Original Article

Does Proximally Coated Single-Wedge Cementless Stem Work Well in Dorr Type C Femurs? Minimum 10-year Followup

Jung-Taek Kim, Hyung Jun Jeong[1], Soong Joon Lee[1], Hee Joong Kim[1,2], Jeong Joon Yoo[1]

Department of Orthopedic Surgery, Ajou University School of Medicine, Ajou Medical Center, Yeongtong-gu, Suwon-si, Gyeonggi-do, [1]Department of Orthopedic Surgery, Seoul National University College of Medicine, [2]Medical Research Center, Seoul National University College of Medicine, Jongno-gu, Seoul, Korea

Abstract

Background: Total hip arthroplasty (THA) with a proximally coated single-wedge (PSW) cementless stem had been generally considered not to be suitable for Dorr Type C femurs. This study compares the long term outcomes of PSW stem according to the type of proximal femoral geometry. **Materials and Methods:** 307 primary THAs in 247 patients were performed with PSW cementless stem and followed up for over 10 years in this retrospective study. According to Dorr's criteria, 89 femurs were classified as Type A, 156 as Type B, and 62 as Type C. They were followed up for an average of 13.2 years (range 10.0–17.3 years). All the hips were evaluated clinically and radiologically. **Results:** There was no significant difference in stem survivorship and clinical outcomes including the incidence of thigh pain and the mean postoperative Harris hip score (HHS) in all three groups. No significant differences were observed in osteolysis, pedestal formation, or cortical hypertrophy among the groups. Radiolucent lines <2 mm in thickness in Gruen zone 4 and 7 ($P = 0.003$ and $P = 0.044$, respectively), spot-weld ($P < 0.001$), and stress shielding ($P = 0.010$) of proximal femur were more pronounced in Dorr C type femora than in Type A or B. Fifty-six intraoperative fractures were identified among 307 hips with PSW stems. The incidence of intraoperative or postoperative femoral fractures was not significantly different among the groups. **Conclusions:** From over a 10-year followup, the PSW stem provided a recommendable option with satisfactory outcomes and excellent stem survivorship regardless of the Dorr type.

Keywords: *Arthroplasty, cementless, hip, proximal femur geometry, replacement*

Introduction

Clinical and radiological results of total hip arthroplasty (THA) using proximally coated single-wedge (PSW) cementless stems were generally excellent.[1-6] The geometry of cementless stems and the morphology of proximal femurs (Dorr types) provide optimal fit for primary stability and secondary biologic fixation.[7-9] As the geometry of PSW shape is designed to be engaged at the metaphysis,[10,11] cementless PSW stem had not been conventionally recommended for the Dorr Type C femurs with concerns of inadequate implant-host bone contact[7,12,13] and the risk of femoral fracture.[14]

Although cement fixation of femoral stem is also considered to be as a standard mode of fixation, the cementless femoral stem is gaining popularity for less difficulty of surgical technique, less cardiopulmonary complications, less blood loss, and less operative time compared with cemented stems.[13,15-18] Therefore, the recent trend of THA implant utilization has the surgeons preferring cementless stem, especially in North America or East Asia.[15,19] Nevertheless, with the Dorr Type C femur, many surgeons prefer cemented stems due to concerns about stability or femoral fractures.[12,14]

Previous studies on PSW cementless stems had rarely examined long term survivorship according to the Dorr types of femur.[6,20-22] Paucity of a long term comparative study makes it difficult to know whether the PSW stem plays a role in Dorr Type C femurs or not. We postulated that the PSW stem could achieve stable fixation without increased risk of femoral fracture even in Dorr Type C femurs, and demonstrate acceptable long term results. The aim of this study was to investigate differences of clinical and radiological outcomes of THA using PSW stem according to the proximal femoral geometry (Dorr types) in more than a 10-year followup. Therefore,

Address for correspondence:
Dr. Jeong Joon Yoo, Department of Orthopedic Surgery, Seoul National University College of Medicine, 103 Daehak-ro, Jongno-gu, Seoul 03080, Korea. E-mail: jjyos@snu.ac.kr

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we investigated: (1) Does the Dorr type have an effect on the long term stability of PSW stem? (2) Does the Dorr type affect radiological signs of bone remodeling with PSW stem after a long term followup? (3) Does the Dorr type influence incidence of periprosthetic fracture during or after THA surgery?

