Scientific Research Publishing

Open Journal of Orthopedics, 2023, 13, 182-193
https://www.scirp.org/journal/ojo
ISSN Online: 2164-3016
ISSN Print: 2164-3008

A Radiographic Evaluation of Short Monolithic Femoral Hip Stem (SMF) for Dysplastic Osteoarthritis: Does Stem Alignment Influence on the Stability?

Kentaro Kaneko[1*], Hiroshi Sunami[2], Atsushi Oka[1], Koji Kanzaki[1], Akihiko Maeda[3], Mariko Asahi[2], Atsushi Kusaba[2], Saiji Kondo[2]

[1]Department of Orthopaedic Surgery, Showa University Fujigaoka Hospital, Yokohama, Japan
[2]Institute of Joint Replacement, Zama General Hospital, Zama, Japan
[3]Department of Orthopaedic Surgery, Showa University Yokohama Northern Hospital, Yokohama, Japan
Email: *ken.hokubu@gmail.com

How to cite this paper: Kaneko, K., Sunami, H., Oka, A., Kanzaki, K., Maeda, A., Asahi, M., Kusaba, A. and Kondo, S. (2023) A Radiographic Evaluation of Short Monolithic Femoral Hip Stem (SMF) for Dysplastic Osteoarthritis: Does Stem Alignment Influence on the Stability? *Open Journal of Orthopedics*, **13**, 182-193.
https://doi.org/10.4236/ojo.2023.134019

Received: March 26, 2023
Accepted: April 23, 2023
Published: April 26, 2023

Abstract

Background: There have been a few reports of SMF^{TM} stem for dysplastic hips. The aim of this study is to evaluate the influence of stem alignment in dysplastic femurs on the stability of the implants and on the bone reaction by means of consecutive radiographical analysis. **Methods:** The preoperative diagnosis is dysplastic osteoarthritis in all patients. Twenty-nine hips in 28 patients after MIS-THA were followed up for two or more years (3.5 years in average). The average age at the surgery was 60. Those who belonged to Crowe's classification I were 19 and those of II were 10 hips. The shape of the femur was classified as Dorr's Type A in 5, B in 21, and C in 3 hips. **Results:** The varus alignment of the stem was 21 hips and non-varus was 8 hips. Crowe's Grade did not have influence on the stem alignment. The ratio of non-varus alignment was more with Dorr's Type C than with others. Achieving rate of mediolateral fixation was significantly higher in the varus alignment than in non-varus. The significant subsidence occurred in 3 hips (10.3%) although all stems became stable within 6 months. No revision was necessary. **Conclusion:** The varus insertion of the stem seemed more secure also in dysplastic femurs, but even non-varus ones seemed acceptable as they brought about no severe problem. Comprehensively evaluating the result, careful selection of the patient is essential to take the advantage of and to overcome the disadvantage of this short stem for dysplastic hips.

Keywords

Total Hip Arthroplasty, Short Stem, MIS, Hip Dysplasia

1. Introduction

In Japan, which has the highest longevity in the world, the diagnosis that most often requires total hip arthroplasty (THA) is hip dysplasia [1]. Dysplastic patients are relatively young and have high activity [1] [2]. For such young and active patients, femoral bone preservation is an essential issue, considering the revision in the future [3] [4]. Recently many types of uncemented short stems have been designed to preserve the bone stock and at the same time to ease the insertion procedure in MIS-THA [4] [5]. Each type has different concept to obtain the initial and long-term stability in the femur [4] [5]. Short Monolithic Femoral hip stem (SMF™) (Smith & Nephew, Inc., Memphis, TN, USA) (**Figure 1**) is a short stem and was improved as a modification of SYNERGY Stem (Smith & Nephew, Inc.) [6]. SMF™ is a proximal fixation type stem and has double tapered shape in the medial-lateral and anterior-posterior planes to provide good proximal fit and fixation [7]. Because of the shape and structural property, the recommended alignment of SMF™ is varus at least for primary osteoarthritis [7]. Dysplastic hips often have dysplastic femurs [8]. Therefore, a question comes if the recommended alignment above is also true in the dysplastic hips. We evaluated the influence of the SMF™ stem alignment on the stability in the dysplastic hips.

2. Methodology

We evaluated 29 hips in 28 dysplastic patients (5 males and 24 females) after THA using SMF™ stems through 2 or more years follow-up. The average age at the surgery was 60 years old (39 to 80). The follow-up period was 2 to 6 years (3.5 years in average). The body weight ranged 41.1 to 91.0 kg and was 58.8 kg in average at the surgery. The average body mass index (BMI) was 23.2 (17.2 - 31.9). Those who belonged to Crowe's classification I were 19 and those of II

(A) (B)

Figure 1. Short monolithic femoral hip stem (SMF). (A) anterior-posterior view; (B) superior-inferior view.

were 10 hips [9]. The shape of the femur was classified as Dorr's Type A in 5, B in 21, and C in 3 hips [10]. All patients started full weight bearing gait from within the day of surgery or next day.

