Outcomes with Two Tapered Wedge Femoral Stems in Total Hip Arthroplasty Using an Anterior Approach

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ABSTRACT

Background: The majority of hip arthroplasties in the United States utilize cementless acetabular and femoral components. Despite their similarities, stem geometry can still differ. The purpose of this study is to compare the clinical results of two wedge-type stem designs.

Methods: A retrospective study of patients who underwent primary THA utilizing a direct anterior approach between January 2016 and January 2017. Two cohorts were established based on femoral stem design implanted. Descriptive patient characteristics and surgical and clinical data was extracted which included surgical time, length of stay (LOS), presence of pain (categorized as groin, hip, or thigh pain) at the latest follow-up, and revisions. Immediate postoperative radiographs were compared with the latest follow-up radiographs to assess limb length discrepancies, stem alignment, and stem subsidence.

Results: A total of 544 patients were included. 297 patients received the Group A stem (morphometric) and 247 patients received the Group B stem (flat-tapered). A significantly higher proportion of Group B stems subsided ≥ 3 mm and were in varus alignment than the Group A design. Additionally, a significantly greater number of patients who received the Group B stem reported postoperative hip and thigh pain. The logistic regression found that the Group B stem was 2.32 times more likely to subside ≥ 3 mm than the Group A stem.

Conclusion: Our study suggests modestly improved radiographic and clinical outcomes and fewer instances of thigh pain, subsidence, and varus alignment in the patients who received the Group A hip stem. Further studies are warranted to assess long-term significance.

1. Introduction

The majority of hip arthroplasties performed yearly in the United States utilize cementless acetabular and femoral components, with current cementless stem designs differing in material, surface coating, and shape. The implant shape determines the areas of cortical contact, in turn determining where fixation is obtained. Single-wedge prostheses are flat in the anteroposterior plane and tapered in the mediolateral plane. Engagement of metaphyseal cortical bone in only the mediolateral plane helps achieve good rotational stability, while the tapered geometry results in minimal diaphyseal contact helping to prevent proximal bone resorption.¹ A proximal hydroxyapatite ingrowth surface stimulates stability through metaphyseal and diaphyseal osseointegration, promoting homogeneous stress distribution at the bone–stem

interface. The long-term results of these stems have been excellent, demonstrating excellent long-term survivorship and a low prevalence of thigh pain.²

Various factors may influence surgeon preference in implant selection, including implant geometry, performance, cost, vendor relationships, and implant familiarity.^{3–5} Although there is a wide variety of commercially-available femoral stems to choose from, there is currently no consensus regarding which stem, if any, is superior to the others. This is largely due to a lack of clinical studies exploring clinical outcomes of these tapered wedge stems relative to one another. National joint registries, such as the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), only collect general outcome data regarding specific stem types, such as revision rates and mortality. In addition, there may exist important stem design differences that

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influence their relative ability to fill the metaphysis and achieve osseous integration.^{6,7} Improvements in stem design over earlier generations include a medial radius of curvature that better conforms to native femur morphology, improved proximal femoral fit and fill and a shorter stem design without loss of initial stability.⁸ Proximal fit is especially important, as taper engagement that occurs distally rather than proximally may result in incomplete osseous integration.⁹ This is of special importance in younger patients, who commonly have narrow distal femoral canals (Dorr type A femurs).¹⁰

The purpose of this study is to compare the clinical outcomes following THA through a direct anterior approach (DAA) with two different wedge-type stem designs. All cases were performed by a single surgeon at a high-volume orthopedic specialty center. We hypothesize that clinical (e.g. intraoperative complications, postoperative pain, readmissions, revisions) and radiographic outcomes (e.g. stem alignment, subsidence, limb length discrepancy) will be similar between both stem designs.

2. Methods

This is a retrospective study of all patients who underwent primary THA by a single surgeon at our institution utilizing a direct anterior approach between January 2016 and January 2017. All primary THA surgeries included in this study were performed consecutively by the senior author (RD) with the assistance of fluoroscopy. Patients were divided into two cohorts for comparison, based on the design of the second-generation flat-tapered stems, Group A (Accolade II®, Stryker Corporation, Kalamazoo, MI) and Group B (Anthology®, Smith & Nephew, London, UK). Stem assignment was based on the day of the week the surgery was performed. All surgeries were performed on a dedicated surgical table similar to those used in lower extremity fracture care (Hana®, Mizuho OSI, Union City, CA). The records and existing data are de-identified and are part of our institutional quality improvement program; therefore, the present study was exempted from human-subjects review by our Institutional Review Board (IRB).

