



Original research

Reduced Incidence of Perioperative Periprosthetic Fractures Using Hybrid Rasp-Impaction Broaching Over Impaction Broaching When Using the Direct Anterior Approach for Total Hip Arthroplasty

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ABSTRACT

Background: A not infrequent complication encountered with the direct anterior approach is perioperative fracture. The purpose of this study was to compare the incidence of perioperative fractures using a hybrid rasp-impaction broach vs an impaction broach for a similarly designed stem.

Methods: Retrospective study of 798 primary total hip replacements by 1 surgeon performed using noncollared dual tapered femoral stems, including 457 implanted using hybrid rasp-impaction broaching and 341 implanted using impaction broaching. Intraoperative and 90-day postoperative fractures were identified in each group. Bivariate tests and multivariate regression analysis were used to compare the 2 groups.

Results: There were 33 (4.1%) fractures in the sample, 13 (2.8%) with hybrid rasp-impaction broaching and 20 (5.8%) with impaction broaching ($P = .034$). Three (0.7%) intraoperative fractures occurred with hybrid rasp-impaction broaching and 12 (3.5%) with impaction broaching ($P = .003$). Five (1.1%) total calcar fractures occurred with hybrid rasp-impaction broaching and 11 (3.2%) with impaction broaching ($P = .034$). Intraoperative calcar fractures occurred with 1 (0.2%) hybrid rasp-impaction broaching and 6 (1.8%) impaction broaching ($P = .021$). In multivariate analyses, hybrid rasp-impaction broaching had a statistically lower odds ratio (OR) for total fracture (OR 0.45 [0.22 to 0.93]); total intraoperative fracture (OR 0.17 [0.05 to 0.60]); total calcar fracture (OR 0.33 [0.11 to 0.97]); intraoperative calcar fracture (OR 0.11 [0.01 to 0.98]); and rate of readmission (OR 0.27 [0.10 to 0.78]).

Conclusion: The use of a hybrid rasp-impaction broach compared with impaction broach led to a reduced incidence of periprosthetic fractures when using a dual tapered stem through the direct anterior approach.

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Introduction

The anterior approach has become a popular surgical approach for total hip arthroplasty promoting the benefits of minimal invasiveness, reduced dislocation rate, and enhanced early recovery protocols [1–7]. A not infrequent complication encountered with the adaptation of this approach is perioperative fracture [3,8,9]. Jewett and Collis [10] experienced a 2.3% trochanteric fracture rate with a 0.12% femoral fracture rate. Matta et al. [3] had a 1.8%

fracture rate of the hip with a 0.6% ankle fracture rate. Woolson et al. [11] presented a minor complication rate of 0.8% calcar fracture and a major complication rate of 5.7% proximal femoral fracture or greater trochanter fracture and a 0.8% femoral shaft fracture. The consequences of perioperative fractures include increased recovery time, inferior functional outcomes, and increased risk of revision [12].

Past investigations have demonstrated factors associated with perioperative fractures to include age, sex, body mass index (BMI), as well as type of implant [13–17]. The adaptation of a collar prosthesis has also reduced the incidence of fracture [18].

Two common types of broaching systems used for preparation of the femur include impaction broaching and hybrid rasp-impaction broaching. Impaction broaching impacts cancellous

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bone of the metaphyseal and diaphyseal regions of the proximal femur against the cortical perimeter in both the medial/lateral and anteroposterior directions. The hybrid rasp-impaction broach is designed to have rasp teeth in the anteroposterior sides of the broach with compaction teeth in the mediolateral sides of the broach. The rasp teeth are smaller and finer in the distal portion of the rasp and courser proximally to help clear distal bone to prevent distal potting of the implant. The impaction sides of the broach provide compaction of the metaphyseal bone against the cortical bone.

No series to date has evaluated the effect of broach design on the incidence of perioperative femur fractures using the direct anterior approach. The purpose of this study is to compare the incidence of perioperative fractures intraoperatively and within the first 90 days postoperatively for 2 dual tapered prostheses of similar design using separate broaching systems. We hypothesize that the type of broach system utilized affects the incidence of fracture.