Stem alignment was determined by Kramhøft's classification and mode of stem fixation by Nakata's and Luger's [11] [12] [13]. We evaluated the stem subsidence, stress shielding, radiolucent lines, spotwelds (cancellous condensation), stress shielding, and cortical hypertrophy on the consecutive radiographs [14] [15] [16]. The locations of the radiographic findings are described along Gruen's zone definition [17]. All the THA were performed through an anterolateral MIS procedure [1]. Neither navigation system nor image intensifier was used. Combined cups were R3 Cup (Smith & Nephew, Inc.) in all hips [1]. The length of SMF™ is about 20% shorter than that of other primary stems to preserve the bone stock [18]. SMF™ stem has a circumferential STIKTITE porous coating (three-dimensional porous structure made of sintered titanium powder, 60% of porous rate) to obtain early bone in-growth in the most proximal part, circumferential grid blasting for bone on-growth in the middle, and satin finish in the distal part (**Figure 1**) [18] [19]. All stems in this study are mono-block. Preoperative plannings were performed manually on two dimensional images in all patients.

Although the number of subjects was small, statistical analyses were carried out using unpaired Student's t-test, the Chi square test, Pearson's correlation coefficient test, and Fisher's Z transformation. Significant differences were reported at $p < 0.05$ in all statistical analyses.

3. Results

The alignment of the stem was varus (on anteroposterior view)-flexion (on lateral view) in 15 (57.7%) (**Figure 2**), neutral-flexion in 7 (24.1%), varus-neutral in 6 (20.7%), and neutral-neutral in 1 hip (3.4%) (**Figure 3**). Crowe's Grade did not have influence on the stem alignment (**Table 1**). The ratio of non-varus alignment (*i.e.*, neutral in anterolateral view) was more with Dorr's Type C than with others ($t = 4.209$, $p = 0.122$) (**Table 1**). The mode of fixation was mediolateral fit in 23 (79.3%) and multi-point in 6 hips (20.7%). Achieving rate of mediolateral fixation was significantly higher in the varus stems (all hips) than in non-varus ones (2 hips) ($t = 14.312$, $p = 0.000$). The significant subsidence (**Table 2**) occurred in 3 hips (10.3%) although all stems became stable within 6 months. The average depth of subsidence was 0.8 (0 - 4.5) mm. Significant correlations were not observed between the body weight and the depth ($r = 0.136$, $p = 0.475$), nor between BMI and the depth ($r = 0.222$, $p = 0.246$). The depth was significantly lower in the varus stems than in non-varus ones ($t = 1.768$, $p = 0.044$) (**Table 2**). The average depth was 0.7 in mediolateral fixation and 1.5 mm in the multi point fixation ($t = 1.437$, $p = 0.081$). Stress shielding was observed in 23 (79.3%) hips. More prevalence of stress shielding was observed in non-varus alignment ($t = 10.07$, $p = 0.007$) (**Table 3**). Radiographic reactions such as spotwelds or cortical hypertrophy were mainly observed at the portion where the stem contacted