2.1. Data collection

Descriptive patient characteristics and surgical data collected using our electronic data warehouse included gender, age, BMI, race, American Society of Anesthesiologists (ASA) score, smoking status, surgical time, and length of stay (LOS). Surgical and clinical data extracted via manual chart review presence of postoperative pain (categorized as groin, hip, or thigh pain) at the latest follow-up and revision for any reason.

Immediate postoperative plain anterior-posterior radiographic images of the hip were compared with radiographic images at the latest follow-up to assess for stem alignment (neutral, varus, valgus) and quantitative evidence of stem subsidence. Latest follow-up radiographs were taken at least three months following the index surgery. Radiographic analysis was performed by two equally trained observers (J.G. and J.P.), who both agreed on the methodology that would be used throughout the measurement process. To ensure consistency, they together performed alignment and subsidence measurements for the first ten patients in the study cohort. The degree of varus or valgus angulation was defined as the angle formed between the central shaft of the stem and the medial or lateral endosteal cortices, respectively. As previously described in literature, a stem was categorized into varus or valgus alignment if the angle deviated $\geq 5^\circ$ from neutral.^{11–13}

For subsidence measurements, radiographic calibration of each x-ray was performed using the known implanted femoral head size. A 90° angle was formed between the long axis of the femoral stem and the most superior aspect of the femoral stem shoulder. A line parallel to the horizontal arm of the perpendicular angle was drawn and brought to the level of the superior tip of the greater trochanter. The distance between these two parallel lines was recorded. Stem subsidence was calculated as

the difference between the immediate postoperative radiographs and the latest follow-up radiograph. Cutoffs of 3 mm and 5 mm were used to denote subsidence levels. All subsidence measurements were conducted at least 3 months postoperatively due to previous literature demonstrating that long-term fixation and diminished risk of progressive subsidence occurs during the first 3–6 postoperative months.^{14,15}

2.2. Statistical analysis

Means and standard deviations were used to describe all continuous variables and frequency distributions were used to describe categorical variables. Fisher's exact test and two-sample t-tests were used to test for significance. Lastly, a regression analysis was performed to control for factors, including the surgical table used, affecting subsidence at latest radiographic follow-up. β coefficients are interpreted as the change in subsidence in millimeters relative to the reference group for that category. A p-value threshold of less than 0.05 was considered statistically significant. All statistical analyses were performed by a statistician using STATA version 15.1 (StataCorp, 2017, College Station, TX).

3. Results

3.1. Patient demographics

A total of 544 patients underwent primary THA during the study period and were included in the present study. Of these, 333 (61.2%) patients were male and 211 (38.8%) were female. Mean age and BMI of the study sample were 64.0 ± 10.1 years and 27.3 ± 4.8 kg/m², respectively. Full demographic information for each study cohort is summarized in Table 1. No significant differences were found between both cohorts with respect to any baseline patient characteristics.

3.2. Surgical and clinical outcomes

Two hundred ninety-seven (54.6%) received the Group A stem and 247 (45.4%) received the Group B stem. Group A and B stems were selected depending on the day of the week. Group A stems were

Table 1
Patient demographics (n = 544).

	Group A/Morphometric (n = 297)	Group B (n = 247)	P-value
Gender			0.659
Female	118 (39.7%)	93 (37.7%)	
Male	179 (60.3%)	154 (62.4%)	
Age			0.655
<55	42 (14.1%)	34 (13.8%)	
55–64	96 (32.3%)	82 (33.2%)	
64–74	107 (36.0%)	97 (39.3%)	
≥ 75	52 (17.5%)	34 (13.8%)	
BMI			0.120
Normal (18.5–24.9 kg/m ²)	88 (29.6%)	93 (37.7%)	
Overweight (25–29.9 kg/m ²)	125 (42.1%)	96 (38.9%)	
Obese (≥ 30 kg/m ²)	84 (28.3%)	58 (23.5%)	
ASA			0.882
1	16 (5.4%)	16 (6.5%)	
2	204 (68.7%)	167 (67.6%)	
3 or 4	77 (25.9%)	64 (25.9%)	
Race			0.650
Caucasian	269 (90.6%)	227 (91.9%)	
Other	28 (9.4%)	20 (8.1%)	
Smoking Status			0.287
Current Smoker	17 (5.7%)	17 (5.7%)	
Former Smoker	96 (32.3%)	93 (31.3%)	
Never Smoked	184 (62.0%)	137 (55.5%)	

