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Two- to 4-Year Followup of a Short Stem THA Construct: Excellent Fixation, Thigh Pain a Concern

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Abstract
Background Short stem cementless femoral components were developed to aid insertion through smaller incisions, preserve metaphyseal bone, and potentially decrease or limit the incidence of thigh pain. Despite some clinical success, the senior author (DDG) believed a higher percentage of his patients who had received a cementless short stem design were experiencing thigh pain, which, coupled with concerns about bone ingrowth fixation, motivated the review of this case series.

Questions/purposes (1) What is the proportion of patients treated with a short stem cementless THA femoral component that develop thigh pain and what are the hip scores of this population? (2) What are the radiographic results, specifically with respect to bone ingrowth fixation and stress shielding, of this design? (3) Are there particular patient or procedural factors that are associated with thigh pain with this short stem design?
Methods Two hundred sixty-one primary THAs were performed in 238 patients by one surgeon between November 2010 and August 2012. During this time period, all patients undergoing primary THA by this surgeon received the same cementless short titanium taper stem. Seven patients (eight hips) died and five patients (five hips) were lost to followup, leaving 226 patients (248 hips) with a mean followup of 3 years (range, 2–5 years). Patients rated their thigh pain during activity or rest at final followup on a 10-point visual analog scale. Harris hip scores (HHS) were obtained at every clinic appointment. Thigh pain was evaluated at the final followup or by contacting the patient by phone. Radiographs were evaluated for bone-implant fixation, bone remodeling, and osteolysis. An attempt was made to correlate thigh pain with patient demographics, implant specifications, or radiographic findings.
Results Seventy-six percent of hips (180 of 238) had no thigh pain, 16% of hips (37 of 238) had mild thigh pain, and 9% (21 of 238) had moderate or severe thigh pain. Preoperatively, mean HHS was 47 (SD, 16) and at last followup, mean HHS was 88 (SD, 13). There were two femoral revisions, one for severe thigh pain and the other for infection. All but two components demonstrated bone ingrowth fixation (99%). Femoral stress shielding was mild in 64% of hips (135 of 212), moderate in 0.5% (one of 212), and severe in no hips. There is an inverse linear

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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relationship between age and severity of thigh pain ($r = -0.196$; $p < 0.0024$).
Conclusions Although reliable fixation was achieved and good HHS were attained, the frequency and severity of thigh pain with this short cementless stem were concerning. The surgeon has subsequently abandoned this short stem design and returned to a conventional length stem. Future study direction might investigate the biomechanical grounds for the thigh pain associated with this stem design.
Level of Evidence Level IV, therapeutic study.

Introduction

Conventional length cementless THA is an established treatment for end-stage arthritis of the hip. THA is now a viable option for younger, active, patients and those with a high body mass index [1]. With this population, effective THA requires preservation of the metaphyseal bone, effective femoral revision options, and easier insertion options through less invasive approaches [18, 27, 36, 45]. Short stem cementless femoral components were developed to preserve metaphyseal bone after THA through proximal load transfer. In addition, shorter broach-only stems can provide easier insertion, especially through smaller direct anterior approaches [18, 27, 36, 45]. Earlier studies have shown that short stems have similar risks of revision as well as comparable fixation and clinical outcomes to conventional length stems [2, 40, 49].

Numerous variations of short stem devices have been designed [11]. Despite increased use of short femoral stems and excellent short- to midterm results, there are still relatively little data on individual short stem designs [49]. It is remains unclear whether all cementless short femoral stem designs are able to achieve comparable long-term clinical results to traditional stems while also achieving the goals of preserving metaphyseal bone and limiting thigh pain. One of the authors (DDG) began using the Tri-Lock Bone Preservation Stem (DePuy, Warsaw, IN, USA) exclusively for all primary THAs in his practice in November 2010. He observed what he believed to be increased thigh pain in these patients as well as radiographic concerns regarding bone fixation of the stem, prompting a more detailed study of this cohort.

With these observations in mind, the authors asked: (1) What is the proportion of patients treated with a short stem cementless THA femoral component that develop thigh pain and what are the hip scores of this population? (2) What are the radiographic results, specifically with respect to bone ingrowth fixation and stress shielding, of this design? (3) Are there particular patient or procedural factors that are associated with thigh pain with this short stem design?