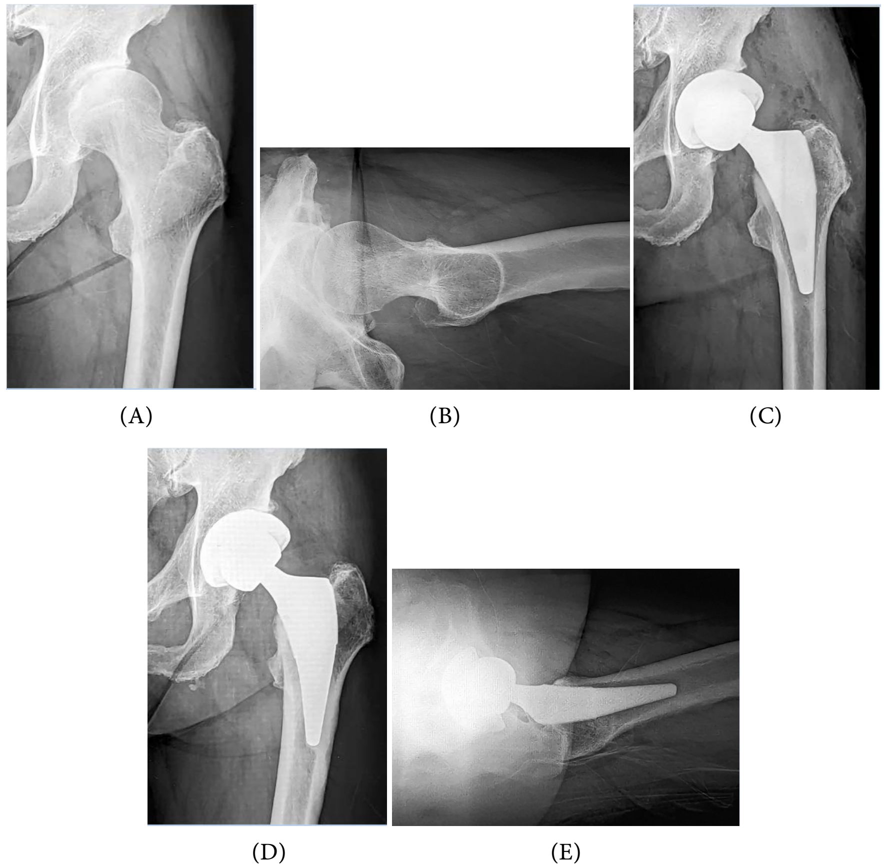


Figure 2. Varus-flexion alignment (68-year-old male). (A) Preoperative anteroposterior XP; (B) Preoperative lateral XP; (C) Just after THA anteroposterior XP; (D) 4.2 years after THA anteroposterior XP—no subsidence, no stress shielding, no radiolucent line, Spot-welds at zone 3 and 4, and cortical hypertrophy at zone 3 were observed; (E) 4.2 years after THA lateral XP.

Table 1. Stem alignment [11] vs. femoral shape.

Stem alignment	**Varus-flexion N = 15** ***AP varus N = 21***	**Varus-neutral N = 6**	**Neutral-flexion N = 7** ***AP neutral N = 8***	**Neutral-neutral N = 1**
Crowe's Grade [9]				
I	11 (52%)	4 (67%)	4 (50%)	0 (%)
II	4 (19%)	2 (33%)	3 (38%)	1 (%)
I	*15 (71%)**		*4 (50%)**	
II	*6 (%)*		*4 (50%)*	
Dorr's Classification [10]				
A	3/15 (20%)	2/6 (33%)	0/7 (0%)	0/1 (0%)
B	11/15 (73%)	4/6 (67%)	6/7 (86%)	0/1 (0%)
C	1/15 (7%)	0/6 (0%)	1/7 (14%)	1/1 (100%)
A	*5/21 (24%)†*		*0/8 (0%)†*	
B	*15/21 (71%)*		*6/8 (75%)*	
C	*1/21 (5%)*		*2/8 (25%)*	

*: t = 0.420, p = 0.517 †: 2.971, p = 0.226.

Table 2. Stem alignment vs. subsidence [16].

Stem alignment	Varus-flexion N = 15 *AP varus N = 21*	Varus-neutral N = 6	Neutral-flexion N = 7 *AP neutral N = 8*	Neutral-neutral N = 1
Stem subsidence	0/15 (0%) *1/21 (5%)*	1/6 (17%)	1/7 (14%) *2/8 (25%)*	1/1(100%)
Subsidence depth (mm)	0.3 (0 - 2.0) *0.6 (0 - 4.5)*‡	0.9 (0 - 4.5)	1.3 (0 - 4) *1.5 (0 - 4)*‡	3

‡: t = 1.065, p = 0.044.