Material and methods

A retrospective study was performed comparing the incidence of periprosthetic fractures, intraoperative and within the first 90 days postoperatively, between 2 groups of patients receiving femoral implants of similar design for primary total hip arthroplasty performed through the direct anterior approach. One group underwent arthroplasty using a noncemented dual tapered stem using impaction broaches (DePuy Non-Collared Corail; Warsaw, IN)

(Fig. 1). The second group underwent arthroplasty using a noncemented dual tapered stem using hybrid rasp-impaction broaches (Zimmer Avenir; Warsaw, IN) (Fig. 2). Both the Corail and Avenir stems are dual tapered fully hydroxyapatite-coated ongrowth stems of similar design.

Both implants for this study are noncollared

The 2 groups were identified from an unselected consecutive series of 1754 primary total hip arthroplasties (1428 patients) performed through a direct anterior approach by 1 surgeon (JH) between March 2008 and January 2019. Figure 3 provides a flow diagram showing patient selection. A total of 956 hips were excluded from the study. The group of excluded femoral implants included 27 cemented stems and 929 noncemented stems shown in Table 1.

The remaining 798 primary total hips were performed using noncollared dual tapered femoral stems. Of these, 457 noncollared dual tapered femoral stems were Avenir stems (Zimmer, Warsaw, IN) using hybrid rasp-impaction broaching (Fig. 1), and 341 were Corail noncollared dual tapered stems (DePuy, Warsaw, IN) using impaction broaching (Fig. 2). A fracture table was used in all cases (OSI Hana Table; Union City, CA). Preoperative templating was performed in all cases. Intraoperative decision for stem size was determined by intraoperative fluoroscopic evaluation of broach fit and position in the canal as well as manual evaluation if a larger broach size would fit.

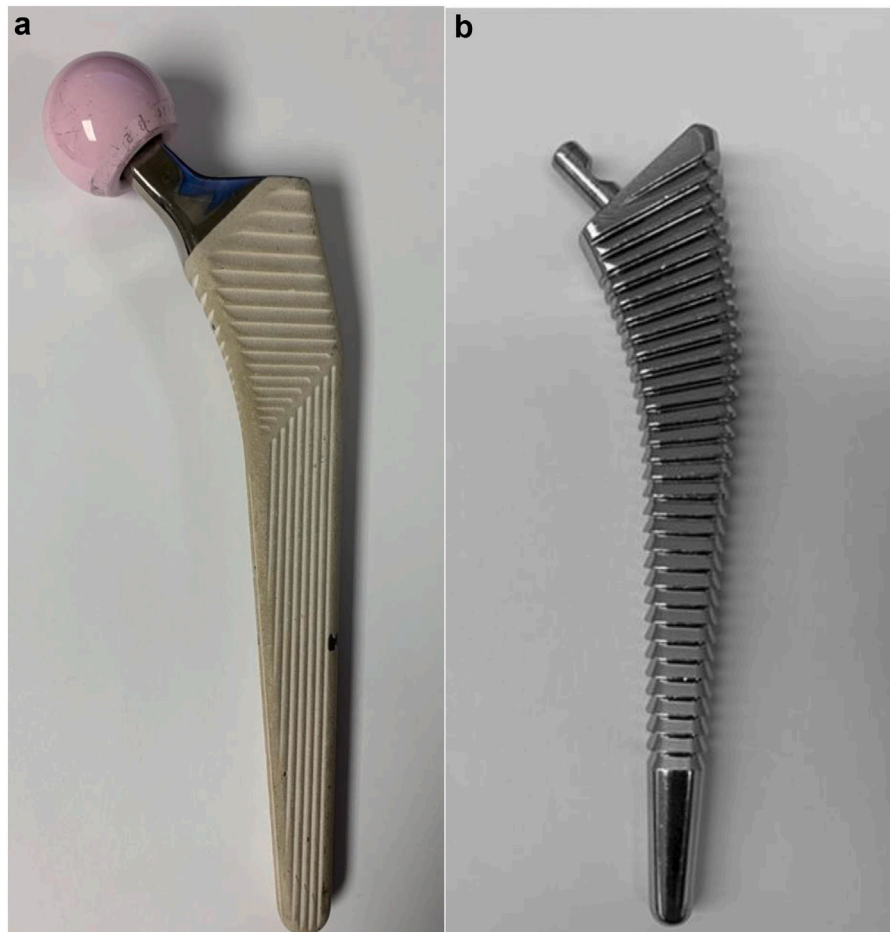


Figure 1. (a) Corail stem. (b) Impaction broach.