Materials and Methods

Material

The study was approved by the Institutional Review Board. 971 primary THAs were performed from 1997 to 2003 in our hospital., Among them, 125 hips were implanted with femoral stems other than PSW stem. Among remaining 846 hips, 307 hips were followed up over 10 years and included in this retrospective study [Figure 1]. During the same period, all THAs were performed with a single design PSW stem except for 125 hips where the deformity was excessive for a PSW stem or consideration of activity and life expectancy at the time of surgery negated use of ceramic-on-ceramic bearing designs. The patients' mean age was 43.2 years (range 18.4–69.6 years). A total of 100 patients were women and 147 patients were men. They were followed up for an average of 13.2 years (range 10.0–17.3 years).

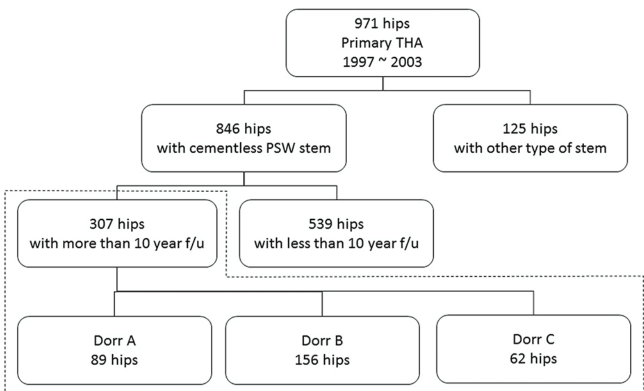

Figure 1: The dashed line indicates 307 hips with >10-year followup which was the population of interest in the present study. As a supplement for the rest of 539 hips with <10-year followup, the reoperation was assessed during the followup period

Of the patients, 193 hips (63%) were diagnosed with osteonecrosis of the femoral head, 33 (11%) were diagnosed with dysplasia, and 33 (11%) with infection sequelae. The remaining hips were cases of degenerative arthritis (19 hips, 6%), sequelae of Perthes disease (17 hips, 6%), rheumatoid disease (11 hips, 4%), and paralytic dislocation with residual poliomyelitis (1 hip, 0.3%).

Preoperative radiographs were assessed to determine the femoral bone type according to the Dorr's criteria.[7] Eighty-nine femurs (29%) were classified as Type A, 156 (51%) as Type B, and 62 (20%) as Type C. In Dorr C group, the patients' mean age was lower ($P = 0.001$), and more patients with rheumatic disease were included ($P < 0.001$), compared to Dorr A and B groups [Table 1]. As a supplement for the rest of 539 hips with <10-year followup, we assessed the duration of followup and survivorship information available in the medical records.

Implants

The design of the titanium alloy stem (Bicontact; AESCULAP AG and Co, Tuttlingen, Germany) was wedge-shaped only in the anteroposterior projection and flat in the lateral projection. The proximal one-third of the stem was coated with plasma-sprayed pure titanium (Plasmapore; AESCULAP AG and Co.,) [Figure 2]. Except for three hips implanted with a cementless porous acetabular cup (Trilogy; Zimmer Inc., Warsaw, IN, USA) and polyethylene liner (Trilogy; Zimmer Inc.), a hemispherical titanium cup (PLASMACUP SC, AESCULAP AG and Co.) with an

