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Original Research

Does Powered Femoral Broaching Compromise Patient Safety in Total Hip Arthroplasty?

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ABSTRACT

Background: During manual broaching (MB) in total hip arthroplasty (THA), off-axis forces delivered to the proximal femur and broach malalignment can lead to fractures and cortical perforations. Powered broaching (PB) is a novel alternative that delivers consistent impaction forces and reduces workload. This is the first large-scale study to compare intraoperative and 90-day rates of periprosthetic femur fractures (PFFs) and perforations in THA performed using MB vs PB.

Methods: Our institutional database was reviewed for all patients undergoing primary cementless direct anterior THA from 2016 to 2021. Three surgeons performing 2048 THAs (MB = 800; PB = 1248) using the same stem design were included. PFFs and perforations within 90 days of the index procedure were compared. Differences in length of surgery and demographics were assessed.

Results: Calcar fractures occurred in <1% of patients (PB [0.96%, 12/1248] vs MB [0.25%, 2/800]; *P* = .06). Rates of trochanteric fractures did not differ (PB = 0.32% [4/1248] vs MB = 0.38% [3/800]; *P* = .84). Cortical perforations occurred in 0.24% (3/1248) of the PB cohort and in 0.75% (6/800) of the MB cohort (*P* = .09). No revisions due to aseptic loosening or PFF occurred within 120 days of surgery.

Conclusions: Our single-center experience with powered femoral broaching in THA demonstrates PB is a safe and efficient means of performing direct anterior THA. Low rates (<1%) of PFF, perforation, and revision can be achieved. Given our positive experience with PB, all surgeon authors utilize PB nearly exclusively for elective primary direct anterior THA.

Introduction

Preparation of the femoral canal during direct anterior (DA) total hip arthroplasty (THA) has traditionally been accomplished with the use of a manual broach and a mallet [1]. During manual broaching (MB), varying amounts of 3-dimensional force are transmitted to the proximal femur with each mallet strike, including off-axis forces perpendicular to the vector of the advancing broach [2]. Because these horizontal forces are directed outward toward at-risk cortical bone, they may increase the risk of intraoperative complications, such as periprosthetic femur fractures (PFFs) [3,4]. PFFs can cause significant morbidity [5] and occur more commonly in cementless THA, with an overall incidence ranging from 0.1% to 18% [6,7]. Perforations of the posterolateral cortex can also occur and tend to be more subtle. They often are due to malalignment of the broach prior to impaction or excessive broaching [4].

Increased attention has recently been drawn to the health and safety of orthopaedic residents and attending surgeons, with a focus on procedure-related musculoskeletal pain, operative ergonomics, and overuse injuries [8-11]. Studies focusing specifically on adult reconstruction (AR) found that surgeons swing a 3- to 5-lb mallet approximately 300 times per day, a contributing factor toward 66.1% of AR surgeons experiencing a work-related injury and 27% requiring time off as a result [9,11]. The most common injuries reported by AR surgeons include low back pain (28%), lateral

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epicondylitis of the elbow (14%), shoulder tendonitis (14%), lumbar disc herniation (13%), and wrist arthritis (12%) [11].

The advent of a novel powered broaching (PB) device provides an alternative to the manual technique. This device delivers a constant impaction energy (3.5 J) in an efficient and ergonomic manner, with both single-hit and 6 Hz continuous modes available [12]. While PB cannot eliminate off-axis forces, it reduces the variation in off-center strikes to the broach handle surface, which has been shown to decrease the percentage of horizontal forces during impaction [2]. PB decreases the physical burden of manual impact on the operator, which may benefit surgeon health and longevity, although long-term effects remain to be seen. Additional advantages have been shown by Bhimani et al. who compared the 2 techniques for 111 DA THAs and found that PB significantly reduced operating room (OR) time while maximizing femoral stem sizing [13].

The current study was designed based on promising early experience with PB and the potential for patient and surgeon benefit. This is the first large-scale study that aims to compare early postoperative complications and revisions in THA performed utilizing MB vs PB. We hypothesized that no differences would be found between groups.