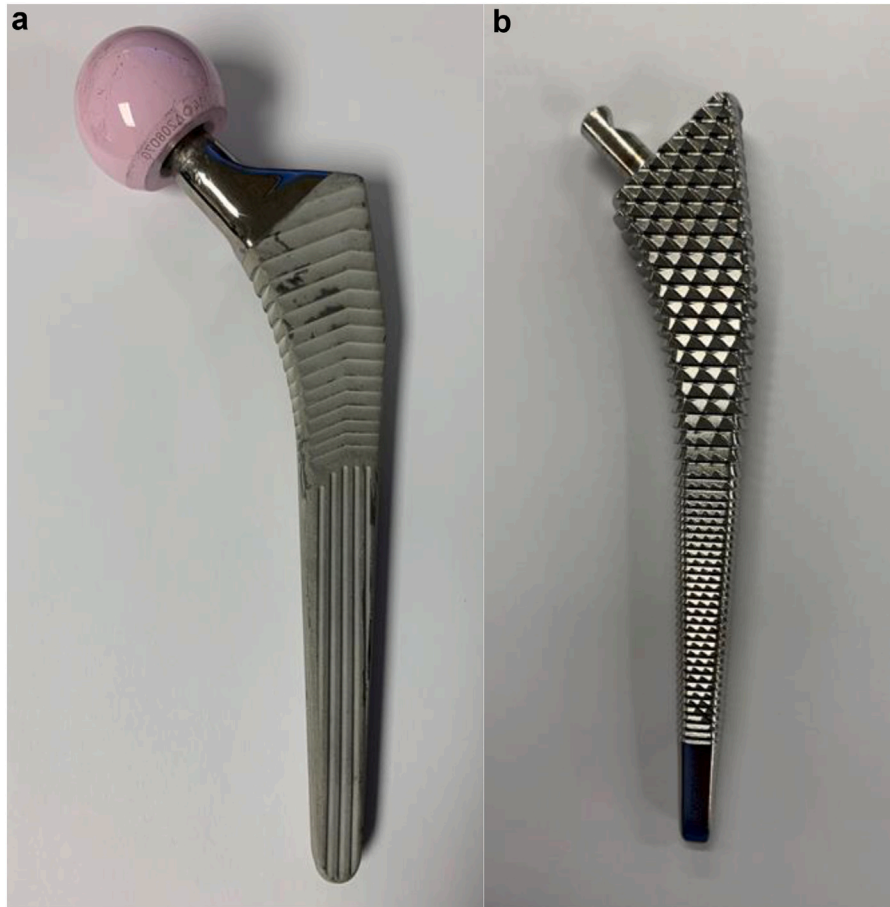


Figure 2. (a) Avenir stem. (b) Hybrid rasp-impaction broach.

Diagnosis for the 457 patients in the hybrid rasp-impaction group consisted of 442 (96.7%) primary osteoarthritis, 11 (2.5%) osteonecrosis, 2 (0.4%) developmental dysplasia of the hip, 1 (0.2%) Perthes, and 1 (0.2%) slipped capital femoral epiphysis. Diagnosis for the 341 patients in the impaction broach group consisted of 317 (92.9%) primary osteoarthritis, 16 (4.7%) osteonecrosis, 3 (0.9%) acute femoral neck fractures, 2 (0.6%) ankylosing spondylitis, 1 (0.3%) femoral neck nonunion, 1 (0.3%) Perthes, and 1 (0.3%) rheumatoid arthritis.

Hospital records including operative reports, postoperative notes, discharge summaries, and postoperative medical records for the first 90 days postoperatively were reviewed. The postoperative endpoint of 90 days coincides with previous studies on postoperative complications [11,17,19]. Age, weight, BMI, sex, side, reoperations, as well as readmissions were extracted from electronic medical records (EPIC, Verona, WI). Records were reviewed for intraoperative and postoperative fractures. Using Intellispace Radiology 4.5 (Philips, Eindhoven, Netherlands), preoperative anteroposterior radiographs of the femur were assessed for DORR ratio and Dorr Type [20]. The inner canal distance at the apex of the lesser trochanter was divided by the inner canal distance at 100 mm inferior of the apex of the lesser trochanter to provide the DORR ratio. The femurs were categorized into Dorr Types according to Dorr Ratio (Dorr ratio < 0.5: Dorr A (Champaigne Flute); Dorr ratio 0.5 to 0.75: Dorr B (Normal); and Dorr ratio > 0.75: Dorr C (Stovepipe)) [21]. The postoperative anteroposterior radiographs of the pelvis and lateral radiographs of the affected hip obtained within the first 90 days postoperative were also evaluated for evidence of intraoperative or postoperative fractures as well. The radiographs were evaluated by the treating surgeon (JH).