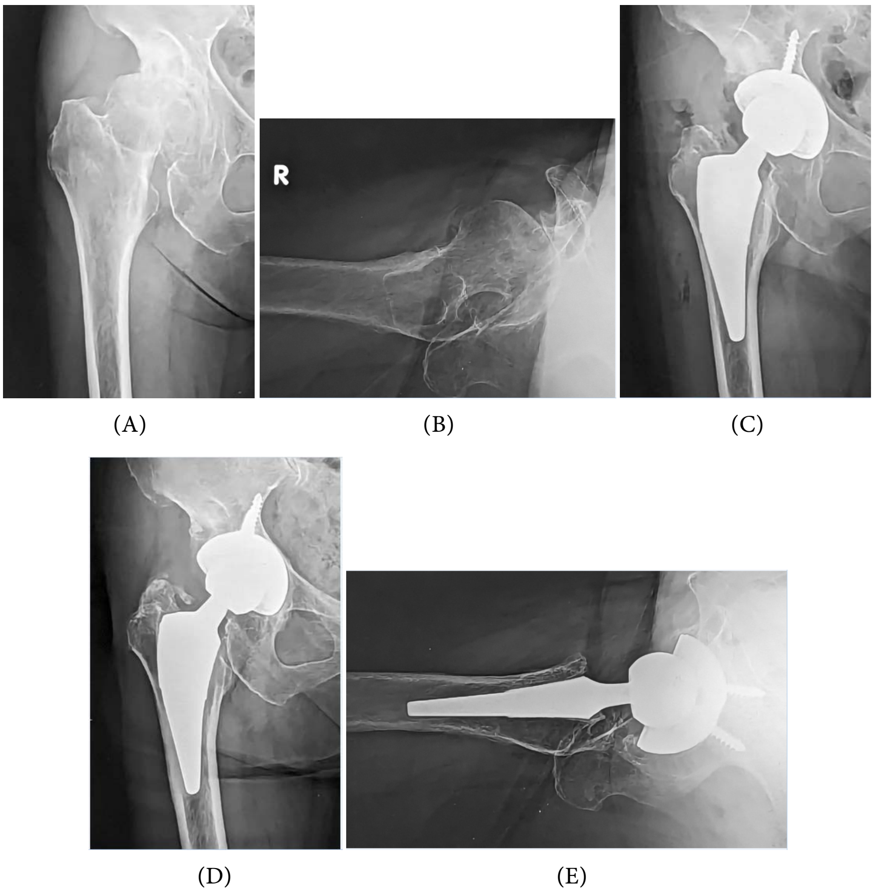


Figure 3. Neutral-neutral alignment (69-year-old female). (A) Preoperative anteroposterior XP; (B) Preoperative lateral XP, Excessive ante-torsion of the neck; (C) Just after THA anteroposterior XP; (D) 2.0 years after THA anteroposterior XP, 3 mm's subsidence, stress shielding of Grade x at zone 2, no radiolucent line at 4 and 7, Spotwelds at zone 2 and 3, and cortical hypertrophy at zone 2 and 3 were observed; (E) 2.0 years after THA lateral XP.

to the lateral cortex (**Table 4-6**). All radiological findings brought about no negative clinical symptoms. Neither intraoperative fracture nor postoperative dislocation occurred. No revision was necessary for all patients.

4. Discussion

As the limitation of this study, number of the patients are small and follow-up

Table 3. Stem alignment vs. stress shielding [14].

Stem alignment	Varus-flexion N = 15 *AP varus N = 21**	Varus-neutral N = 6	Neutral-flexion N = 7 *AP neutral N = 8**	Neutral-neutral N = 1
Stress shielding				
Grade 0	6	0	1	0
1	9	3	1	0
2	0	3	5	1
Grade 0	*6*§		*1*§	
1	*12*		*1*	
2	*3*		*6*	

§: t = 10.07, p = 0.007.

Table 4. Stem alignment vs. cortical hypertrophy [15].

Stem alignment	Varus-flexion N = 15 *AP varus N = 21*	Varus-neutral N = 6	Neutral-flexion N = 7 *AP neutral N = 8*	Neutral-neutral N = 1
Zone 1, 2	0 (0%), 3 (20%)	0 (0%), 1 (17%)	0, 2 (29%)	0 (0%), 1 (100%)
3, 4	9 (60%), 0 (0%)	0 (0%), 0 (0%)	6 (86%), 0 (0%)	1 (100%), 0 (0%)
5, 6	0 (0%), 0 (0%)	1 (17%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
7, 8	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
9, 10	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
11, 12	0 (0%), 2 (13%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
13, 14	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
Zone 1, 2	*0 (0%), 4 (19%)*		*0 (0%), 2 (38%)*	
3, 4	*9 (43%), 0 (0%)*		*7 (100%), 0 (0%)*	
5, 6	*1 (5%), 0 (0%)*		*0 (0%), 0 (0%)*	
7, 8	*0 (0%), 0 (0%)*		*0 (0%), 0 (0%)*	
9,10	*0 (0%), 0 (0%)*		*0 (0%), 0 (0%)*	
11, 12	*0 (0%), 2 (10%)*		*0 (0%), 0 (0%)*	
13, 14	*0 (0%), 0 (0%)*		*0 (0%), 0 (0%)*	

Table 5. Stem alignment vs. radiolucent line [15].

