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Long-term clinical comparison of three different femoral stems in Total Hip Arthroplasty with femoral shortening in patients with high-riding hips

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Abstract

Background Developmental hip dysplasia is a common cause of hip arthrosis in young adults, necessitating total hip arthroplasty (THA) for improved function and pain relief. In cases of high-riding hips, transverse femoral shortening osteotomy is often required to facilitate reduction and prevent neurovascular complications. However, the choice of femoral stem in such cases remains controversial due to variations in design and osteoconductive properties. This study aimed to compare the clinical and radiological outcomes of three different femoral stems used in THA with transverse femoral shortening osteotomy.

Methods A retrospective cohort study was conducted on 107 patients who underwent THA with transverse femoral shortening osteotomy between 2004 and 2014. Patients were divided into three groups based on the femoral stem used: Group 1 (Summit Tapered Stem (Depuy®) ($n = 39$), Group 2 (SL-PLUS Rectangular Stem (Smith & Nephew®) ($n = 31$), and Group 3 (Wagner Cone Prosthesis (Zimmer®) ($n = 37$). Clinical outcomes were assessed using the Harris Hip Score (HHS), and radiological evaluations included osteointegration and union rates. One-way ANOVA was used to compare continuous variables among groups, and post-hoc Tukey's HSD test was applied for pairwise comparisons. Kaplan-Meier survival analysis was performed to evaluate implant survivorship.

Results The mean preoperative HHS significantly improved from 42.7 ± 6.7 to 84.6 ± 11.5 postoperatively ($p < 0.001$). Group 3 had significantly higher final HHS compared to Group 1 ($p = 0.0002$), while no significant differences were observed between Group 1 and Group 2 ($p = 0.1947$) or Group 2 and Group 3 ($p = 0.0723$). The overall 10-year survival rate was 87.8%, with Group 3 demonstrating the highest survivorship (91%) and Group 2 the lowest (83%). Intraoperative femoral fissure or fracture rates were significantly higher in Group 1 compared to Group 3 ($p = 0.0006$), and with a significantly increased need for additional plating in Group 1 ($p = 0.0031$).

Conclusions This study suggests that cylindrical fully porous-coated femoral stems (Wagner Cone Prosthesis) provide better clinical outcomes, fewer intraoperative complications, and higher long-term survival rates compared to

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tapered and rectangular stems in THA with femoral shortening osteotomy. These findings highlight the importance of implant selection in optimizing patient outcomes.

Clinical trial number Not applicable.

Keywords Total hip arthroplasty, Femoral shortening osteotomy, Developmental hip dysplasia, Femoral stem design, Harris hip score, Prosthesis survivorship

Introduction

Developmental hip dysplasia is a common cause of hip arthrosis at a young age [1, 2, 3]. Due to the high functional expectations of patients in this age group, total hip arthroplasty has an important place in treatment [2, 4]. Dysplasia varies greatly in severity and presents a broad spectrum of reconstructive challenges when performing total hip arthroplasty [5, 6]. Femoral shortening osteotomy is required to reduce the hip more easily and avoid neurovascular complications, especially in crowe type 3 and type 4 hips [7, 8]. However, performing femoral osteotomy also adds the risks associated with osteotomy such as non-union, bleeding, prolongation of the operation time [9].

Recently, increasing attention has been focused on subtrochanteric osteotomy performed with different surgical techniques: step-cut, transverse or oblique [8, 10, 11]. Further, various femoral stems have been reported that can be used with femoral osteotomy [9, 12, 13, 14]. In the literature, proximal single/third porous coated tapered stems, rectangular stems, cylindrical fully porous coated stems as well as modular stems have been reported to be used with osteotomies [4, 15, 16, 17, 18] Although the literature in primary hip arthroplasty is moving more towards robotic surgery, the problems of implant selection in highly dysplastic hips are still largely unresolved [19, 20]. Currently, the osteotomy techniques and implant choice is usually made according to the surgeon's experience and the patient's pathoanatomical characteristics.

To our knowledge, various case series reporting the results of many femoral stems have been published in the literature [5, 7, 11, 21, 22]. However, there are very few studies comparing the results of different femoral stems in femoral shortening osteotomy. The effect of design and osteoconductive properties differences on the results of femoral stems in this patient group is not well known due to their different clinical and anatomical features.

Therefore, the aim of this study was to investigate the effects of three different femoral stems on clinical and radiological results in a large patient group who underwent transverse femoral shortening osteotomy. Our hypothesis was that cylindrically shaped stems are associated with better clinical and radiological outcomes in patients undergoing transverse femoral shortening osteotomy than tapered and rectangular stems.

Materials and methods

Patients

The study was approved by the institutional ethics review board and adhered to the principles of the Declaration of Helsinki. This was a single-centre, multi-surgeon case series. Between 2004 and 2014, a total of 177 patients who underwent THA with femoral shortening osteotomy at our hospital were retrospectively evaluated. The inclusion criteria were as follows: total hip arthroplasty performed with femoral shortening osteotomy due to Crowe type 3 and 4 coxarthrosis [23], transverse femoral shortening osteotomy, minimum 10 year follow-up. Only patients with high-riding dislocated hips classified as Crowe type 3 or 4 were included in order to ensure surgical homogeneity, as these cases typically require transverse femoral shortening osteotomy to achieve proper reduction and reduce neurovascular risk. The exclusion criteria were as follows: Patients who have previously had hip surgery from the same side, patients operated with a femoral stem other than these 3 stems were excluded from the study; 1)Summit Tapered (Depuy ®, Warsaw, IN) 2) SL-PLUS (Smith & Nephew ®, Memphis, TN) 3) Wagner Cone Prosthesis (Zimmer ® Warsaw, IN). After exclusion, 107 hips who underwent total hip arthroplasty with transverse femur shortening osteotomy were included in the study. The study flowchart in Fig. 1.