Unadjusted univariate comparison of the 2 groups was performed using chi-square analysis, Fisher's exact test, and *t*-tests. We used logistic regression to analyze fracture outcomes, controlling for age, sex, BMI, and ASA scores. We report odds ratios (OR) and 95% confidence intervals for all regression analyses. *P* values ≤ .05 were considered significant. All analyses were conducted using STATA 14.2 (StataCorp LLC, College Station, TX). The Sutter Health Institutional Review Board approved the study protocol.

Results

The series of 798 patients was made up of 331 males and 467 females, 443 right hips and 355 left hips. The right to left ratio and the female to male ratio were similar in the 2 groups. Patient demographics in each group are listed in Table 2. The average age in each group was 66 years (range, 29 to 98). The average BMI was 28.2 (range, 18 to 47) for the hybrid rasp broach group and 28.6 (range, 18 to 56) for the impaction broach group (*P* = .34).

Of the 798 primary hip arthroplasties, a full 90-day follow-up occurred with 781 hips (97.9%). Eleven hips (1.4%) had 60 to 89 days of follow-up, 3 (0.4%) had 30 to 59 days of follow-up, and 3 (0.4%) had less than 30 days of follow-up.

The entire group experienced a total of 33 (4.1%) interoperative and postoperative periprosthetic fractures; 15 (1.9%) were intraoperative, and 18 (2.3%) were postoperative. There were 16 (2.0%) calcar fractures (7 [0.9%] intraoperative, 9 [1.1%] postoperative) and 15 (1.8%) greater trochanter fractures (8 [1.0%] intraoperative, 7 [0.9%] postoperative). There was 1 femoral shaft fracture (0.1%) and 1 intertrochanteric fracture (0.1%) (Table 3).

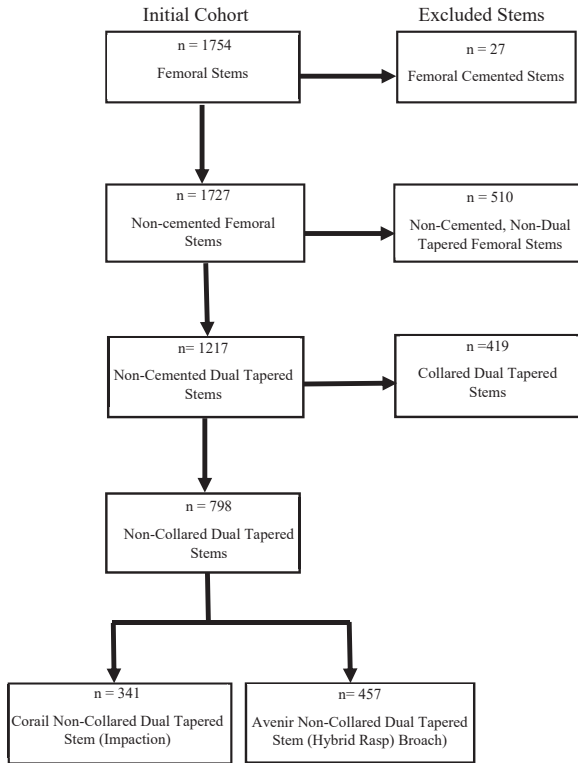


Figure 3. Flow diagram of patient selection.

The fractures in the impaction group included 7 avulsion fractures of the greater trochanter (4 intraoperative and 3 postoperative) and 2 fractures of the greater trochanter during broach removal. Six intraoperative calcar fractures were due to broaching, and 5 fractures postoperative were due to wedging of the stem.

The fractures in the hybrid rasp group included 4 avulsion fractures of the greater trochanter (2 intraoperative and 2 postoperative). Intraoperatively, 1 fracture of the greater trochanter was due to broach removal, and 1 was due to implant insertion. One calcar fracture occurred intraoperative with implant insertion. Two calcar, 1 femoral shaft, and 1 intertrochanteric fractures in the hybrid rasp group occurred due to wedging of the implant postoperatively without an injury and 2 calcar fractures due to wedging of the implant due to a fall. When comparing the incidence of wedging of the implant as a cause for postoperative fractures in the impaction group (63%) to the incidence of wedging as a cause for fracture in the hybrid broach group (60%), there was no statistical difference ($P = .91$).