Material and methods

Institutional review board exemption was obtained prior to the start of the study. Our institutional research database and hospital-based electronic medical record were queried for all adult patients undergoing primary cementless DA THA performed consecutively by 3 fellowship-trained AR surgeons using the same stem design from 2016 through 2021. Study subjects younger than the age of 18 years, revision cases, and THAs performed outside of the hospital setting were excluded. A prototype device was trialed by one surgeon (WGH) from May 2018 to December 2018, and as a result, all cases during that period were excluded for that surgeon. The other surgeons (RAS and CJM) adopted the device in a mixed-use fashion from January 2019 to May 2019. During this time, reliable data on when the device was used were unavailable, so these cases were also excluded. All THAs were done using the PB device beginning in January 2019 for 1 surgeon (WGH) and in June 2019 for the remaining 2 surgeons (RAS and CJM). All cases were done using MB prior to the transition to PB. For subjects in both groups, the femoral canal was prepared using an all-broach technique for a cementless, hydroxyapatite-coated, and triple-tapered collared stem (ACTIS, Depuy Synthes, Warsaw IN, USA). Femoral canal broaching and stem impaction was achieved using a conventional mallet and impactor (MB group) or with PB (PB group) using the KINCISE Surgical Automated System (Depuy Synthes, Warsaw IN, USA) (Fig. 1). There was 1 recorded case where a conical reamer was used in addition to MB by a surgeon (CJM).

Demographic data including sex, age at time of surgery, body mass index, and preoperative American Society of Anesthesiology classifications were analyzed (Table 1). Operating room event times including time entering the room, procedure start and stop time, and time exiting the room were compared between groups (Table 2). Periprosthetic fractures occurring intraoperatively through 90 days of the index procedure and intraoperative cortical perforations were compared between groups with regard to location, timing, and treatment of the fractures (Table 3). PFFs were divided into 2 groups – trochanteric and calcar. The cohort was also reviewed for any cases of aseptic stem loosening within 120 days of surgery and revision surgeries due to loosening or fractures.

Statistical analysis was performed using IBM SPSS Statistics for Windows, v27.0 (IBM Corp., Armonk NY, USA). Continuous variables were analyzed for descriptive statistics including means, standard deviations, and interquartile ranges using a Student's t-test. A chi-square test with Yates correction for large groups and Fisher's exact test for small subgroups was applied to compare fracture and perforation rates with respect to sex, age, and body mass index. Differences in preoperative American Society of Anesthesiology classification between groups were compared using the Mann-Whitney U test. A P value of <.05 was used as the threshold for statistical significance.

Results

A total of 2048 primary DA THA cases (MB = 800; PB = 1248) performed by 3 surgeons were included. At the time of surgery, subjects in the MB group were on average 1.6 years younger (65.6 ± 10.0 (33.2-93.6) vs 67.2 ± 10.5 (21.3-93.3) years; $P < .01$) and had a lower preoperative American Society of Anesthesiology classification (2.3 ± 0.5 vs 2.4 ± 0.5; $P < .01$) compared to the PB group; however, overall differences were small (Table 1). No significant difference in sex or body mass index was found between the 2 groups. PB was associated with a decreased procedural time by approximately 3 minutes (73.1 ± 19.6 vs 75.9 ± 22.5 minutes, $P < .01$) and a shortened total OR duration by approximately 8 minutes (105.5 ± 22.2 vs 113.2 ± 25.8 minutes, $P < .01$) compared to the manual technique (Table 2).

The rate of femoral calcar fracture with PB was 0.96% (12/1248) compared to MB (0.25%, 2/800), which did not reach statistical significance ($P = .06$). The 0.32% (4/1248) trochanteric fracture rate among the PB cases was no different than the 0.38% (3/800) rate among the MB cases ($P = .84$). While the cortical perforation rate of 0.24% (3/1248) in the PB group was lower than the MB rate of 0.75% (6/800), there was no statistical difference between techniques with the numbers available ($P = .09$) (Table 3). All 14 calcar fractures from both groups occurred intraoperatively and were treated with cerclage cable fixation at the time of the index procedure. In the MB group, 3 greater trochanter fractures occurred intraoperatively and were treated conservatively, with weight bearing allowed as tolerated. There were 4 greater trochanter fractures in the PB group; however, all occurred postoperatively and were again treated conservatively. In the 1 MB case where reaming was done in addition to broaching, no PFFs or perforations occurred. Neither group had any cases of aseptic stem loosening within 120 days

Table 1
Patient demographics.

	Manual broaching (MB)	Powered broaching (PB)	*P*-value
	N = 800	N = 1248	
% Female	60%	58%	.20
Age at surgery	65.6 ± 10.0 (33.2-93.6)	67.2 ± 10.5 (21.3-93.3)	**<.01**
Body mass index	28.8 ± 6.3 [N = 794]	29.1 ± 5.9 [N = 1209]	.17
Preoperative ASA	2.3 ± 0.5 [N = 651]	2.4 ± 0.5 [N = 1038]	**<.01**

ASA, American Society of Anesthesiology.
Bold values indicate statistical significance.