Stem alignment	Varus-flexion N = 15 *AP varus N = 21*	Varus-neutral N = 6	Neutral-flexion N = 7 *AP neutral N = 8*	Neutral-neutral N = 1
Zone 1, 2	0 (0%), 1 (7%)	0 (0%), 0 (0%)	1 (14%), 0 (0%)	0 (0%), 0 (0%)
3, 4	0 (0%), 8 (53%)	0 (0%), 0 (0%)	3 (43%), 5 (71%)	0 (0%), 1 (100%)
5, 6	2 (13%), 0 (0%)	0 (0%), 0 (0%)	4 (57%), 1 (14%)	0 (0%), 0 (0%)
7, 8	1 (7%), 1 (7%)	0 (0%), 1 (17%)	2 (29%), 1 (14%)	1 (100%), 0 (0%)
9, 10	0 (0%), 1 (7%)	0 (0%), 0 (0%)	0 (0%), 3 (43%)	0 (0%), 1 (100%)
11, 12	0 (0%), 1 (7%)	0 (0%), 0 (0%)	2 (29%), 1 (14%)	1 (100%), 1 (100%)
13, 14	0 (0%), 1 (7%)	0 (0%), 0 (0%)	1 (14%), 0 (0%)	0 (0%), 0 (0%)
Zone 1, 2	*0 (0%), 1 (5%)*		*1 (13%), 0 (0%)*	
3, 4	*0 (0%), 8 (38%)*		*3 (38%), 6 (75%)*	
5, 6	*2 (10%), 0 (0%)*		*4 (50%), 1 (13%)*	
7, 8	*1 (5%), 1 (5%)*		*3 (38%), 1 (13%)*	
9, 10	*0 (0%), 1 (5%)*		*0 (0%), 4 (50%)*	
11, 12	*0 (0%), 1 (5%)*		*3 (38%), 2 (25%)*	
13, 14	*0 (0%), 1 (5%)*		*1 (13%), 0 (0%)*	

Table 6. Stem alignment vs. Spotwelds [15].

Stem alignment	Varus-flexion N = 15 *AP varus N = 21*	Varus-neutral N = 6	Neutral-flexion N = 7 *AP neutral N = 8*	Neutral-neutral N = 1
Zone 1, 2	0, 1 (5%),	0 (0%), 0 (0%)	0 (0%), 1 (14%)	0 (0%), 0 (0%)
3, 4	0, 8 (53%)	5 (83%), 4 (67%)	4 (57%), 1 (14%)	0 (0%), 1 (100%)
5, 6	2 (13%), 0 (0%)	4 (67%), 3 (50%)	0 (0%), 0 (0%)	0 (0%), 0 (0%)
7, 8	1 (5%), 1 (7%)	0 (0%), 0 (0%)	0 (13%), 1 (14%)	1 (100%), 0 (0%)
9, 10	0 (0%), 7 (47%)	0 (0%), 0 (0%)	0 (0%), 3 (43%)	0 (0%), 1 (100%),
11, 12	0 (0%), 1 (5%)	0 (0%), 3 (50%)	2 (29%), 1 (14%)	1 (100%), 1 (100%)
13, 14	0 (0%), 1 (5%)	0 (0%), 0 (0%)	0 (0%), 1 (14%)	0 (0%), 0 (0%)
Zone 1, 2	*0 (0%), 1 (5%)*		*0 (0%), 1 (13%)*	
3, 4	*5 (24%), 12 (57%)*		*4 (50%), 2 (25%)*	
5, 6	*6 (29%), 0 (0%)*		*0 (0%), 0 (0%)*	
7, 8	*1 (5%), 1 (5%)*		*1 (13%), 1 (13%)*	
9 ,10	*0 (0%), 7 (33%)*		*0 (0%), 4 (50%)*	
11, 12	*0 (0%), 4 (19%)*		*3 (38%), 2 (25%)*	
13, 14	*0 (0%), 1 (5%)*		*0 (0%), 1 (13%)*	

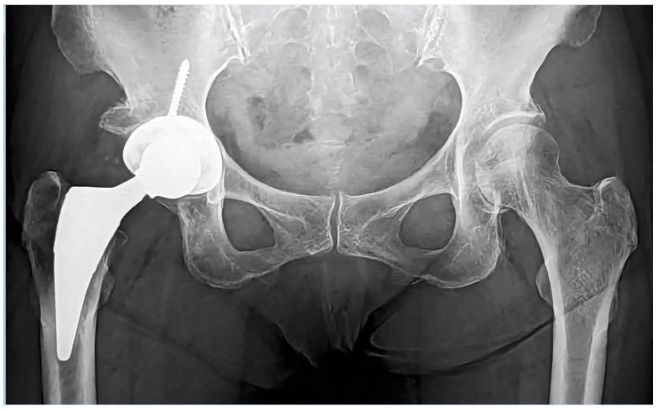
term provides only for short term evaluation, while mid- or long-term result of this stem is relatively few in the database, this study can be evaluated as the report for dysplastic hips [6] [7] [20]. SMF™ stem is a proximal fixation type as its proximal surface structure to aim at bone affinity indicates [6] [7]. As shown in our result, relatively high prevalence of distal radiolucent line was observed. This line seemed to be brought about by the successful proximal fixation [6] [7]. At the same time, as far as the alignment was varus, good proximal fixation and proper stress distribution seemed to be provided in SMF™ stem, because the prevalence of stress shielding was significantly lower in varus than in non-varus alignment.