The patients were divided into three groups according to the femoral stem type. There were 39 patients with proximal porous-coated tapered femoral stem in group 1 (Summit Tapered (Depuy ®, Warsaw, IN), 31 patients with Zweymuller type rectangular femoral stem in group 2 (SL-PLUS (Smith & Nephew ®, Memphis, TN), and group 3 with 37 patients using cylindrical type femoral stem. (Wagner Cone Prosthesis, Zimmer ® Warsa w, IN).

Data collection

Demographic, intraoperative and follow-up data of all patients reviewed. Variables collected included age, sex, affected side, body-mass index, smoking status, Crowe classification and Dorr types of femur. We recorded intraoperative complications (neurovascular damage, intraoperative femoral fracture), both early and late postoperative complications (dislocation, infection, femoral nonunion, heterotopic ossification with clinical manifestation).

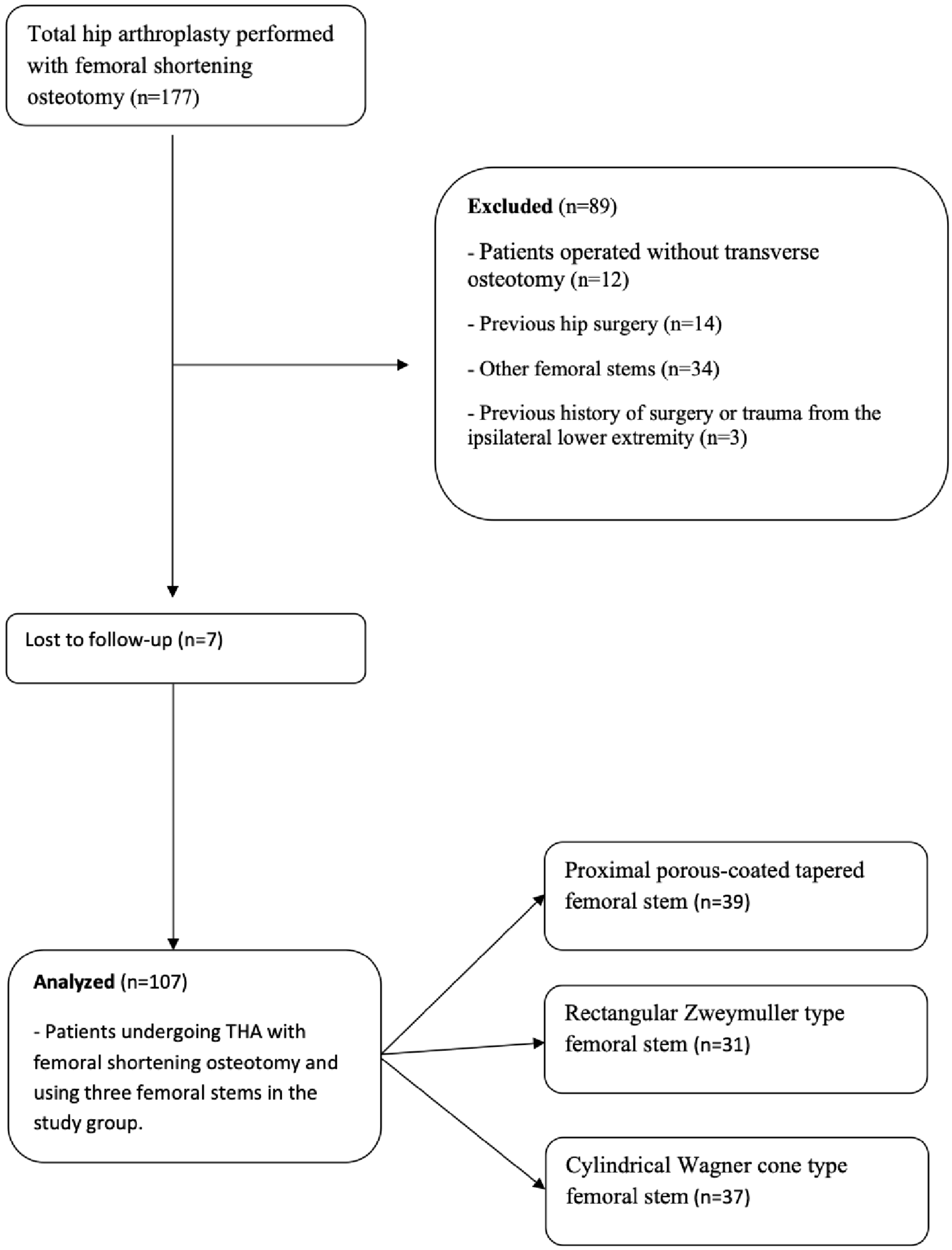

Fig. 1 Study flowchart

Clinical and radiological evaluation

Clinical and radiographic data were obtained for all patients before surgery and at follow-up examinations. Clinical evaluation was done based on the Harris Hip Score (HHS). Postoperative HHS scores were categorized as excellent for > 90, good for 80–89, moderate for 70–79, and poor for < 70 [24]. Union was defined as the presence of progressive callus, cortical continuity, and painless weight bearing. The function of the sciatic and femoral nerves was carefully examined but did not include routine electrophysiological testing. Limb length discrepancy (LLD) was calculated by measuring the distance between the anterior superior iliac spine and the medial malleolus of each lower extremity. Physical examination was performed preoperatively, at the sixth week, third and the sixth months and one year postoperatively, and two-year intervals and thereafter until the last visit.

Standard radiographs included an anteroposterior (AP) view of the pelvis and AP, lateral views of the proximal femur and full-length weight bearing lower extremity radiographs were obtained preoperatively, 1-year postoperatively and final follow-up in all patients. Magnification of all radiographs was calibrated using the known diameter of the artificial femoral head. Osteointegration of the stems were graded as stable bone ingrowth, stable fibrous and loose according to Engh et al. [25] Heterotopic ossification was classified according to the system of Brooker et al. [26] All proximal femurs were structurally classified preoperatively according to Dorr classification [27]. All radiographic examinations and measurements were performed by two blinded orthopaedic surgeon. All radiographs were obtained digitally using DDR Inventor V (JSB Medics Co., Bucheon City, South Korea), and measurements were taken using the Infinitt PACS System (Infinitt Healthcare Co., Seoul, South Korea).