Table 1: Patient demographics for the three Dorr groups

Demographics	Dorr type			P
	A	B	C	
Number of hips	89	156	62	
Mean age at operation (years)	45.6 (20.4-64.8)	43.8 (19.0-67.7)	38.0 (18.4-69.6)	0.001$^{¥}$*
Gender (male:female) (number of hip)	49:40	100:56	35:27	0.315§
Mean followup period (years)	13.1 (10.0-17.3)	13.1 (10.2-16.9)	13.6 (10.0-17.0)	0.174$^{¥}$
Preoperative diagnosis (number of hips, percentages of each Dorr group)				
Osteonecrosis of the femoral head	60 (67%)	102 (65%)	31 (50%)	0.061§
Developmental dysplasia	9 (10%)	17 (11%)	7 (11%)	1.000§
Infection sequelae	11 (12%)	15 (10%)	7 (11%)	0.807§
Degenerative arthritis	7 (8%)	8 (5%)	4 (6%)	0.703‡
Perthes disease	2 (2%)	10 (6%)	5 (8%)	0.202‡
Rheumatoid arthritis	0 (0%)	3 (2%)	8 (13%)	<0.001‡*
Paralytic dislocation with residual poliomyelitis	0 (0%)	1 (0.6%)	0 (0%)	1.000‡

‡Fisher's exact test, §Chi-square test, $^{¥}$ANOVA test, *P<0.05 are considered statistically significant outer coating of plasmapore and an alumina acetabular insert (BIOLOX forte; CeramTec AG, Plochingen, Germany) were implanted. The 28-mm alumina femoral head (BIOLOX forte; CeramTec AG) was secured with a Morse taper in all THAs.

Operative procedure

The THA was performed by three experienced surgeons with the following approaches: an anterolateral approach in 13 hips, a lateral approach with a trochanteric osteotomy in 31 hips, a lateral approach without a trochanteric osteotomy in 12 hips, and a posterolateral approach in 251 hips. The various approach methods used were distributed evenly among the three Dorr types.

Postoperative care

Patients were instructed to walk with partial weight bearing with crutches for 6 weeks postoperatively. Followup visits were scheduled at 6 weeks, 3 months, 6 months, 12 months, and then yearly.

Clinical evaluation

Clinical assessment using the Harris hip score (HHS) was performed preoperatively and postoperatively.[23] Three experienced surgeons had evaluated the patients postoperatively at the out-patient department. By the principle of our medical center, all patients had been evaluated and recorded with regard to the thigh pain, which was defined as pain in the anterior or lateral thigh below the inguinal area.[24] If indicated, the spinal evaluation had been conducted to rule out the pain of spinal origin. For implant survivorship analysis, the criterion for failure was revision or impending revision of the femoral component for aseptic loosening. Intraoperative and postoperative complications were identified by review of medical records and radiographs.

Figure 2: Photograph showing the Bicontact hip stem with ceramic femoral head. The Bicontact femoral component is a straight, tapered, rectangular, collarless titanium alloy stem, the proximal one-third of which is coated with Plasmapore with a plasma-spray technique

Radiographic evaluation

We used the measurement function installed in our picture archiving and communication system (PACS; M-view, INFINITT, Seoul, Korea). The 6-week radiographs were considered to be the baseline for comparisons. Serial radiographs were examined with regard to implant subsidence, implant migration, osteolysis, pedestal, cortical hypertrophy, spot-weld, stress shielding, and radiolucent line [Figure 3].[25] Any changes to implant position over 3 mm or 3 degrees were noted as subsidence or migration in consideration of postural change or measurement error.[26] The subsidence was assessed with the use of a fixed point of reference on the stem and the lesser trochanter of femur according to the method of Teloken *et al*.[26] Periprosthetic cystic or scalloped lesions with a diameter over 2 mm that had not been present on the immediate postoperative radiograph were defined as periprosthetic osteolysis.[2] The presence of an intramedullary shelf of new bone was defined as a pedestal.[27] Any observed cortical hypertrophy and radiolucent lines were located on modified Gruen zones.[3,25,27-29] Spot-weld was defined as endosteal new bone contacting the porous surfaces.[27] Stress shielding was evaluated according to the system of Engh *et al*.[30] The status of biologic fixation of the femoral stem was assessed using the criteria of Engh *et al*.[27]