implanted on a Thursday and Group B stems implanted on a Wednesday. There were no selection criteria for this and patients were assigned based on available operating room slots. Overall, surgical time was significantly greater for surgeries in which the Group B stem was implanted (71.6 ± 14.0 min vs. 68.2 ± 14.3 min; $p < 0.047$), although this difference is likely not clinically significant. Length of stay between both cohorts was similar (Group A, 0.89 ± 0.84 days vs. Group B, 0.87 ± 0.91 days; $p = 0.849$).

Three (1.2%) patients in Group B suffered intraoperative fractures. One patient was noted to have a 4 mm by 4 mm chip fracture on the medial calcar prior to canal preparation likely incurred during the femoral neck osteotomy. Two patients were noted to have non-displaced fractures following trialing at the levels of the anteromedial aspect of the calcar and the lesser trochanter, respectively. All were treated intraoperatively with a single cable and without weight bearing restrictions without further complication.

Postoperatively, among those who received the Group A stem, there were a total of 44 (14.8%) patients who experienced postoperative pain, broadly categorized into groin (13, 4.4%), hip (24, 8.2%) and thigh (7, 2.4%) pain. In Group B, there was a total of 63 (25.5%) patients who experienced postoperative pain – 11 (4.5%) instances of groin pain, 39 (15.8%) of hip pain, and 13 (5.3%) of thigh pain. A significantly greater number of patients in Group B suffered from postoperative pain of any kind ($p = 0.007$). There were a total of six (2.0%) revisions in Group A – two irrigation and debridement procedures, two due to aseptic loosening of the acetabular component, and two periprosthetic fractures with acute subsidence of the femoral component. There were five (2.0%) revisions in Group B – four irrigation and debridement procedures and one revision due to aseptic loosening of the femoral component. There was no significant difference in the total number of revisions between cohorts ($p = 0.997$). Full surgical and clinical outcome data is summarized in Table 2.

3.3. Radiographic outcomes

The average radiographic follow-up time for the entire cohort was 44.26 ± 31.49 weeks. Follow-up time was comparable for both groups. The average total subsidence at latest follow-up was 1.35 ± 1.59 mm for Group A versus 1.55 ± 1.73 mm for Group B. Total subsidence was similar between groups ($p = 0.155$). Revision cases were not included in the calculation for subsidence. Overall, 32/297 (10.8%) stems in Group A and 45/247 (18.2%) in the Group B demonstrated radiographic subsidence ≥ 3 mm; using this cutoff, a significantly greater number of stems in Group B experienced subsidence ≥ 3 mm ($p = 0.014$). Using a 5 mm cutoff, there was no difference in the proportion of stems that subsided (Group A, 9 [3.0%] vs. Group B, 10 [4.1%]); $p = 0.640$). There were 3 (1.0%) stems found to be in varus and 3 (1.0%) in valgus in Group A; in Group B, there were 32 (13.4%) stems in varus and 1 (0.4%) in valgus ($p < 0.001$). Twelve (4.0%) patients in Group A were found to have a leg length discrepancy ≥ 3 mm, compared to 6 (2.4%) patients in Group B ($p = 0.343$). Full radiographic outcome data is summarized in

Table 3.

4. Discussion

Numerous femoral stem designs are currently in use for THA. Factors such as stem geometry, performance, cost, vendor relationships, and implant familiarity play important roles in surgeon implant preference.^{3–5} Although it has been demonstrated that there exist important differences in composition and geometry between these stems which may, in turn, have important clinical implications, few studies have evaluated their relative clinical performance.¹⁶ National joint registries such as the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR), collect general outcome data regarding specific stem types, such as revision rates and mortality; however, do not report granular data. The purpose of this study was to, therefore, report on several clinical and radiographic outcomes with two cementless stems.