Table 2
Length of surgery and OR event times.

	Manual broaching	Powered broaching	*P* value
	N = 733	N = 1106	
Procedure duration (mins)	75.9 ± 22.5 (40.0-177.0)	73.1 ± 19.6 (41.0-196.0)	**<.01**
OR duration (mins)	113.2 ± 25.8 (68.0-222.0)	105.5 ± 22.2 (63.0-236.0)	**<.01**

OR, operating room.
Bold values indicate statistical significance.

Table 3
Comparison of intraoperative through 90-day postoperative complication rates.

	Manual broaching	Powered broaching	*P* value
	N = 800	N = 1248	
All complications	1.38% (11)	1.52% (19)	.79
All fractures	0.63% (5)	1.28% (16)	.15
Trochanteric fractures	0.38% (3)	0.32% (4)	.84
Calcar fractures	0.25% (2)	0.96% (12)	.06
Perforations	0.75% (6)	0.24% (3)	.09

postoperatively and no revisions occurred due to aseptic loosening or PFF.

There was a total of 21 fractures in both groups. Further investigation into the demographic risk factors behind these complications showed that 71.4% (15/21) of fractures occurred in patients older than the age of 65 years and 61.9% (13/21) of these patients were older than 65 years of age and female. For the intraoperative calcar fractures, 57.1% (8/14) occurred in patients older than 65 years of age and 42.9% (6/14) were older than 65 years of age and female. All trochanteric fractures recorded occurred in female patients and all were 65 years of age and older (Table 4). All complications, including fractures and perforations, were analyzed for the case number when each event occurred (Table 5). Because individual surgeons contributed different case volumes to the study, further breakdown of complication rates by surgeon and broaching technique is included in Table 6.

Table 5
Breakdown of all complication events by surgeon and case number.

Group	Case #	Event	Surgeon
Powered broaching	1	Troch fx	WGH
	24	Calcar fx	WGH
	100	Calcar fx	CJM
	133	Troch fx	WGH
	175	Perforation	CJM
	227	Calcar fx	RAS
	332	Calcar fx	WGH
	359	Troch fx	WGH
	388	Calcar fx	WGH
	389	Troch fx	WGH
	530	Calcar fx	CJM
	634	Calcar fx	WGH
	680	Perforation	WGH
	744	Perforation	WGH
	769	Calcar fx	WGH
	836	Calcar fx	WGH
	881	Calcar fx	WGH
	999	Calcar fx	WGH
	1073	Calcar fx	CJM
Manual broaching	111	Perforation	WGH
	123	Calcar fx	WGH
	173	Calcar fx	WGH
	204	Perforation	WGH
	245	Perforation	WGH
	343	Perforation	WGH
	350	Perforation	WGH
	352	Perforation	WGH
	453	Troch fx	WGH
	557	Troch fx	CJM
	622	Troch fx	WGH

Discussion

Our investigation demonstrates low rates of PFFs, cortical perforations, and revisions with the use of a novel PB technique in THA. When analyzing all fracture cases, we found the majority occurred in female patients over the age of 65 years, which corroborates previous studies describing the independent risk factors for PFFs in THA [6,7,14]. Our results indicate that older age and female sex may particularly predispose patients to fractures of the greater trochanter, as all 7 patients who experienced trochanteric PFFs fit those demographics. Our data also shows an apparent increase in calcar fractures with PB (0.96%) compared to MB (0.25%) that does not reach statistical significance ($P = .06$). With this difference in fracture rates, only 48% power is achieved. However, with the available study population in the PB ($n = 1248$) and MB ($n = 800$) groups, the test reaches 80% power when there is a 1.2% difference statistically. Regarding the small difference ($P = .09$) in cortical perforation rates between PB (0.24%) and MB (0.75%), this may be explained in part by the more consistent and less forceful impactions with PB. Rather than perforating, it is reasonable to assume the broach deflects off the lateral cortex in cases where greater force may have caused a perforation. The importance of this investigation is that it is the first large study demonstrating the operative and short-term safety profile of powered femoral broaching in THA.