Three of the 5 postoperative calcar fractures in the impaction broach group required return to the operating room for open

Table 1 List of excluded stems in the original series of 1754 hip arthroplasties.

Cemented stems	Femoral stem types
	23 Cemented Versys (Zimmer, Warsaw, IN)
	4 Summit (DePuy, Warsaw, IN)
Noncemented stems	Femoral stem types
	419 Corail Collared (DePuy, Warsaw, IN)
	488 ML Taper (Zimmer, Warsaw, IN)
	10 Trilock (DePuy, Warsaw, IN)
	5 Fitmore (Zimmer, Warsaw, IN)
	3 Anthrology (Smith, Nephew Richards, Memphis Tennessee)
	2 Polarstem (Smith, Nephew Richards, Memphis Tennessee)
	2 Summit (DePuy, Warsaw, IN)

Table 2 Patient demographics of hybrid rasp-impaction broach group and impaction broach group.

Femoral stem types	Hybrid rasp-impaction (n = 457)	Impaction (n = 341)	P value
Average age (y) (range)	66 ±(9.8)	66 ± 11.1	.41
Right/Left	Right -260 (57%) Left -197 (43%)	Right -182 (53%) Left -159 (47%)	.36
Female/Male	Female - 264 (58%) Male -193 (42%)	Female - 203 (60%) Male -138 (40%)	.62
Body mass index (kg/m ²)	28.2 ± 5.3	28.6 ± 9.5	.34

reduction and internal fixation due to femoral component loosening. The remaining 2 had subsidence of the component into a stable position obtaining ongrowth fixation without further migration. One patient had 11 millimeters of shortening and has been followed up for 7 years postoperatively while the second has had 18 mm of shortening and has been followed up for 10 years postoperatively.

Bivariate results are shown in Table 3. The total number of intraoperative and postoperative fractures was significantly less in the hybrid rasp-impaction broach group, 13 (2.8%), than that in the impaction broach group, 20 (5.8%), ($P = .034$). The difference in total intraoperative fractures was significantly less for the hybrid rasp-impaction broach, 3 (0.7%), than for impaction broaching, 12 (3.5%), ($P = .003$).

With regard to calcar fractures, the total number of hips with calcar fractures intraoperative and within the first 90 days was significantly less in the hybrid rasp-impaction broach group, 5 (1.1%), than that in the impaction broach group, 11 (3.2%), ($P = .034$). The intraoperative calcar fracture rate was also significantly lower in the hybrid rasp-impaction group, 1 (0.2%), than that with impaction broaching, 6 (1.8%), ($P = .021$). The differences in postoperative fractures were not statistically significant.

The incidence of greater trochanter fractures was less overall and in the intraoperative group with hybrid rasp-impaction broaching. This was not statistically significant.

Reoperations were less frequent in the hybrid rasp-impaction broach group, 3 (0.7%) vs 8 (2.3%) in the impaction broach group ($P = .043$). Readmissions were also less in the hybrid rasp-impaction broach group, 5 (1.0%) vs 13 (3.8%) in the impaction broach group ($P = .011$) (Table 4). The average operative time for the

Table 3 Bivariate analyses of fracture data of hybrid rasp-impaction broach group compared with impaction broach group.

Femoral stem types	Total	Hybrid rasp-impaction broaching	Impaction broaching	P value
# Hips	798	457	341	
Total fracture	33 (4.1%)	13 (2.8%)	20 (5.8%)	.034
Intraoperative	15 (1.9%)	3 (0.7%)	12 (3.5%)	.003
Postoperative	18 (2.3%)	10 (2.2%)	8 (2.3%)	.88
Calcar fracture	16 (2.0%)	5 (1.1%)	11(3.2%)	.034
Intraoperative	7 (0.9%)	1 (0.2%)	6 (1.8%)	.021
Postoperative	9 (1.1%)	4 (1.1%)	5 (1.4%)	.43
Greater trochanter fracture	15 (1.9%)	6 (1.3%)	9 (2.6%)	.17
Intraoperative	8 (1.0%)	2 (0.4%)	6 (1.8%)	.06
Postoperative	7 (0.9%)	4(0.9%)	3 (0.9%)	.99
Intertrochanteric fracture (postoperative)	1 (0.1%)	1 (0.2%)	0	1
Femoral shaft fracture (postoperative)	1 (0.1%)	1 (0.2%)	0	1

Table 4

Bivariate analyses of reoperation, readmission, and operative time data of hybrid rasp-impaction group compared with impaction group.