Statistical methods

Statistical analysis was performed using SPSS version 19.0 (IBM Corp., Armonk, NY, USA.). Chi-square test, Fisher's exact test, or the linear-by-linear test were performed to compare nominal variables among three groups. One-way analysis of variance test was used to compare continuous variables across three groups. Bonferroni method was used as *post hoc* analysis. To determine the significance of trend relationship of stress shielding across the Dorr groups, we used the Kendall's tau-c test. A value of $P < 0.05$ was considered statistically significant.

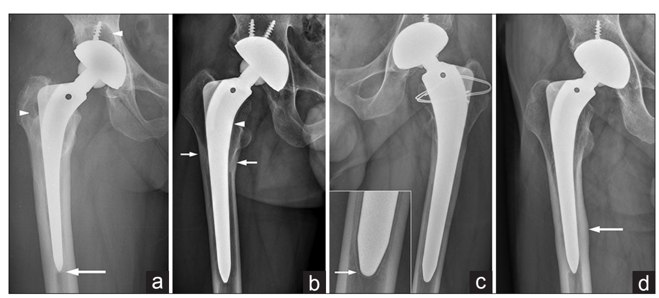

Figure 3: (a) Periprosthetic osteolysis at Gruen zone 1 and acetabular area (arrow head) and pedestal (arrow) were observed on Anteroposterior radiographs of hip of Dorr A group 8 years after primary total hip arthroplasty. (b) Endosteal new bone formation (spot-weld, arrow) was observed at metadiaphyseal junction of Dorr C femur with radiolucent line <2mm in thickness at Gruen zone 7 (arrow head), 11.4 years after primary total hip arthroplasty. (c) Radiolucent line <2mm in thickness (arrow) was observed at Gruen zone 4 of Dorr C femur 16.4 years after primary total hip arthroplasty (left bottom: magnified radiograph of Gruen zone 4). (d) Cortical hypertrophy (arrow) was observed at Gruen zone 5 of Dorr B femur 13.7 years after primary total hip arthroplasty

Results

Clinical results

The mean preoperative HHS for all patients was 50.4 ± 20.6 points (9–88), and the mean postoperative score at the last followup was 95.6 ± 9.0 points (50–100). The mean preoperative HHS was not significantly different (P = 0.187) and neither was the mean postoperative HHS (P = 0.898) among three Dorr groups. The perioperative improvement of HHS was significant in all three groups (P < 0.001 in all three groups).

Among 307 hips with over 10-year followup, two patients (two hips) who belonged to Dorr B group had mild thigh pain, but it did not limit activity. The prevalence of thigh pain among groups was not significantly different (P = 0.704). No implant had been revised or on impending revision. Implant survivorship at the last followup was 100% in all the Dorr groups [Table 2].

The 42% of the patients with <10-year followup visited our clinic over 5 years after index surgery and the mean followup period was 4.3 years. Among 539 hips, one stem (Dorr B) was revised for nonunion of intraoperative fracture at 2½ years after primary arthroplasty.

Radiologic results

No stem revealed subsidence over 3 mm or angular migration over 3 degrees. Periprosthetic osteolysis sized 15 mm × 27 mm at Gruen zone 1 was observed in a patient of Dorr A group with alumina on alumina bearing. The patient had undergone surgery for bone graft and liner change 8 years after the initial THA. The femoral stem was stable and not revised. After changing the ceramic liner to polyethylene liner, the patient was followed up for 8 more years without any signs of loosening.

Pedestal sign was observed at the distal tip of the stem in 80 hips (26%) without significant difference among Dorr groups (P = 0.323). Cortical hypertrophy was observed in 56 femurs (18%) without significant difference among Dorr groups (P = 0.196). Cortical hypertrophy was most frequently seen on Gruen zone 5 (87% of femurs with cortical hypertrophy). The zonal distribution of cortical hypertrophy was similar among Dorr groups. Fifty-two hips (17%) had a radiolucent line in Gruen zone 4 or 11 and 37 (12%) had one in Gruen zone 7. Such lines were not progressive or symptomatic or associated with features of a failed fixation.