Surgical technique

All patients were operated on using an posterior approach described by Yasgur et al. [28] After femoral head resection and total capsulectomy, we removed osteophytes covering the true acetabulum. Acetabular preparation was performed and anatomically reconstruct the center of rotation of the hip. The acetabulum was under-reamed by 1 mm, depending on the bone quality. A cementless, porous-coated, hemispheric acetabular component was implanted in the anatomical hip center position with the use of the press-fit technique, with the surgeon aiming for 40° of inclination and 15° of anteversion. Femoral head bone grafting on the acetabular side was not used. All of the acetabular components were fixed with 2 or 3 dome screws. Anterior capsule, iliopsoas, and gluteus maximus release were performed when required. First on the femoral side proximal femoral reaming and rasping were performed. Transverse subtrochanteric shortening osteotomy was performed on all patients, and the amount of femoral shortening was determined during the operation previously described overlapping technique by Park et al. [29] Using the overlapping technique, excessive resection was prevented. After femoral reaming and rasping was completed, prophylactic cable was placed distal to the osteotomy before the trial femoral stem was inserted. The osteotomy site was augmented with autogenous graft from the acetabular reaming and resected femoral fragment with a cable. Proximal and distal femoral fragments were stabilized by the insertion of the femoral stem, primarily. Two or three cables were also used for additional stability. Additional plates were not routinely used in our patients. The indication for the utilisation of an additional plate is the development of an intraoperative fracture or fissure, or inadequate stability of the osteotomy line with stems and cables. The choice of femoral stem was primarily based on the operating surgeon's familiarity and experience with specific implant systems. No predefined selection criteria were applied; instead, each surgeon used the stem type they routinely employed in their standard surgical practice. Despite differing recommendations in the literature, all patients received subcutaneous enoxaparin for VTE prophylaxis, in accordance with the institutional protocol at the time of the study [30]. In line with previous studies recommending the use of non-selective NSAIDs for heterotopic ossification prophylaxis, all patients received a non-selective NSAID postoperatively [31, 32].

Postoperative rehabilitation

Patients were mobilized early with two crutches allowing toe-touch the day after surgery. Passive and active-assisted range-of-motion exercises were initiated. Patients were allowed to bear partial-weight at 4 weeks. routine postoperative assessments were done at 6, 12, 24, and 52 weeks with the clinical and radiologic evaluation. Patients who had radiologic signs of the union at the osteotomy site were allowed to full weight-bearing.

Statistical analysis

All data were analyzed using the software SPSS 19.0 for Windows (SPSS Inc., Chicago, Illinois, USA). In the descriptive statistics of the data, mean, standard deviation, frequency and ratio values were used. The distribution of variables was evaluated with the Kolmogorov-Simirnov test. Continuous variables were presented as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro-Wilk test. Since the data met the assumption of normality, one-way analysis of variance (ANOVA) was performed to compare the mean Harris Hip Scores (HHS) among the three groups. When a statistically significant difference was detected, Tukey's Honest Significant Difference (HSD) post-hoc test was applied to determine pairwise differences between the groups. Categorical variables were compared using the Chi-square test, and in cases where a significant result was observed, pairwise comparisons were conducted using post-hoc analysis with Bonferroni correction. A p-value < 0.05 was considered statistically significant for all tests.

Results

Demographics

The mean follow-up period was 172.8 months (range, 131 to 232 months). Mean patient age at the time of surgery was 45.8 years (range, 25–61 years). Mean body mass index was 28.0 (range, 18–37). In this study, 12 hips were classified as Crowe III and 95 hips were classified as Crowe IV. Patient characteristics are shown in Table 1. There was no significant difference between the patient groups using different femoral stems in terms of age (n.s.), gender (n.s.), follow-up time (n.s.), BMI (n.s.), smoking status(n.s.), Dorr types(n.s.) and Crowe types(n.s.).

Table 1 Patient characteristics

	All patients ($n=107$)	Group 1 ($n=39$)	Group 2 ($n=31$)	Group 3 ($n=37$)	*p*
Age (years)	45.8 ± 10.9	44.2 ± 10.3	46.5 ± 11.2	44.2 ± 11.8	n.s.
Follow-up (mean, months)	172.8 ± 31.8	174.1 ± 29.4	162.4 ± 31.7	177.5 ± 34.7	n.s.
Sex (male/female)	8/99	3/37	2/29	3/34	n.s.
BMI (kg/m^2)	28.0 ± 3.8	27.6 ± 4.1	28.8 ± 3.0	28.0 ± 4.0	n.s.
Smoker/non-smoker	19/88	8/31	6/25	5/32	n.s.
Crowe Classification (3 / 4)	12/95	5/34	3/28	4/33	n.s.
Dorr types (A/B/C)	41/66/0	19/20/0	12/19/0	13/24/0	n.s.

Table 2 All clinical outcome parameters

	All patients ($n=107$)	Group 1 ($n=39$)	Group 2 ($n=31$)	Group 3 ($n=37$)	*p*
Preoperative HHS	42.7 ± 6.7	41.5 ± 6.6	43.8 ± 7.4	43.2 ± 6.3	n.s.
HHS at last follow-up	84.6 ± 11.5	82.1 ± 14.3	83.2 ± 10.1	88.8 ± 6.4	**F = 8.77** $p=0.0001$
Improvement in HHS	41.9 ± 8.8	40.6 ± 9.7	39.4 ± 7.6	45.6 ± 5.6	**F = 10.01** $p=0.0001$
Good or Excellent results / HHS	84 (%78)	29 (%74)	24 (%77)	31 (%81)	n.s.
LLD Preoperative (mm)	38.3 ± 7.1	37.2 ± 6.2	37.9 ± 6.3	40.0 ± 8.4	n.s
LLD Postoperative (mm)	11.9 ± 5.1	12.0 ± 3.6	13.0 ± 5.1	11.1 ± 6.5	n.s
Mean Length of osteotomized fragment (cm)	3.3 ± 0.6	3.4 ± 0.6	3.1 ± 0.7	3.2 ± 0.4	n.s.
Operative Time (min)	132.2 ± 18.1	135.0 ± 23.6	129.0 ± 15.1	128.5 ± 13.5	n.s.