Because of recent spread of MIS procedure, the usage of short stems has been increasing in THA [4]. Short stems seem to allow preservation of bone stock, with decreased stress shielding and also a lower incidence of thigh pain, compared with conventional stems [21]. On the other hand, a concern in short stems exists, such as more frequent risk of subsidence or radiologic reactions than those of conventional uncemented stems [22]. Subsidence of uncemented stems can be generally accepted within the first three months, but after that osseointegration and stability should have occurred [23]. In our case, 2 out of 29 hips showed 3 mm or more subsidence though they became stable and no aggravation occurred after that. In both of these two hips, the stems were multi-point fit as the result of undersizing of the stem. On the other hand, some other stems were inserted in non-varus alignment to avoid the "undersizing". We could not judge which was the better, "undersizing" or "non-varus alignment" in this study, though both of them should be avoided of course, if possible.

Dysplastic hips are often accompanied by coxa valgus as the result of subdislocation [24] [25]. We concerned offset when varus insertion. In addition, when the stem is inserted deeper than expected, a longer head (for mono-block stems) can be generally adapted to compensate the leg length. However, such compensation emphasizes the excessive offset with varus insertion (**Figure 4**). Fortunately, we had no problem of the offset in this study.

This type of stem should be inserted along the femoral neck axis [4]. Thus, reserving the calcar ring (as the guide of insertion) enables the varus insertion and the dispersion of excessive valgus load. When the neck preservation is insufficient, the stem will be inserted into neutral alignment along the metaphyseal cortex and the lateral cortex cannot resist the valgus load. In dysplastic hips, shortening and/or and hypoplasia of the femoral neck is often observed [8] [24]. Such cervical bony shape may have contributed to our result. In addition, preserving enough neck length often disturbs the surgical procedure in the shallow, narrow, and small bony acetabulum against the contracture and/or shortening of the leg length due to sub-dislocation in dysplastic hips [8] [24]. The inferior portion (and also posterior one in anterior approaches) of the acetabulum is often

(A)



(b)

Figure 4. Excessive offset (80-year-old female). (A) Before the surgery the femur showed coxa valga. (B) The stem was inserted in a varus alignment and also into the canal deeper the expected. An extra-long head was adapted to compensate the leg length and resulted in much more offset than the contralateral hip while the patient did not complain of the rotator muscles irritation or the internal rotation disturbance due to the excessive offset (6 years after THA).

hidden by the medial part of the neck when the osteotomy is performed just below the capital. This may disturb the procedure to set the cup in the anatomical (*i.e.*, lower and more medial than the sub-dislocated alignment) in dysplastic acetabulum [8]. In dysplastic hips, we often encounter the excessive anterior-torsion of the neck (**Figure 3(B)**) [24]. This deformity, when the enough neck length is preserved, increases the difficulty in accessing to the acetabulum and also complicates the insertion of rasps or stem into the twisted femoral canal (although SMF™ has the configurational advantage of more easiness to slip through the twisted neck until the proper fit than other short stems) [6] [7]. Thus, we are often in a dilemma to decide the priority between "enough resection of the neck to secure the access to the acetabulum" and "preserving the neck", especially in MIS-THA for dysplastic hips [24]. Recent trend in MIS-THA is to preserve maximally the ligaments around the hip and the preserved remaining soft tissue tension makes the dilemma more serious [26]. On the other hand, it was also true that even stems inserted in non-varus alignment or even stems showed early subsidence finally became stable and required no revision. In other words, SMF is a stem that has a potential to accept the non-varus insertion, at least in dysplastic hips.

As an additional concern, the surface finish and the anteroposterior bulkiness of the stem may give more difficulty at the time of stem removal and more bone damage in the proximal femur would be considered at the future revision THA with SMF™ than with other straight even-surface stems (*e.g.*, SL PLUS™ stem), while the preservation of proximal cortex in diaphysis is much attractive nonetheless [7] [27].

5. Conclusion

The varus insertion of the stem seemed more secure also in dysplastic femurs, but even non-varus was acceptable as it brought about no severe problem. Comprehensively evaluating the result, careful selection of the patients is essential to take the advantage of and to overcome the disadvantage of SMF™ for dysplastic hips.

Conflicts of Interest

The study was performed in accordance with the Declaration of Helsinki. No benefit in any form has been received or will be received from a commercial party related directly or indirectly to the subject of this study. No funds have been received or will be received in support of this study.

Acknowledgements

The authors respectfully dedicate this work to our late colleague, Prof. Yoshikatsu Kuroki.