Patients and Methods

Between November 2010 and August 2012, 261 primary THAs (238 patients) were performed by the senior author. All of those procedures used the design reviewed here and no patients undergoing primary THA were selectively treated with another design. At 2 to 4 years after the index THA, 226 patients (248 hips [95%]) were living, seven patients (eight hips [3%]) had died, and five patients (five hips [2%]) were lost to followup. The stem reviewed in this study is a titanium, circumferentially proximally coated mediolateral (ML) taper short femoral stem, which was implanted with a 32- or 36-mm modular cobalt-chrome or ceramic femoral head (Fig. 1). The stem length (95–119 mm) increases with ML size. The femoral component was implanted with the Pinnacle Sector 2 acetabular component (DePuy) in all hips. Highly crosslinked polyethylene (Altrex; DePuy) liners were used in all hips.

The mean age of the patients at the time of the index THA was 64 years (range, 21–91 years) and there were 104 men and 134 women. One patient had a preoperative

Fig. 1 This is a photograph of the Tri-Lock® Bone Preservation Stem.

diagnosis of osteonecrosis and all other patients had a preoperative diagnosis of osteoarthritis. Consent for study participation was obtained as per the protocol previously approved by the institutional review board. Mean clinical followup was 3 years (range, 2–5 years) for living patients and 3 years (range, 0.04–5 years) for the entire cohort.

All surgical procedures were performed by the author (DDG) through an anterolateral approach. The stem was inserted with a broach-only technique. For all cases, the acetabulum was reamed to 1 mm less than the diameter of the component used. One, two, or three 5-mm titanium alloy dome screws were used to augment fixation at the surgeon's discretion.

Patients were progressed to full weight bearing as tolerated, typically transitioning from a walker or crutches to a cane to no support over a period of 4 weeks.

An AP pelvis radiograph was obtained in the recovery room, at 6 weeks, and at 1-year followup. AP pelvis and frog leg lateral hip films were performed at 2- to 3-year intervals after the 1-year followup. Crosstable lateral radiographs were only obtained if there was concern for instability or iliopsoas tendinitis. Patients returned to the clinic for followup or, if they were unable to return, received local radiographs, which were sent to us for evaluation. Early postoperative and interval followup radiographs included AP projections of the pelvis that included the tip of the femoral prosthesis and lateral projections of the femur that included the hip.

Followup clinical evaluation of the patients included the Harris hip score (HHS) [20], a history and examination, and determination of whether future revision surgery was planned. HHS was obtained preoperatively and at every clinic visit. Patients were given the surveys over the phone or answered them alone (on paper or through the Internet). Patients were also asked if they had thigh pain at their most recent followup visit. The question did not specify whether the pain was at rest or during activity. If a patient wanted clarification on what thigh pain was, the author who administered the survey (RLA) clarified that it was pain occurring below the hip and above the knee. If they responded "yes," the followup questions asked them how often they had thigh pain (all the time, most of the time, some of the time, a little of the time, or never), a single location where the pain was located (front, side, or back), and to rate their thigh pain on a 10-point visual analog scale [3, 4]. For the HHS, a higher score reflects higher function. On the visual analog scale used for thigh pain (0–10), higher score reflects more severe pain. Radiographic observations and measurements were based on the AP radiographs from the early postoperative period and those at final followup. Among the 226 living patients not lost to followup (248 hips), 217 (88%) hips had a minimum 2-year followup radiograph. Some patients were willing to take the survey but refused to participate in the radiographic followup. Two authors not involved in the surgery reviewed all radiographs (RLA, JJC) with interpretation reported by consensus. Correction for magnification was completed by standardizing all measurements against the known size of the femoral head. Femoral component fixation was evaluated for bone ingrowth, stable fibrous fixation, or unstable fibrous fixation according to the criteria of Engh et al. [9]. Femoral component subsidence was determined using the relationship of the top of the lesser trochanter to the medial aspect of the stem collar, defined as a decrease of at least 5 mm between the initial postoperative radiograph and those from final followup. Osteolysis was defined as any nonlinear radiolucency at the bone-prosthesis interface that was at least 5 mm according to the seven femoral zones defined by Gruen et al. [17]. Femoral component stress shielding was defined using a modification of the criteria defined by Engh and Bobyn [8]. Mild stress shielding was limited to the upper third of the implant, moderate stress shielding extended to the middle third, and severe stress shielding extended below the middle third. Acetabular components were evaluated for bone-prosthesis radiolucencies and acetabular component migration according to the criteria of Massin et al. [12, 21, 28]. The definition of acetabular osteolysis was the same as that for femoral osteolysis. Radiographic evidence of loosening was defined as definite or probable loosening, including cases revised for femoral loosening or unstable fibrous fixation.