Clinical outcomes

The mean Harris Hip Score significantly improved from 42.7 (range, 30–48) preoperatively to 84.6 (range, 56–98) postoperatively. In all, 107 patients 84 (78%) were scored as having a good or excellent result (80–100), 18 (17%) had a fair result (70–79), and 5 (5%) had a poor result (< 70). The mean Limb length discrepancy reduced significantly from 38.3 mm (range 0–68 mm) preoperatively to 11.9 mm (range 0–32 mm) postoperatively. There was no significant difference between the three groups in terms of preoperative HHS, and preoperative and postoperative LLD. The mean length of the osteotomized bone fragment for all three groups is presented in Table 2. There was no statistically significant difference between the groups. The results indicate a statistically significant difference between Group 1 and Group 3, with Group 3 demonstrating significantly higher final follow-up Harris Hip scores compared to Group 1 ($p=0.0002$). However, No statistically significant differences were observed between Group 1 and Group 2 ($p=0.1947$) or between Group 2 and Group 3 ($p=0.0723$). All clinical outcome scores and data for all three groups are summarised. in Table 2. Figure 2 illustrates the comparison of preoperative and postoperative Harris Hip Scores (HHS) among the three study groups.

Radiological results

In our study, we found nonunion in 8 of 107 hips and delayed union in 6 hips. The mean time to union was 4.8 months (range 3–13), excluding 8 patients with nonunion. There was no difference between the groups in terms of fracture union time. Heterotopic ossification was observed during follow-up in 6 hips in total. Stress shielding was found in 21 of 107 hips during follow-up. Although less stress shielding was observed in the proximal porous coated (Group 1) group, there was no significant difference between the groups in terms of stress shielding and heterotopic ossification. A sample of three cases in which 3 different femoral stems were used are shown in Figs. 3, 4 and 5.

Intraoperative and postoperative complications

An intraoperative femoral fissure or fracture development was noted during preparation or stem placement of the femoral canal in 23 of 107 operations. There was a statistically significant difference in intraoperative fissure/fracture rates between Group 1 and Group 3 ($p=0.0006$), indicating a higher incidence of fractures in Group 1. However, no significant differences were observed between Group 1 and Group 2 ($p=0.2010$) or between Group 2 and Group 3 ($p=0.1419$).Of these 23 fractures, 16 were fixed with additional plates and screws and 7 were fixed with 1 or 2 extra cables. Post-hoc analysis using Tukey's HSD test revealed a statistically significant difference in the need for plating between Group 1 and Group 3 ($p=0.0031$), indicating a higher incidence of plating requirement in Group 1. However, no significant differences were observed between Group 1 and Group 2 ($p=0.3291$) or between Group 2 and Group 3 ($p=0.1913$). There was no statistically significant difference in the

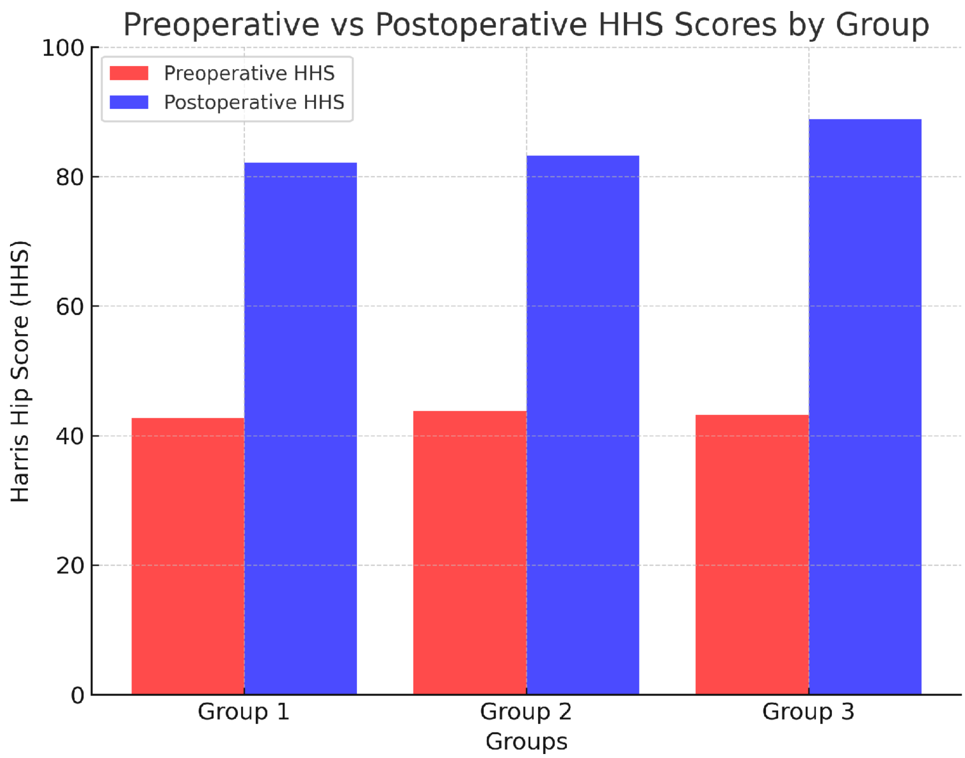

Fig. 2 Comparison of Preoperative and Postoperative Harris Hip Scores (HHS) Among Groups