References

[1] Kusaba, A., Asahi, M., Hirano, M., Sunami, H. and Kondo, S. (2020) Ceramic on

Ceramic Bearings for Dysplastic Hips: Analysis of Uncemented 2,861 THAs. *Journal of Long-Term Effects of Medical Implants*, **30**, 275-282. https://doi.org/10.1615/JLongTermEffMedImplants.2020036091

[2] Kusaba, A. (2009) Uncemented Ceramic on Ceramic Bearing for Dysplastic Hips. In: Cobb, J.P., Ed., *Modern Trends in THA Bearings—Material and Clinical Performance*, Springer Medizin/Dietrich Steinkoppf Verlag, Darmstadt, 213-219.

[3] Malahias, M.A., Tejaswi, P., Chytas, D., Kadu, V., Karanikas, D. and Thorey, F. (2021) The Clinical Outcome of the Metha Short Hip Stem: A Systematic Scoping Review. *HIP International*, **31**, 24-33. https://doi.org/10.1177/1120700020903719

[4] Munakata, Y., Kuramitsu, Y., Usui, Y. and Okazaki, K. (2021) Comparison of Radiographic Changes in Rectangular Curved Short Stem with Thin Versus Thick Porous Coating for Cementless Total Hip Arthroplasty: A Retrospective Study with a Propensity Score Matching. *Journal of Orthopaedic Surgery and Research*, **13**, 247. https://doi.org/10.1186/s13018-021-02397-3

[5] Falez, F., Casella, F. and Papalia, M. (2015) Current Concepts, Classification, and Results in Short Stem Hip Arthroplasty. *Orthopedics*, **38**, S6-S13. https://doi.org/10.3928/01477447-20150215-50

[6] Freeman, M.H., Kildow, B.J., Larson, T.J., Bailey, Z.C., Lyden, E.R. and Garvin, K.L. (2021) Ten-Year Survivorship and Risk of Periprosthetic Fracture of a Cementless Tapered Stem. *Orthopedic Clinics of North America*, **52**, 317-321. https://doi.org/10.1016/j.ocl.2021.05.005

[7] Bostian, P.A., Grisez, B.T., Klein, A.E. and Frye, B.M. (2021) Complex Primary Total Hip Arthroplasty: Small Stems for Big Challenges. *Arthroplasty Today*, **23**, 150-156. https://doi.org/10.1016/j.artd.2021.02.016

[8] Kusaba, A., Sunami, H., Kondo, S. and Kuroki, Y. (2011) Uncemented Ceramic on Ceramic Bearing Couple for Dysplastic Osteoarthritis. *Seminars in Arthroplasty*, **22**, 240-247. https://doi.org/10.1053/j.sart.2011.09.005

[9] Crowe, J.F., Mani, V.J. and Ranawat, C.S. (1979) Total Hip Replacement in Congenital Dislocation and Dysplasia of the Hip. *The Journal of Bone and Joint Surgery. American Volume*, **61**, 15-23. https://doi.org/10.2106/00004623-197961010-00004

[10] Dorr, L.D., Faugere, M.C., Mackel, A.M., Gruen, T.A., Bognar, B. and Malluche, H.H. (1993) Structural and Cellular Assessment of Bone Quality of Proximal Femur. *Bone*, **14**, 231-242. https://doi.org/10.1016/8756-3282(93)90146-2

[11] Kramhøft, M., Gehrchen, P.M., Bødtker, S., Wagner, A. and Jensen, F. (1996) Inter- and Intraobserver Study of Radiographic Assessment of Cemented Total Hip Arthroplasties. *The Journal of Arthroplasty*, **11**, 272-276. https://doi.org/10.1016/S0883-5403(96)80077-5

[12] Nakata, K. (2010) Primary Stability of Tapered Wedge-Shaped Cementless Stems in Patients with Stove Pipe Canal and Type C Bone: Biomechanical Estimation of Primary Micromotion. *Japanese Journal of Joint Diseases*, **29**, 485-494. (In Japanese)

[13] Luger, M., Feldler, S., Klasan, A., Gotterbarm, T. and Schopper, C. (2021) The Morphology of the Proximal Femur in Cementless Short-Stem Total Hip Arthroplasty: No Negative Effect on Offset Reconstruction, Leg Length Difference and Implant Positioning. *Journal of Orthopaedic Surgery and Research*, **20**, 730. https://doi.org/10.1186/s13018-021-02876-7

[14] Engh, C.A., Bobyn, J.D. and Glassman, A.H. (1987) Porous-Coated Hip Replacement. The Factors Governing Bone Ingrowth, Stress Shielding, and Clinical Results. *The Journal of Bone and Joint Surgery. British Volume*, **69**, 45-55. https://doi.org/10.1302/0301-620X.69B1.3818732