None of the radiolucent lines measured over 2 mm in width. Significant linear association across the 3 groups were observed in spot-weld (P < 0.001), stress shielding around the femoral component (P = 0.010), and radiolucent lines around the distal tip of the femoral component (P = 0.003) and medial cortex of proximal femur (P = 0.044). In order of approximation to Dorr Type C, more spot-welds and radiolucent lines were observed. The higher grade of stress shielding was evaluated in order of approximation to Dorr Type C (Kendall's tau-c = 0.117). All hips had radiographic evidence of a bone-ingrown prosthesis, and none was loosened at the most recent followup [Table 2].

Complications

A femoral fracture occurred in 56 hips (18%) during stem implantation, and circumferential wiring was required in 51 hips. All of these intraoperative fractures healed without affecting the stability of stems. The occurrence of intraoperative fracture in each Dorr group was not significantly different (P = 0.550).

Table 2: Clinical and radiographic outcomes according to Dorr types

Clinical and radiographic outcomes	Dorr type			P
	A (%)	B (%)	C (%)	
Preoperative HHS†	55.7±20.5	50.0±19.4	43.2±22.9	0.187¥
Postoperative HHS†	95.6±10.6	95.1±9.4	96.5±4.2	0.898¥
Thigh pain (number of hip)‡	0	2	0	0.704‡
Implant survivorship (%)	100	100	100	
Migrated stem (number of hip)	0 (0 %)	0 (0 %)	0 (0 %)	
Osteolysis (number of hip)‡	1 (1 %)	0 (0 %)	0 (0 %)	0.492‡
Pedestal (number of hip)‡	19 (21 %)	41 (26 %)	20 (32 %)	0.323§
Cortical hypertrophy (number of hip)‡	16 (18 %)	24 (15 %)	16 (26 %)	0.196§
Radiolucent line >2 mm (number of hip)‡	0 (0 %)	0 (0 %)	0 (0 %)	
Radiolucent line <2 mm (number of hip)‡	16 (19 %)	41 (49 %)	26 (31 %)	0.002#*
Tip of stem (zone 4, 11)	7 (8 %)	29 (19 %)	16 (26 %)	0.003#*
Medial cortex of proximal femur (zone 7)	9 (10%)	14 (9%)	14 (22.6%)	0.044#*
Spot-weld (number of hip)‡	42 (47 %)	83 (53 %)	50 (81 %)	<0.001#*
Stress shielding (over grade 3, number of hip)‡	0 (0 %)	9 (6 %)	8 (13 %)	0.010K*
Intraoperative fracture (number of hip)‡	14 (16 %)	28 (18 %)	14 (23 %)	0.550§
Postoperative fracture (number of hip)‡	1 (1 %)	4 (3 %)	0 (0 %)	0.600‡

†Reported as number of hips and % of each group, ‡Fisher's exact test, §Chi-square test, #Linear by linear association test, ¥ANOVA test, KKendall's tau-c test, *P<0.05 are considered statistically significant. HHS=Harris hip score

Five patients had periprosthetic fractures after the index operation. One patient showed Vancouver Type B1 periprosthetic femoral fracture at 6 years postoperatively and was treated with three cerclage wires.[31] Four patients revealed stable fractures around great trochanter (Type A_G), which was treated without surgery. There was no significant difference in the incidence of postoperative periprosthetic fracture among three Dorr groups (P = 0.600). All the patients who had sustained periprosthetic fracture were treated successfully without revising stem, and none of the fractures affected survivorship of implant. Other complications such as fractures of ceramic bearing in 3 hips and dislocations in 3 hips were not related to Dorr types.