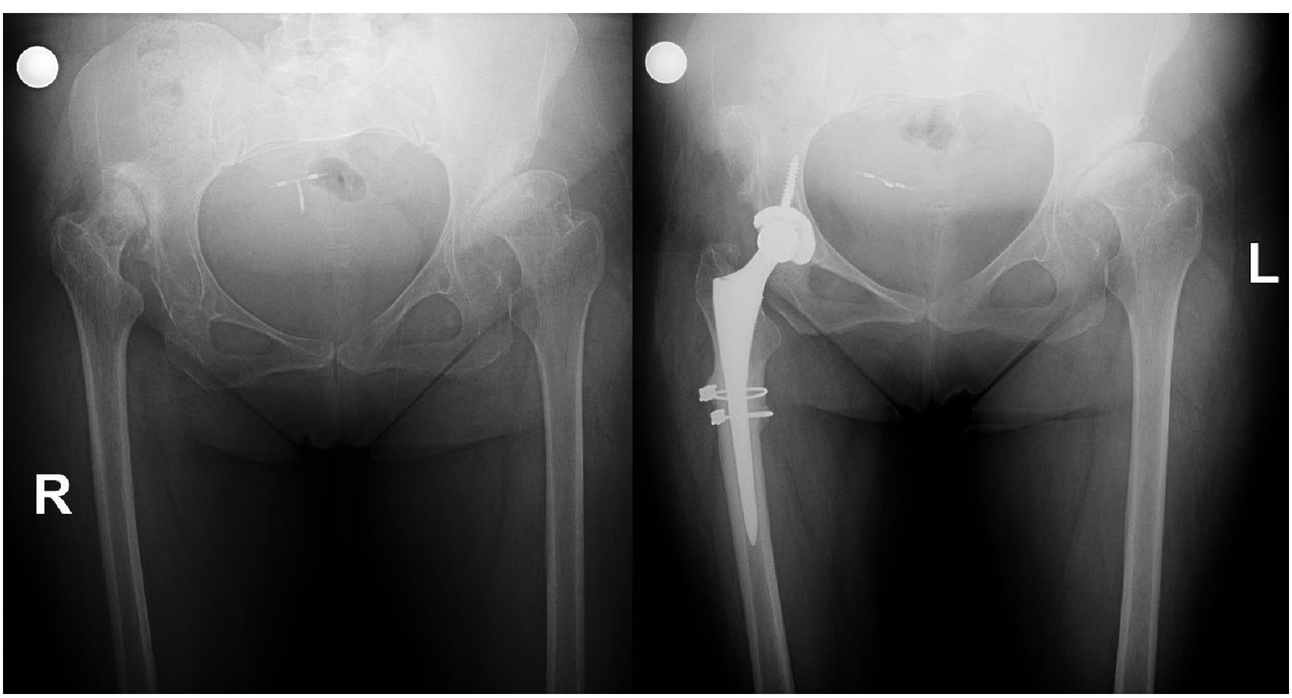

Fig. 3 Preoperative and Follow-up Anteroposterior Pelvic Radiographs of a Patient with a Proximal Porous-Coated Tapered Stem

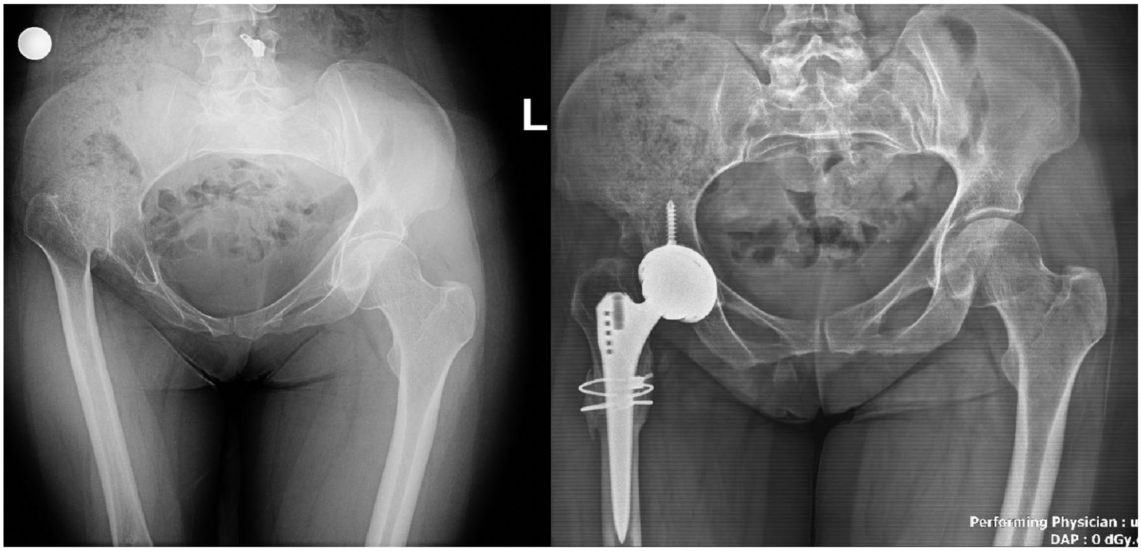

Fig. 4 Preoperative and Follow-up Anteroposterior Pelvic Radiographs of a Patient Treated with a Rectangular Femoral Stem