Femoral stem types	Hybrid rasp-impaction	Impaction	P value
Reoperations (%)	3 (0.6%)	8 (2.3%)	.043
Readmissions (%)	5 (1.1%)	13 (3.8%)	.011
Operative time (min)	98 ± 16.2	107 ± 21.6	<.02

impaction group is statistically significantly greater ($P < .001$) (Table 4).

Of the 33 hips with fractures, 22 (66%) were Dorr type A femurs, and 11 (33%) were Dorr type B femurs. Of the 764 hips without fractures, 593 (77%) were DORR type A femurs, and 171 (22%) were Dorr type B femurs with 1 Dorr type C femur. There was no statistically significant difference in the ratio of femurs with fractures to those without ($P = .18$).

Logistic regression analysis with OR and 95% confidence intervals are presented in Table 5. Hybrid rasp-impaction broach had a statistically lower OR for total fracture (OR 0.45 [0.22 to 0.93]); total intraoperative fracture (OR 0.17 [0.05 to 0.60]); total calcar fracture (OR 0.33 [0.11 to 0.97]); intraoperative calcar fracture (OR 0.11 [0.01 to 0.98]); and rate of readmission (OR 0.27 [0.10 to 0.78]). Logistic regression analyses also found statistically significant increased incidence of postoperative calcar fractures with increased age (OR 1.08 [1.01-1.17]) and increased BMI (OR 1.14 [1.04 to 1.260]).

Discussion

Bivariate analyses from this study demonstrated a statistically significant reduction in the incidence of total fractures and total intraoperative fractures when using a hybrid rasp-impaction broaching over impaction broaching for preparation of the femur when using dual tapered stems with the direct anterior approach. Bivariate analysis also showed a significant reduction of calcar fractures in total as well as intraoperative calcar fractures when using the hybrid rasp-impaction broach. Logistical regression analysis, controlling for age, sex, BMI, and ASA scores, confirmed statistically significant reductions in total fractures, total intraoperative fractures, total calcar fractures, and intraoperative calcar fractures. Because of the limited number of intertrochanteric and femoral shaft fractures, we were unable to identify any statistically significant association comparing the 2 broaching systems.

The hybrid rasp-impaction broach preparation differs from impaction broach in that the rasp broach removes cancellous bone debris from the metaphyseal region in the anterior and posterior planes allowing the implant to seat on cortical bone. The pure impaction broach impacts the cancellous bone against the metaphyseal region as well as the cortical bone of the canal. We surmise that impaction broaching increases hoop stresses within the metaphysis, which exceeds the bone integrity primarily in the calcar region but also to a lesser extent within the greater trochanter. This process occurs during the femoral preparation, and this may be the primary cause for an increased incidence of perioperative fractures in the impaction broach group.

Compromise of the bone leading to wedging of the implant postoperatively resulting in fractures occurred in 9 patients without an injury and 2 with injury. The geometry of both implants was similar composed of a more obtuse wedge proximally. There was no statistically significant difference in the percentages of Dorr type A, B, and C femurs in both the fracture group and the non-fracture group.

Table 5
Multivariable regression analyses.