Discussion

The present study has shown that PSW stem achieved good clinical and radiological results with excellent survivorship in all three Dorr type femurs through a >10-year followup. In the study, we also noted the differences in radiographic findings among the three groups.

Khanuja *et al*. suggested the classification of cementless stem according to their geometries which determine where fixation is obtained and how much host bone is contacted.[10,11] Bicontact stem is classified as single wedge (Type 1) stem that obtains initial stability by engaging metaphyseal cortical bone. Although cementless stems have generally been considered unsuitable for Dorr Type C femurs, they have been tried on Dorr C femurs with excellent results in long term followups of more than 10-years[32-34] [Table 3]. For single wedge stem, McLaughlin and Lee compared the survivorship of Taperloc stem (Biomet, Warsaw, IN) in Dorr Type C femur to that in Dorr Type A and B femur after mean 16.6-year followup.[6] Nearly 98% of the stems in Type C femurs survived compared to 94% of them in Type A and B femurs. In this study, we could get another evidence to show that PSW stem works well in Type C femur over 10-year followup.

In general, patients with Dorr C bone are older.[7] However, the unusual finding of mean age difference across Dorr types in our cases was considered to be related to the distribution of causes of THAs. As the causes of THAs according to Dorr types were analyzed, both Dorr A and B groups had more patients with osteonecrosis of femoral head (ONFH) and Dorr C group had more patients with rheumatic disease [Table 1]. Contrary to western countries where degenerative arthritis is the primary cause of THA, around 60% of the causes of THAs in East Asia are ONFH, which often requires THA in 5^{th} or 6^{th} decades.[40] Similar to the epidemiologic study, the mean age of the study group was 43.2, and the oldest was only 69.6. Thus, the distribution of ONFH may affect the mean age of each group. Apart from the onset of the disease, the difference of activity level according to the disease would affect the proximal geometry of proximal femur. Although differences of activity level were not exactly reported on any studies with Dorr groups, activity level was known to affect bone mineral density after THA.[41] Developmental hip disease or hip disease which developed in youth makes the long standing deformities of hip joint and also the limitation of activities for a long time.[42]

Thigh pain is reportedly multifactorial.[43,44] As various factors, such as extent of the coating, stem size, modular mismatch, and time interval after surgery, had been suggested as the determinants of thigh pain, those results had been applied to the designs of modern cementless stems. Recent long term studies about thigh pain mostly reported <2% of incidence which is definitely lower than first generation cementless stem.[45] Whether the study is retrospective or prospective also can affect the incidence

Table 3: Results of hip arthroplasty studies according to Dorr classification

Author	Year	Stem	Stem type[10]	Number of hips (Dorr group A : B : C)	Followup period (year)	Stem survivorship (Dorr group A : B : C)
Hozack *et al*.[22]	1996	Taperloc	1	Not available (105)	6.1 (5-)	100%*
Keisu *et al*.[20]	2001	Taperloc	1	15 : 52 : 23	5 (2-11)	100% : 100% : 100%
Teloken *et al*.[26]	2002	Trilock	1	25 : 42 : 0	37 cases: 15 years, 12 cases: 10 years	95.5% at 15 years
Reitman *et al*.[34]	2003	Mallory-Head	3A	20 : 19 : 33	13.2 (10-)	100% : 100% : 100%
Incavo *et al*.[35]	2004	Secure-Fit	2	28 : 40 : 10	3.17 (2-5)	100% : 100% : 100%
Kelly *et al*.[32]	2007	Omnifit HA	2	0 : 0 : 13	11.5 (9-14)	100%
Nishino *et al*.[36]	2008	Synergy	2	3 : 27 : 7	5.8 (5-6.8)	100%*
Healey *et al*.[21]	2009	Trilock	1	144 : 136 : 110	4.7 (2.0-8.9)	99.8%*
Meding *et al*.[33]	2010	Bi-Metric	2	625 : 1569 : 127	5.9 (2-19.5)	100% : 99.4% : 100%
Dalury *et al*.[37]	2012	Summit	2	0 : 0 : 43	6 (4-9)	100%
Issa *et al*.[38]	2014	Omnifit HA	2	238 : 137 : 0	8 (3-11)	97.5% : 98%
Bonutti *et al*.[39]	2014	Secure-Fit	2	0 : 0 : 105	6 (2-11)	95%
McLaughlin and Lee[6]	2016	Taperloc	1	282 (A + B) : 59	N/A (A + B): 16.6 (C)	94% (A + B) : 98% (C)
The present study		Bicontact	1	89 : 156 : 62	13.2 (10-17.3)	100% : 100% : 100%