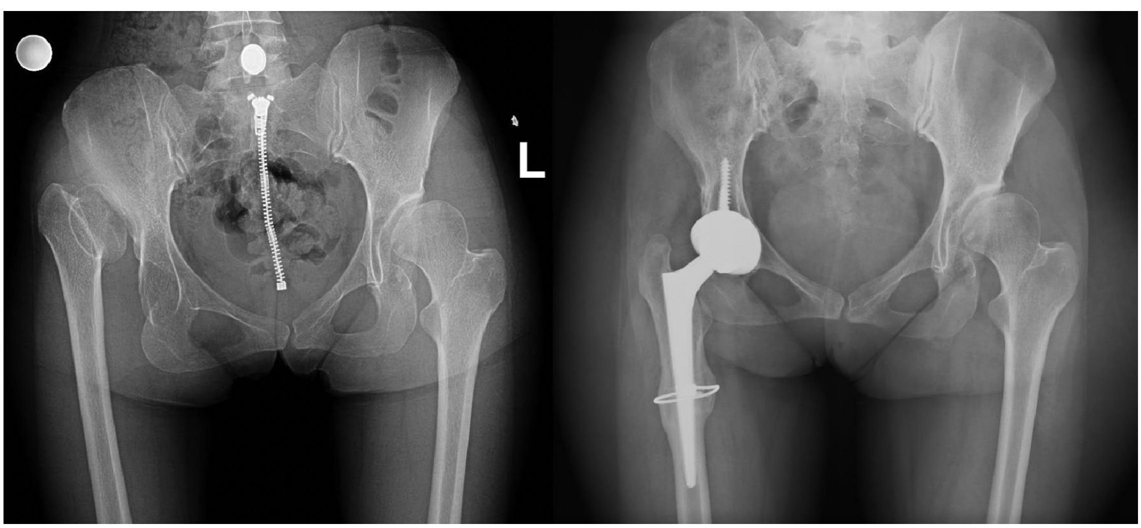

Fig. 5 Preoperative and Follow-up Anteroposterior Pelvic Radiographs of a Patient Treated with a Wagner Cone Cylindrical Femoral Stem

mean operative time among the three groups (Group 1: 135.0 ± 23.6 min; Group 2: 129.0 ± 15.1 min; Group 3: 128.5 ± 13.5 min; $p = 0.904$). The mean perioperative blood transfusion requirement was also comparable between the groups (Group 1: 2.1 ± 0.6 units; Group 2: 1.9 ± 0.3 units; Group 3: 1.8 ± 0.3 units), and the difference did not reach statistical significance ($p = 0.169$).

One of the patients underwent two staged revision due to infection in the long-term follow-up, and two patients were debrided within the first month due to early infection. Nonunion occurred at the osteotomy line in 8 of 107 hips, and femoral revision was required in 5 of these patients. Two of these patients were in the rectangular stem group and one in the cylindrical stem group and these patients had no complaints except pain at the osteotomy line. The femoral stems were fixed to the bone distal and proximal to the osteotomy line. Although grafting and additional plate application were recommended, the patient refused. Dislocations occurred in 8 of 107 hips; 4 patients were revised due to recurrent dislocations. The other four did not dislocate again after closed reduction. Sciatic nerve palsy developed in two patient and recovered after one year of follow-up. Trochanteric bursitis developed in 3 patients, and cable removal was performed in 1 of them. Squeaking or clicking did not occur in any patient. All radiological findings and their distribution by groups and all complications are summarized in Table 3.

Revision and survivalship of components

Revision surgery was performed on 13 patients in a total of 107 hips. Of these, 5 were due to femoral nonunion,

Table 3 Radiological findings and complications

	All patients ($n=107$)	Group 1 ($n=39$)	Group 2 ($n=31$)	Group 3 ($n=37$)	*p*
Union time (mean, months)	4.8	5.6	4.9	4.4	n.s.
Stress Shielding	21	4	9	8	n.s.
Heterotopic Ossification	14	5	4	5	n.s.
Intraoperative femoral fissure or fracture	23	12	8	3	$p=0.043$
Requirement for additional plate	16	9	6	1	$p=0.032$
Delayed union / Nonunion	14	7	5	2	n.s.
Dislocation	8	3	3	2	n.s.
Revision	13	5	5	3	n.s.

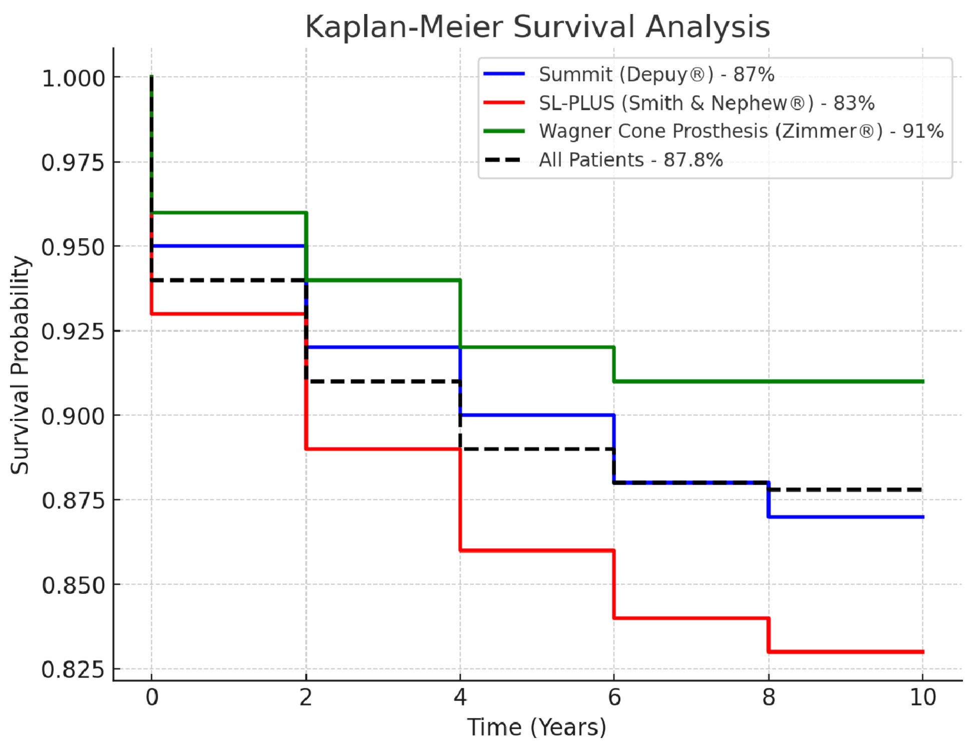

Fig. 6 Kaplan-Meier Survival Analysis of Femoral Stems Over a 10-Year Follow-Up Period