The morphometric, Group A stem was designed based on a large database of three-dimensional models rendered from computed tomography scans.¹⁷ Its design prioritizes metaphyseal proximal fit, with a size-specific medial radius of curvature that increases with stem size.⁹ In this way, it was designed to better accommodate a patient population with an increasing number of males in the 40–60 year age group; these patients are more likely to have Dorr Type A femurs, which are associated with higher rates of complications.^{3,10,17,18} The stem is available in 12 sizes with stem length ranging from 93 mm to 126 mm in 3 mm increments, with standard (132°) and high offset (127°) neck options.¹⁹ The Group B stem is also offered in 12 sizes, ranging from 100 mm to 122 mm in length increasing in 2 mm increments, dual-offset options, and a consistent 131° neck angle.²⁰ Progressing to the high offset option results in a decrease in leg length with the Group A stem, whereas leg length with Group B is unaffected.²¹

In this study of 544 direct anterior primary THA procedures, of which 297 were performed with the Group A stem and 247 with the Group B stem, Group A patients reported significantly less postoperative hip (8.0% vs. 15.8%) and thigh (2.4% vs. 5.3%) pain ($p = 0.007$). The number of intraoperative femur fractures (Group A, 0 [0.0%] vs. Group B, 3 [1.2%]; $p = 0.057$), postoperative traumatic periprosthetic fractures (Group A, 2 [0.7%] vs. Group B, 3 [1.2%]; $p = 0.510$), and revisions (Group A 6 [2.0%], vs. Group B, 5 [2.0%]; $p = 0.997$) were comparable between both groups. A significantly greater proportion of Group B stems subsided ≥ 3 mm (45 [18.2%] vs. 32 [10.8%], $p = 0.014$) and were in varus alignment (32 [13.4%] vs. 3 [1.0%], $p < 0.001$) than the Group A stem. Subsidence ≥ 5 mm did not differ between the groups (10 [4.0%] vs. 9 [3.0%], $p = 0.640$).

To our knowledge, this is the first study to explore these radiographic outcomes with these two stem designs. Previously published studies largely concern the previous iteration of the Group A stem (Accolade TMZF®, Stryker Orthopaedics, Mahwah, NJ, USA). Jacobs et al. reported on 188 primary THAs in which the previous generation stem was utilized, reporting an average subsidence of 1.3 ± 1.7 mm at one year.²²

Table 2
Surgical and clinical outcomes (n = 544).

	Group A/Morphometric (n = 297)	Group B (n = 247)	P value
Surgical Time (minutes)	68.2 (14.3)	71.6 (14.0)	0.047
Length of Stay (days)	0.89 $\pm$ 0.84	0.87 $\pm$ 0.91	0.849
Postoperative Pain	44 (14.8%)	63 (25.5%)	0.007
Groin	13 (4.4%)	11 (4.5%)	
Hip	24 (8.0%)	39 (15.1%)	
Thigh	7 (2.4%)	13 (5.3%)	
Intraoperative Fracture	0 (0.0%)	3 (1.2%)	0.057
Revisions	6 (2.0%)	5 (2.0%)	0.997

Table 3
Radiographic outcomes (n = 544).

	Group A/Morphometric (n = 297)	Group B (n = 247)	P value
Average total subsidence (mm)	1.35 $\pm$ 1.59	1.55 $\pm$ 1.73	0.155
Subsidence ≥ 3 mm	32 (10.8%)	45 (18.2%)	0.014
Subsidence ≥ 5 mm	9 (3.0%)	10 (4.1%)	0.640
Stem Alignment			<0.001
Neutral	291 (98.0%)	206 (86.2%)	
Varus	3 (1.0%)	32 (13.4%)	
Valgus	3 (1.0%)	1 (0.4%)	
Limb Length	12 (4.0%)	6 (2.4%)	0.343
Discrepancy ≥ 3 mm			

Similar to our findings with the most current implant, approximately 10% of hips were found to have subsidence ≥ 3 mm. Interestingly, men demonstrated significantly greater subsidence at one year than women, perhaps prompting the previously described designed changes intended to target this demographic. White et al. analyzed 81 femoral stems of the previous design, finding an average subsidence of 1.4 ± 2.2 mm at two years. They found that larger implants were more likely to subside, as were patients with a smaller canal index.²³ Subsidence, a known cause of early failure after THA, may be caused by poor initial fixation.²⁴ The current stem design allows for a better proximal fit than the previous one which increased in size distally as stem size increased, potentially resulting in increased distal engagement.^{23,25} Furthermore, the second generation stem, which is shorter than its predecessor by approximately 15 mm, showed a reduced percentage of distal engagements compared to the first-generation design.^{7,9,17}