Our results suggest a significantly shorter duration of surgery with PB compared to manual. We believe the reduction in OR time may be even greater than we report, as the most junior surgeon (RAS) began practice in 2019 and exclusively used PB during their practice learning curve. Patients included in the MB cohort consisted of cases done by surgeons that had previously performed a minimum of 400 DA THA. However, increased surgeon and OR staff experience over multiple years cannot be ruled out as an explanation of decreased OR times and likely contributed in the PB group. While increased efficiency in the operating room may benefit hip arthroplasty patients by decreasing the risk of deep surgical site and periprosthetic joint infections, the 3 minutes of procedure time saved with PB is likely not large enough to provide any clinical benefit [15-17]. In addition to time saved, the short-term advantages of using PB from the surgeon's perspective are clear: improved ergonomics and decreased physical workload while operating. Longitudinal studies would be required to determine the benefits to surgeon health and longevity with the use of automated surgical tools such as the PB device described in this study.

A recent investigation by Bhimani et al. [13] was the first to compare powered femoral broaching in THA with the manual technique; however, their limited sample size of 111 THAs prevented an adequate analysis of adverse events as they reported only one – an intraoperative nondisplaced calcar fracture in an elderly female with osteoporosis. Other recent investigations have reported low overall rates of PFFs in primary DA THA that corroborate

Table 4
Breakdown of fracture events by age and sex.

	Number of events	Male	Female	Age >65 y	Age >65 y and female
All fractures	N = 21	6 (28.6%)	15 (71.4%)	15 (71.4%)	13 (61.9%)
Calcar fractures	N = 14	6 (42.9%)	8 (57.1%)	8 (57.1%)	6 (42.9%)
Trochanteric fractures	N = 7	0 (0%)	7 (100%)	7 (100%)	7 (100%)

Table 6
Breakdown of complication rates by surgeon and broaching technique.

MD	MB cases	MB comp. rate	PB cases	PB comp. rate	Total comp. rate
CJM	159	0.63%	350	1.14%	0.98%
RAS	-	-	228	0.44%	0.44%
WGH	641	1.56%	670	2.09%	1.83%
Total	800	1.38%	1248	1.52%	1.46%

our results [18,19]. Most notably, a multicenter study of 5090 primary DA THAs reported a PFF rate of 0.84%, which falls between the 0.25% (MB) and 0.96% (PB) PFF rates in our study groups [18]. The most frequently used femoral implant in that large study was a press-fit, cementless, and collared design like the stem utilized in this investigation. However, it should be noted that the broach described in this study functions by compacting and extracting bone, whereas other designs may only remove or compact bone. It is unclear how the specific broach differences may impact fracture rates.

The investigation does have limitations. The inherent nature of this retrospective study design makes detection bias a possibility. Extensive measures are taken at our institution to prevent omission of any adverse events during or after surgery through an established protocol for the past 20 years; however, it is possible that there were unrecorded fractures or perforations. The follow up window was limited to 90 days to best capture these events, based on our expectation that short-term complications would be treated by the operative surgeon and thus recorded in our database. Still, it is possible that patients sustained complications and sought care elsewhere that was not recorded. Additionally, there may have been instances during the PB study period where MB was performed if the device was broken or unavailable. While these occurrences were rare, we are unable to retrospectively track individual cases when the device was not used. For one surgeon (WGH), data on conical reamer use was only available for 2021. Although there were no cases with the reamer recorded during this year, we are unable to capture earlier cases for this surgeon when it may have been used. However, as this device is rarely utilized at our institution, we expect that these cases would constitute a small portion of all THAs and be distributed among both groups. The exclusion of data from the prototype and mixed-use periods by our 3 surgeons slightly reduced the potential study population size but fortunately limited the impact of a learning curve using PB on our results, as these periods were during the initial adoption of the device. Future prospective studies that include analysis of preoperative bone classifications would build on the findings of this study and add further understanding of fracture risk in THA using PB. Finally, this study was conducted at a single-institution with high-volume, fellowship-trained surgeons using 1 PB device and one stem design. As a result, the generalizability of these findings may not be applicable to other implants or PB tools.

Conclusions

Our single-center experience with powered femoral broaching in THA demonstrates PB is a safe and efficient means of performing DA THA. Low rates (<1%) of PFFs, cortical perforations, and 120-day revisions can be achieved. Given our positive experience with PB, all surgeon authors currently utilize this method nearly exclusively for elective primary DA THAs.

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Conflicts of interest

William G. Hamilton is speakers bureau for Depuy Synthes and Total Joint Orthopaedics; receives royalties from Depuy Synthes and Total Joint Orthopaedics; is a paid consultant for Depuy Synthes and Total Joint Orthopaedics; and receives research support from Biomet, Depuy Synthes, and Inova Health Care Services. Robert A. Sershon is a paid consultant for 2ndMD. All other authors declare no potential conflicts of interest.

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Figure 1. Continuous powered broaching is performed via an offset handle attachment connected to the femoral broach.