[15] Engh, C.A. and Bobyn, J.D. (1988) The Influence of Stem Size and Extent of Porous Coating on Femoral Bone Resorption after Primary Cementless Hip Arthroplasty. *Clinical Orthopaedics and Related Research*, **231**, 7-28. https://doi.org/10.1097/00003086-198806000-00002

[16] Engh, C.A., Massin, P. and Suthers, K.E. (1990) Roentgenographic Assessment of the Biologic Fixation of Porous-Surfaced Femoral Components. *Clinical Orthopaedics and Related Research*, **257**, 107-128. https://doi.org/10.1097/00003086-199008000-00022

[17] Gruen, T.A., McNeice, G.M. and Amstutz, H.C. (1979) "Modes of Failure" of Cemented Stem-Type Femoral Components: A Radiographic Analysis of Loosening. *Clinical Orthopaedics and Related Research*, **141**, 17-27. https://doi.org/10.1097/00003086-197906000-00002

[18] McCalden, R.W., Korczak, A., Somerville, L., Yuan, X. and Naudie, D.D. (2015) A Randomised Trial Comparing a Short and a Standard-Length Metaphyseal Engaging Cementless Femoral Stem Using Radiostereometric Analysis. *The Bone & Joint Journal*, **97**, 595-602. https://doi.org/10.1302/0301-620X.97B5.34994

[19] Naudie, D.D., Somerville, L., Korczak, A., Yuan, X., McCalden, R.W., Holdsworth, D. and Bourne, R.B. (2013) A Randomized Trial Comparing Acetabular Component Fixation of Two Porous Ingrowth Surfaces Using RSA. *The Journal of Arthroplasty*, **28**, 48-52. https://doi.org/10.1016/j.arth.2013.06.041

[20] Miyake, Y., Nanba, Y., Umebara, K., Kawamoto, T., Furuichi, S. and Mitani, S. (2019) Postoperative Stem Alignment and Bony Reaction of Short Stem (SMF). *Hip Joint*, **45**, 392-396. (In Japanese) https://doi.org/10.1007/s00590-021-03017-w

[21] Sousa, A., Vale, J., Diniz, S., Neves, P., Ramos, J. and Coelho, R. (2022) Comparison of Short-Stem versus Conventional Stem for Hip Arthroplasty in Patients Younger than 60 Years: 7-14 Years Follow-Up. *European Journal of Orthopaedic Surgery & Traumatology*, **32**, 693-700. https://link.springer.com/article/10.1007/s00590-021-03017-w

[22] Suksathien, Y., Chuvanichanon, P., Tippimanchai, T. and Sueajui, J. (2022) Insufficient Lateral Stem Contact Is an Influencing Factor for Significant Subsidence in Cementless Short Stem Total Hip Arthroplasty. *World Journal of Orthopedics*, **18**, 444-453. https://www.wjgnet.com/2218-5836/full/v13/i5/444.htm

[23] Dyreborg, K. andersen, M.R., Winther, N., Solgaard, S., Flivik, G. and Petersen, M.M. (2020) Migration of the Uncemented Echo Bi-Metric and Bi-Metric THA Stems: A Randomized Controlled RSA Study Involving 62 Patients with 24-Month Follow-Up. *Acta Orthopaedica*, **91**, 693-698. https://doi.org/10.1080/17453674.2020.1802682

[24] Takaoka, K., Sakamaki, T. and Yanagimoto, S. (1998) The Asian Hip. In: Callaghan, J.J., Rosenburg, A.G. and Rubash, H.E., Eds., *The Adult Hip*, Lippincott-Raven, Philadelphia, 1105-1124.

[25] Morishita, M. (1989) A Roentogenographical Study on the Alignment of the Lower Extremities in Secondary Coxarthrosis. *The Journal of the Japanese Orthopaedic Association* (*Nihon Seikeigeka Gakkai Zasshi*), **63**, 1047-1059. (In Japanese)

[26] Fujita, M., Hayashi, S., Kamenaga, T., Fujishiro, T., Matsumoto, T. and Kuroda, R. (2022) Ligament Preserving Total Hip Arthroplasty Prevents Different Leg Length and Femoral Offset. *Acta Ortopédica Brasileira*, **6**, e242758. https://doi.org/10.1590/1413-785220223001e242758

[27] Inacio, M.C., Lorimer, M., Davidson, D.C., De Steiger, R.N., Lewis, P.L. and Graves, S.E. (2018) What Is the Risk of Revision Surgery in Hydroxyapatite-Coated Femoral

Hip Stems? Findings from a Large National Registry. *Clinical Orthopaedics and Related Research*, **476**, 2353-2366. https://doi.org/10.1097/CORR.0000000000000513