The results presented here support prior research demonstrating favorable outcomes with the current generation, Group A morphometric stem. Grant et al. analyzed 61 fit-and-fill stems and 65 morphometric tapered wedge stems for the percentage canal fill at various bony landmarks, as well as subsidence. The morphometric stem was found to fill a greater percentage of the canal at all landmarks measured and had less subsidence at latest radiographic follow-up (0.3 mm vs. 1.1 mm, $p = 0.001$). Colacchio et al. directly compared the Group A morphometric stem with its prior iteration with regards to intraoperative femur fracture rates, which is a commonly cited concern of cementless components.^{26–28} They found that 41/1510 (2.7%) of the patients who received the first-generation stem experienced intraoperative femur fractures, versus 5/800 (0.6%) patients who received the second-generation stem. The authors attributed the lower rate to the better canal fit promoted by the size-specific medial curvature design. Fleischman et al. performed a similar albeit larger study of 6473 hips, reporting intraoperative fracture rates of 1.8% for the first-generation stem and 0.2% for second-generation stems.⁸

Few studies have published outcomes with the use of the Group B stem. Beaulé et al. sought to determine the geometric and structural parameters of common cementless tapered femoral stems to better understand their early clinical performance with respect to bony fixation and published their preliminary results.¹⁶ The Group B stem was included as was the previous generation of the Group A stem, among others. Stiffness-size curves between different stem designs were similar, but flexibility varied markedly. The first generation stem was found to be the most flexible by a large margin due to the TMZF alloy used (titanium, molybdenum, zirconium and iron alloy; subsequently abandoned in favor of a Ti–6Al–4 alloy), while the Group B stem was found to be stiffer, ranked fourth out of the six stems tested. Theoretically, there may be greater micromotion in more flexible stems, which in turn may inhibit early implant osseointegration and cause subsidence; however, this study did not compare clinical outcomes. Hailer et al. analyzed the Nordic Arthroplasty Register Association database, and identified 22 different types of uncemented stems used in 116,069 procedures; the Group A stem accounted for 2.6% of all stems, while the Group B stem accounted for 0.8%.²⁹ Both stems demonstrated excellent survivorship, with fewer than 25 cases of aseptic loosening after 10 years for each stem. In a study exploring complication rates following the direct anterior approach for THA with several different stem types, 126 Group B stems were included in a cohort of 226 tapered wedge stems.³⁰ There were three total cases (1.3%) of aseptic loosening in this cohort, one of which occurred with the Group B stem. All three patients were revised to a triple taper fit and fill stem.

There are several limitations inherent to this study. All of the cases included in this study were performed by a single surgeon who exclusively utilizes the DAA with assisted fluoroscopy for THA at a high volume academic orthopedic specialty hospital, potentially affecting the generalizability of these results. Moreover, the clinical performance of a tapered wedge stem depends on a complex combination of patient and surgical factors; compatibility stem geometry and specific femoral

morphology was not accounted for here and should be explored in future studies. It is difficult to conclude precisely why a higher proportion of Group B stems resulted in clinically significant postoperative pain than Group A stems, as the reasons for hip and thigh pain following THA are complex and multifactorial.^{31,32} A possible explanation for the Group B stem more likely to be placed in varus could either be due to a technique or stem geometry issue. It is possible that if the Group B stem were to be placed in appropriate alignment there would be less subsidence and less thigh pain. It is also possible that Group B stems were less conducive to the anterior approach leading to a varus position more frequently. Additionally, radiographic follow-up time was limited. Despite this, previous literature has demonstrated that long-term fixation and diminished risk of progressive subsidence occurs during the first three weeks to three months postoperatively.^{14,15} This time period is well-covered by the present study. Possible observer bias may have been introduced due to only the first ten patients having alignment and subsidence measurements done as a tandem.

5. Conclusion

Surgeons who routinely perform an anterior approach for THA can expect largely similar clinical outcomes using both stem designs explored in the present study. Our results suggest modestly improved clinical and radiographic outcomes, especially with regards to hip and thigh pain, subsidence, and malalignment in patients who received a morphometric femoral stem with a size-specific medial radius of curvature. Further studies are warranted to assess the long-term performance of these implants.

Declaration of competing interest

Mr. Gabor, Dr. Singh, and Dr. Padilla has nothing to disclose.

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