References

[1] Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty: indications, technique, and results. J Am Acad Orthop Surg 2014;22:595–603. https://doi.org/10.5435/JAAOS-22-09-595.

[2] Greenhill DA, Abbasi P, Darvish K, Star AM. Broach handle design changes force distribution in the femur during total hip arthroplasty. J Arthroplasty 2017;32:2017–22. https://doi.org/10.1016/j.arth.2016.12.031.

[3] Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res 2005;441:115–24.

[4] Schwartz JTJ, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. J Bone Joint Surg Am 1989;71:1135–42.

[5] Haughom BD, Basques BA, Hellman MD, Brown NM, Della Valle CJ, Levine BR. Do mortality and complication rates differ between periprosthetic and native hip fractures? J Arthroplasty 2018;33:1914–8. https://doi.org/10.1016/j.arth.2018.01.046.

[6] Sershon RA, McDonald 3rd JF, Ho H, Hamilton WG. Periprosthetic femur fracture risk: influenced by stem choice, not surgical approach. J Arthroplasty 2021;36:S363–6. https://doi.org/10.1016/j.arth.2021.02.012.

[7] Abdel MP, Watts CD, Houdek MT, Lewallen DG, Berry DJ. Epidemiology of periprosthetic fracture of the femur in 32 644 primary total hip arthroplasties: a 40-year experience. Bone Joint J 2016;98-B:461–7. https://doi.org/10.1302/0301-620X.98B4.37201.

[8] McQuivey KS, Deckey DG, Christopher ZK, et al. Surgical ergonomics and musculoskeletal pain in orthopaedic surgery residents: a multicenter survey study. J Am Acad Orthop Surg Glob Res Rev 2021;5:e20.00119. https://doi.org/10.5435/JAAOSGlobal-D-20-00119.

[9] Ryu RC, Behrens PH, Malik AT, Lester JD, Ahmad CS. Are we putting ourselves in danger? Occupational hazards and job safety for orthopaedic surgeons. J Orthop 2021;24:96–101. https://doi.org/10.1016/j.jor.2021.02.023.

[10] Vajapey SP, Li M, Glassman AH. Occupational hazards of orthopaedic surgery and adult reconstruction: a cross-sectional study. J Orthop 2021;25:23–30. https://doi.org/10.1016/j.jor.2021.03.026.
[11] Alqahtani SM, Alzahrani MM, Tanzer M. Adult reconstructive surgery: a high-risk profession for work-related injuries. J Arthroplasty 2016;31:1194–8. https://doi.org/10.1016/j.arth.2015.12.025.
[12] Konow T, Batz J, Beverland D, et al. Variability in femoral preparation and implantation between surgeons using manual and powered impaction in total hip arthroplasty. Arthroplast Today 2022;14:14–21. https://doi.org/10.1016/j.artd.2021.10.005.
[13] Bhimani AA, Rizkalla JM, Kitziger KJ, Peters Jr PC, Schubert RD, Gladnick BP. Surgical automation reduces operating time while maintaining accuracy for direct anterior total hip arthroplasty. J Orthop 2020;22:68–72. https://doi.org/10.1016/j.jor.2020.03.057.
[14] Ponzio DY, Shahi A, Park AG, Purtill JJ. Intraoperative proximal femoral fracture in primary cementless total hip arthroplasty. J Arthroplasty 2015;30:1418–22. https://doi.org/10.1016/j.arth.2015.02.043.
[15] Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. J Bone Joint Surg Br 2005;87:844–50. https://doi.org/10.1302/0301-620X.87B6.15121.
[16] Namba RS, Inacio MCS, Paxton EW. Risk factors associated with surgical site infection in 30 491 primary total hip replacements. J Bone Joint Surg Br 2012;94-B:1330–8. https://doi.org/10.1302/0301-620X.94B10.29184.
[17] Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. Clin Orthop Relat Res 2008;466:1710–5. https://doi.org/10.1007/s11999-008-0209-4.
[18] Barnett SL, Peters DJ, Hamilton WG, Ziran NM, Gorab RS, Matta JM. Is the anterior approach safe? Early complication rate associated with 5090 consecutive primary total hip arthroplasty procedures performed using the anterior approach. J Arthroplasty 2016;31:2291–4. https://doi.org/10.1016/j.arth.2015.07.008.
[19] Berend KR, Mirza AJ, Morris MJ, Lombardi Jr AV. Risk of periprosthetic fractures with direct anterior primary total hip arthroplasty. J Arthroplasty 2016;31:2295–8. https://doi.org/10.1016/j.arth.2016.03.007.