*Rates are not available according to Dorr types. N/A=Not avaliable of thigh pain.[46] As the current study has retrospectively evaluated thigh pain with PSW stem, it shows 0.6% of incidence which is similar to the recent retrospective studies.[45]

In the present study, significant trends across the 3 groups were observed in signs of bone remodeling including spot-weld, stress shielding, and radiolucent line around proximal femur and stem tip. Dorr *et al*. reported that remodeling in Dorr Type C femurs appeared delayed until 2 years after surgery and reached to the equal level of Dorr A and B types after 4 years postoperatively. However, as Engh and Bobyn had calculated the theoretic degree of stress shielding in the stem-implanted femur, decreased ratio of the outer diameter of the femur to the diameter of stem (i.e., femur with thin cortex and large stem) increases bending stiffness which results in increasing the degree of stress shielding in turn.[47] Our study and other clinical studies also support Engh and Bobyn's calculation with more pronounced remodeling in Dorr Type C femurs.[22,34,36,38]

A fracture of the femur during the final seating of the stem into the medullary canal occurred in 18% of the hips in this series. The high occurrence might be related to both the design of the stem and the composition of etiologic disease. High rates of femoral fracture are not uncommon in association with the Bicontact stems used in the present study. These high rates of fractures seem to be associated with the prosthetic design with two flanges anteroposteriorly and a lateral derotational wing.[2,48] Long standing changes in the anatomy which were resulted from developmental hip disease are known to make the femur more vulnerable to fracture during surgery.[42] In this study, developmental hip disease, such as dysplasia and Perthes' disease, was the etiology of THA in 17% of overall cases and 34% of cases which sustained intraoperative fracture. Thus, the Bicontact stem should be seated with caution when applied to the hip deformities with long standing changes.

Although the low incidence and cases of postoperative fractures made it difficult to generalize the observations, the postoperative periprosthetic fracture was not affected by Dorr types or affected the stability of stem in this study. Previously reported results also revealed that postoperative fractures are independent to preoperative femur type and do not compromise the survivorship of stem.[21,34]

Although this study provided clinically meaningful information, it had a few limitations. First, it was a retrospective review of case series. Thus, all the confounding factors could not be controlled and limited information was available on the medical records and radiographs. However, we see that over 300 femurs with over 10 years followup in this study had shown excellent results and it would provide enough significance to prove our conclusions. Second, as patients who were followed for over 10 years were included in this study, only survivors who were relatively young at the time of surgery could be selected. To supplement the limitation, we also reviewed the patients followed up <10 years and notified one stem revision caused by the nonunion of intraoperative fracture. Although a patient whose preoperative radiograph indicated B type femur of Dorr classification went through revision of stem, one case of stem revision did not indicate statistical difference among the types of the proximal femur. As the purpose of this study was to assess the long term results of PSW stem according to preoperative femoral morphology, the scope of the study was not affected by the study design. Third, the mean age of Dorr C group was lower than ones of the other groups. Fourth, the activity level of the patients was not assessed in the present study.

Conclusion

From over a 10-year followup, THA performed with PSW stems revealed satisfactory clinical and radiological outcomes with excellent stem survival regardless of Dorr types of the femur. Of note was that the remodeling process around the stem was more pronounced in Dorr Type C femur. The present study revealed that the PSW stem could be a viable option for Dorr Type C femur.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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