4 recurrent dislocation, 1 two-staged revision due to enfection, 1femoral and 2 acetabular loosening. At the end of the entire follow-up period and any revisions, the survival rates in 3 different femoral stem groups are as follows; Summit (Depuy®) was 87%, SL-PLUS (Smith & Nephew®) was 83%, and Wagner Cone Prosthesis (Zimmer ®) was 91%. When all patient groups were examined, the survival rate was 87.8%. The Kaplan-Meier survivorship curve, as shown in Fig. 6, demonstrates the 10-year survival rates of the three femoral stem groups. At the end of the follow-up period, the survival rates were 87% for the Summit (Depuy®) group, 83% for the SL-PLUS (Smith & Nephew®) group, and 91% for the Wagner Cone Prosthesis (Zimmer®) group. There was no statistically significant difference in survivorship between the groups (log-rank test, $p=0.633$) The Kaplan-Meier survivorship analysis including only femoral stem-related revisions is presented in Fig. 7. The 10-year survival rates were 92.3% for Group 1 (Summit), 93.5% for Group 2 (SL-PLUS), and 97.3% for Group 3 (Wagner Cone Prosthesis). Similarly, no statistically significant difference was observed among the groups in this restricted analysis (log-rank test, $p=0.638$).

Discussion

The most important findings of this study were that three different femoral stem designs used in patients who underwent THA with transverse femoral shortening osteotomy in high riding hips had similar clinical and radiological results and complications during the 10-year follow-up. In our study, THA surgery performed with transverse femoral shortening osteotomy in this patient group had very satisfactory results in a-10 year follow-up with all three different femoral stems.

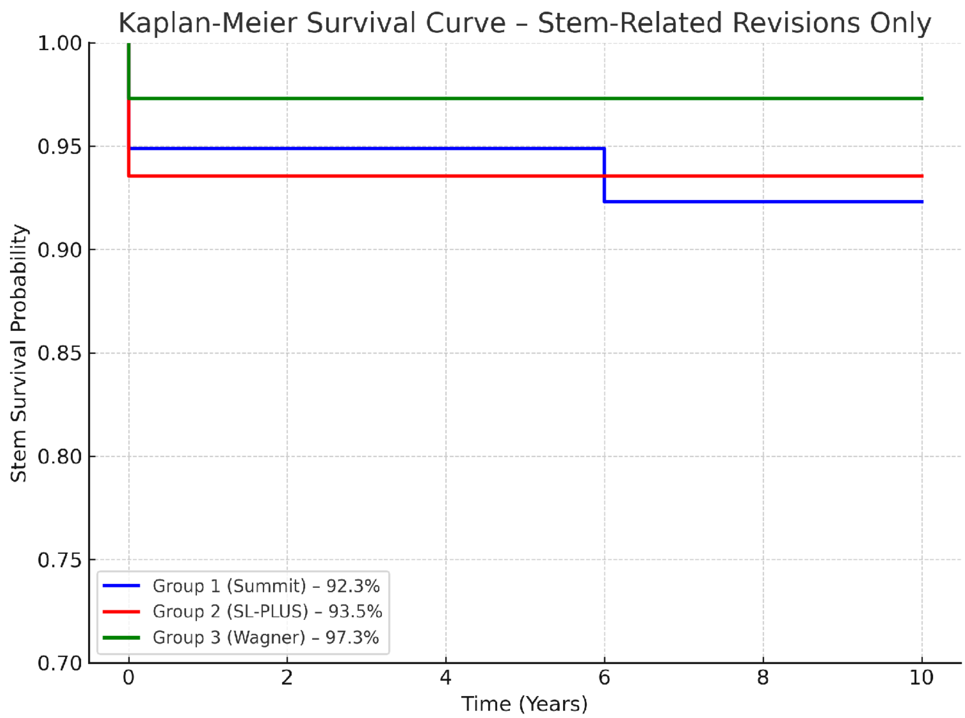

Fig. 7 Kaplan-Meier survival curve showing 10-year stem-related survivorship across three femoral stem groups

Another important finding of our study was that proximal porous coated stems were associated with more intraoperative complications in this patient group and the need to use more plates to fix the osteotomy. Cylindrical full porous coated stems were associated with better long-term results and fewer complications compared to other stems.

The three femoral stems we included in our study also prove excellent long-term results in primary hip arthroplasty [33, 34, 35]. However, there is limited information in the literature on femoral stem selection in high-riding hips. According to many authors, femoral reconstruction in high dysplastic hip arthroplasty constitutes a challenging and complicated part of the surgery due to the very different anatomical structures of the patients and variable femur shortening requirements [1, 22, 28, 36]. Therefore, there is no consensus on the different femoral stem and surgical techniques in femoral reconstruction are available in the literature [37, 38].

Numerous techniques for femoral shortening osteotomy have been described, including step-cut, oblique, double-chevron, and transverse methods. Among these, the transverse osteotomy remains the most widely used due to its simplicity, ease of application, and reproducibility [11, 17, 39]. Despite its relatively limited inherent rotational stability, this technique allows for controlled adjustment of femoral anteversion, which is particularly valuable in dysplastic hips with distorted femoral morphology.

In the last 20 years, there have been studies in the literature reporting satisfactory results with transverse osteotomy using different femoral stems. These studies reported results with tapered, rectangular, cylindrical, modular and cemented femoral stems [37, 38, 40, 41]. However, very few studies have published comparative results of these femoral stems.

