Femoral revision with a fluted, tapered, modular stem seventy patients followed for a mean of 3.9 years. J Arthroplasty. 2006;21(3):372-80.
16. Jang HG, Lee KJ, Min BW, Ye HU, Lim KH. Mid-term results of revision total hip arthroplasty using modular cementless femoral stems. Hip Pelvis. 2015;27(3):135-40.
17. Schuh A, Werber S, Holzwarth U, Zeiler G. Cementless modular hip revision arthroplasty using the MRP Titan Revision Stem: outcome of 79 hips after an average of 4 years' follow-up. Arch Orthop Trauma Surg. 2004;124(5):306-9.
18. Abdel MP, Cottino U, Larson DR, Hanssen AD, Lewallen DG, Berry DJ. Modular fluted tapered stems in aseptic revision total hip arthroplasty. J Bone Joint Surg Am. 2017;99(10):873-81.
19. Aslam-Pervez N, Riaz O, Gopal S, Hossain F. Predictors of intraoperative fractures during hemiarthroplasty for the treatment of fragility hip fractures. Clin Orthop Surg. 2018;10(1):14-9.
20. Lee SW, Kim WY, Song JH, Kim JH, Lee HH. Factors affecting periprosthetic bone loss after hip arthroplasty. Hip Pelvis. 2021;33(2):53-61.
21. Chandler H, Clark J, Murphy S, et al. Reconstruction of major segmental loss of the proximal femur in revision total hip arthroplasty. Clin Orthop Relat Res. 1994;(298):67-74.
22. Wirtz DC, Heller KD, Holzwarth U, et al. A modular femoral implant for uncemented stem revision in THR. Int Orthop. 2000;24(3):134-8.
23. Cameron HU. The long-term success of modular proximal fixation stems in revision total hip arthroplasty. J Arthroplasty. 2002;17(4 Suppl 1):138-41.
24. Tamvakopoulos GS, Servant CT, Clark G, Ivory JP. Medium-term follow-up series using a modular distal fixation prosthesis to address proximal femoral bone deficiency in revision total hip arthroplasty: a 5- to 9-year follow-up study. Hip Int. 2007;17(3):143-9.
25. Weiss RJ, Beckman MO, Enocson A, Schmalholz A, Stark A. Minimum 5-year follow-up of a cementless, modular, tapered stem in hip revision arthroplasty. J Arthroplasty. 2011;26(1):16-23.
26. Fink B, Urbansky K, Schuster P. Mid term results with the curved modular tapered, fluted titanium Revitan stem in revision hip replacement. Bone Joint J. 2014;96(7):889-95.
27. Hoberg M, Konrads C, Engelien J, et al. Outcome of a modular tapered uncemented titanium femoral stem in revision

hip arthroplasty. Int Orthop. 2015;39(9):1709-13.

28. Shah RR, Cipparrone NE, Parilla FW, Robinson MG, Gordon AC, Goldstein WM. Survivorship of the Modular Femoral Revision Stem. Orthopedics. 2019;42(5):294-8.
29. Dyreborg K, Petersen MM, Balle SS, Kjersgaard AG, Solgaard S. Observational study of a new modular femoral revision system. World J Orthop. 2020;11(3):167-76.
30. Zheng K, Li N, Zhang W, et al. Mid- to long-term outcomes of cementless modular, fluted, tapered stem for massive femoral bone loss in revision total hip arthroplasty. Orthop Surg. 2021;13(3):989-1000.