Femoral stem types	Total fracture	Total intraoperative fractures	Total postoperative fractures	Total calcar fracture	Intraoperative calcar fracture	Postoperative calcar fracture	Postoperative greater trochanter fracture	Total greater trochanter fracture	Intraoperative greater trochanter fracture	Postoperative trochanter fracture	Readmission	Reoperation
Age	1.03 (0.99-1.06)	1.00 (0.95-1.05)	1.03 (0.97-1.08)	1.03 (0.98-1.09)	0.98 (0.92-1.06)	1.08* (1.01-1.17)	1.01 (0.96-1.07)	1.01 (0.95-1.09)	1.01 (0.94-1.09)	1.01 (0.94-1.09)	0.99 (0.95-1.04)	0.97 (0.92-1.03)
Sex	1.79 (0.81-3.97)	1.27 (0.41-3.90)	2.81 (0.78-10.21)	1.57 (0.53-4.67)	0.81 (0.16-4.16)	2.3 (0.47-11.66)	2.49 (0.68-9.17)	1.97 (0.38-10.16)	3.38 (0.38-29.85)	3.38 (0.38-29.85)	1.15 (0.43-3.09)	1.02 (0.30-3.49)
ASA	0.94 (0.47-1.88)	0.80 (0.29-2.14)	1.48 (0.55-3.97)	0.41 (0.146-1.14)	0.40 (0.10-1.68)	0.47 (0.12-1.87)	2.17 (0.83-5.74)	1.47 (0.40-5.46)	3.19 (0.77-13.4)	3.19 (0.77-13.4)	2.32 (0.97-5.54)	1.51 (0.48-4.75)
BMI	1.00 (0.98-1.07)	0.96 (0.87-1.07)	1.01 (0.93-1.11)	1.06 (0.98-1.15)	0.90 (0.74-1.10)	1.14* (1.04-1.26)	0.95 (0.86-1.05)	1.00 (0.89-1.12)	0.89 (0.75-1.05)	0.89 (0.75-1.05)	1.02 (0.95-1.10)	1.07 (0.98-1.16)
Hybrid broach	0.45* (0.22-0.93)	0.17* (0.05-0.60)	0.65 (0.23-1.84)	0.33* (0.11-0.97)	0.11* (0.01-0.98)	0.71 (0.18-2.80)	0.48 (0.17-1.38)	0.24 (0.05-1.20)	1.06 (0.23-4.90)	1.06 (0.23-4.90)	0.27* (0.10-0.78)	0.28 (0.07-1.07)
	P = .031	P = .006		P = .045	P = .048	P = .008						P = .015

Values in bold with asterisk signify statistically significant value.

Leg length shortening, stem retroversion, subsidence of the implant, and implant loosening are all morbidities of perioperative fractures. If a fracture occurs postoperatively, the patient may require reoperation for open reduction and internal fixation and possibly revision of the stem. An early return to the operating room for reoperation has been associated with a rate of infection as high as 33% [22]. An infection rate of 6.4% has also been reported by Sheth et al. [17] after reoperation for periprosthetic fracture.

The rates of postoperative fracture within the first 90 days were similar for both groups of rasp designs. This infers that impaction broaching does not produce a greater incidence of subclinical fractures leading to postoperative fractures than hybrid rasp-impaction broaching.

Although previous studies have identified greater age, female sex, and increased BMI as risk factors for perioperative fracture [14–16], in our study, logistical regression analyses were unable to identify a statistically significant increased risk of fracture with regard to female sex or increased BMI or ASA level. Greater age and increased BMI were associated with a statistically significant higher risk of postoperative calcar fracture.

Along with the factors of age, sex, and BMI, implant design has also been implicated in perioperative fractures. Christiansen et al. [23] identified a greater risk of periprosthetic fractures with single tapered ingrowth implants over dual tapered implants with a collar. Instrumentation such as calcar milling with a tooth design have been identified by Berend and Lombardi as a cause for increased incidence of intraoperative calcar fractures [13]. The type of broaching system used with the direct anterior approach has not been previously evaluated.

Logistical regression analyses also found the hybrid rasp broach group had a statistically significant lower incidence of readmission. The greater incidence of readmissions with the impaction broach may be influenced by the negative effect of periprosthetic fractures on readmission rates. Bivariate analyses demonstrated a statistical difference in reoperation rates, but this was not confirmed by logistical regression analyses.

The strength of this study is that the procedures were performed by a single surgeon with the same technique. The surgeon performing the surgery utilizes 2 hospitals, and the decision for implant selection was determined by hospital contracting. The surgeon was comfortable with both systems. One weakness of this study is that it is a longitudinal retrospective study. The study was outside of the surgeon's learning curve of 100 patients [8]. A prospective randomized study would provide an optimal evaluation of the difference in fracture incidence. A second weakness in the study is that although the implants are similar, they are not exactly the same and are produced by different companies.

Conclusions

Hybrid rasp-impaction broaching produces a benefit of reduced risk on periprosthetic fracture over impaction broaching when preparing the femur through the direct anterior approach. The results although are limited to dual tapered stems. The decision to use a dual tapered stem was based on the surgeon's familiarity with the stem and its ease of insertion through the direct anterior approach. Risk of fracture is just one factor when addressing stem choice for surgery. A surgeon should factor in personal familiarity with instrumentation and implant as well as femoral anatomy and surgical approach when choosing a femoral implant for total hip arthroplasty. The purpose of the current study was to solely focus on intraoperative and 90-day postoperative periprosthetic fractures. Future work will address the

long-term durability of the components using the different broaching systems.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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