Özden et al. published the 10-year follow-up results of 45 hips. They reported higher complication rates with tapered stems than with cylindrical stems [9]. Muratli et al., in their biomechanical study, compared two different femoral stems and four different osteotomy methods, found differences in measurement between tapered stems and cylindrical stems in some loadings [42]. However, in the present study, we found that cylindrical stems were associated with better results than tapered stems with proximal porous-coated. We also found more intraoperative proximal femur fractures in the tapered stem group.

An intraoperative femur fracture is known to be one of the most common complications in THA patients who underwent femoral shortening osteotomy. It has been reported in the literature to be between 5 and 22% [16, 43]. It has been observed that fractures frequently occur in the proximal segment due to the tapered design while attempting to stabilize the press-fit of the femoral stem on the distal segment of the osteotomy. We think that this complication is more common with tapered stems with one-third of the stem covered proximally due to the anatomical incompatibility of this design with the shortened femur. However, we believe that adapting the cylindrical stem to the difference in medullary width between the distal and proximal segments after shortening is less traumatic and less likely to cause fracture. Conversely, cylindrical stems appear to better accommodate the canal diameter mismatch between the proximal and distal segments after osteotomy, distributing the load more evenly and thereby reducing the risk of fracture.

Glassman et al. described stress shielding characteristics in different femoral stem designs [44]. Although we expect less stress shielding in proximally coated tapered designs, in our study, no significant difference was found between the three groups in terms of stress shielding and it was observed that it did not affect the clinical and radiological results. The stress shielding advantage expected from stems with proximal metaphyseal involvement was not observed in clinical and radiological results in this study. In our study, proximally coated stems were associated with more intraoperative fractures and similar stress shielding results were observed.

In their biomechanical study published in 2016, Tuncay et al. reported that using straight, cylindrical femoral stems can increase rotational stability of the transverse osteotomy more than the rectangular cross-sectional stems, although the latter one has the advantages of rectangular geometrical design [13, 17]. In our study, we did not find any significant difference in the mean time-to-union, non-union or delayed-union in the three femoral stem groups in patients who did not use any additional fixation material. We did not observe any difference in stability between the stems that could cause a difference in clinical and radiological results.

The Wagner cone prosthesis, a cylindrical and fully porous coated stem, may offer certain biomechanical advantages in this context [13]. Its straight diaphyseal design facilitates press-fit fixation in the often narrow and stovepipe-shaped femoral canals observed in dysplastic hips. In addition, the geometry of the stem allows for reliable axial alignment and distal fixation, especially after transverse osteotomy, regardless of proximal femoral deformities, and the stem allows the surgeon to dial in anteversion for optimal stability [34]. These design features may explain the favourable results observed with this stem type in complex DDH cases. Its compatibility with the osteotomy line may also eliminate the need for an additional plate. However, individual stem selection should ultimately be guided by intraoperative assessment and the surgeon's familiarity with the implant.

In the last ten years, many studies on total hip arthroplasty with femoral shortening osteotomy have reported good and excellent results between 70 and 90%. In addition, studies using many different femoral stems have reported 10-year survival of over 80% [31, 32, 34, 35, 39, 40]. In our study, our patient group, which included 107 hips, had a good or excellent outcome of 78% and survival of 87.8% at 10-year follow-up. Although this shows that all three femoral stems can be used in crowe type 3 and type 4 hips in the long term, our observation in this study is that cylindrical stems are associated with fewer intraoperative complications and better long-term survival, suggesting a potential advantage in this challenging surgical population.

This study has several inherent limitations. First, its retrospective design introduces the potential for selection bias and limits control over confounding variables. A prospective, randomised study would provide more robust evidence. Furthermore, the study was conducted at a single centre with multiple surgeons, which may limit the generalisability of the findings to other institutions with different surgical techniques and patient populations. Another limitation of this study is that, although we also focused the survival analysis on femoral stem-related revision causes, the distinction between femoral and acetabular component failures is often challenging in clinical settings, potentially leading to overlapping interpretations Furthermore, although all patients were followed for at least 10 years, differences in follow-up time between individuals may have influenced the survival analysis. Finally, femoral stem selection was based on surgeon preference and patient anatomy rather than a standardised selection protocol, which may have influenced the results. Despite these limitations, this study provides valuable comparative data on femoral stem selection in THA with transverse femoral shortening osteotomy and contributes to the understanding of long-term clinical and radiological outcomes in cases of high-riding hip dysplasia.

Conclusion

This study demonstrates that femoral stem design significantly impacts clinical outcomes, complication rates, and long-term survivorship in total hip arthroplasty with transverse femoral shortening osteotomy. Cylindrical fully porous-coated stems (Wagner Cone Prosthesis) were associated with superior clinical outcomes, fewer intraoperative fractures, and higher implant survival rates compared to tapered (Summit) and rectangular (SL-PLUS) stems. However, all three femoral stems provided satisfactory long-term results, indicating that multiple implant options can be successfully used in this challenging patient population. The findings highlight the importance of implant selection, and further prospective studies are needed to establish standardized guidelines for optimal femoral stem choice.

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Author contributions

Conceptualization, K.A. and A.A.; Methodology, K.A, Y.A.; Software, K.A.,O.I.T.; Validation, Y.A., D.A. and M.M.; Formal Analysis, Y.A., D.A.; Investigation, K.A. and O.I.T; Resources, K.A. and M.M; Data Curation, Y.A and O.I.T. and A.A.; Writing– Original Draft Preparation, K.A., O.I.T.; Writing– Review & Editing, Y.A.,M.M and A.A; Visualization, D.A. and M.M; Supervision, A.A.; Project Administration, K.A. and A.A.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Consent for publication

Written informed consent was obtained from all patients.

Ethical approval

University of Health Sciences Baltalimani Bone Diseases Training and Research Hospital institutional review board approved the study protocol. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Competing interests

The authors declare no competing interests.

Conflict of interest

Kutalmis Albayrak, Yakup Alpay, Ozgur Ismail Turk, Deniz Akbulut, Muhammed Mert and Akif Albayrak declare that they have no conflict of interest.

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