We were interested to see if the presence and severity of thigh pain correlated with any of the patient demographics, implant specifications, HHS, or radiographic findings. Pearson correlation coefficients were calculated for continuous categories: age, body mass index, and HHS. T-tests were used to compare variables with two groups: sex, stem offset, head type (cobalt-chrome and ceramic), head diameter, and cortical hypertrophy. Analysis of variance was used for categorical variables with more than two categories: stem size, stress shielding and stem position. Probability values < 0.05 were considered significant.

Results

A total of 16% of patients (37 hips) had mild thigh pain, 7% (16 hips) had moderate, and 2% (five hips) had severe thigh pain (Fig. 2). Of the patients with thigh pain, 49% reported having it a little of the time, 34% reported some of the time, 14% reported most of the time, and 3% had thigh pain all the time. Forty-four percent of patients with thigh pain located the pain anteriorly, 51% laterally, and 5% posteriorly. Preoperatively, mean HHS was 47 (SD, 16) and at last followup, mean HHS was 88 (SD, 13). There were five reoperations, two for infection, two for heterotopic ossification, and one for thigh pain. One of the infections required a femoral revision. The two hips with heterotopic ossification were bilateral THAs in the same patient and neither required femoral revision. The overall proportion of femoral component revision was 0.8% (two hips).

Radiographic evaluation of the 217 hips in living patients with minimum 2-year radiographic followup (average, 3 years) demonstrated femoral bone ingrowth in 215 (99%) hips. For the two hips that did not have bone ingrowth, both demonstrated stable fibrous ingrowth radiographically at 2.4- and 2.9-year followup. Of the seven patients (eight hips) who died before the minimum 2- to 4-year followup, all stems were bone-ingrown at last followup. None of the patients who died had undergone revision surgery before their death. The patients who showed sclerosis on most recent radiographs (13 hips) reported no thigh pain. The patients without sclerosis (204 hips) had a mean thigh pain of 0.38 on a scale of 0 to 10. These groups were statistically different ($p < 0.001$). Femoral stress shielding was mild in 64% (135 of 217 hips), moderate in 0.5% (one of 217 hips), and severe in no hips. Radiographic evaluation of the acetabular construct showed all of them to be osseointegrated (212 of 217 hips). Stem position was neutral in 89%, varus in 8%, and valgus in 2%. Cortical hypertrophy was present in 2% (four hips). Of the original 248 hips, there were five reoperations.

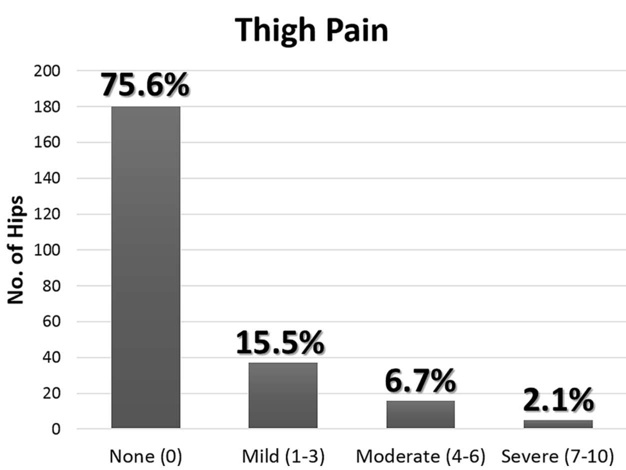

Fig. 2 Patient-reported thigh pain from the visual analog scale is shown.

Of the factors tested, younger age and lower HHS were correlated with increasing severity of thigh pain ($p < 0.05$). Pearson correlation coefficient for age and thigh pain showed a very weak correlation ($r = -0.196$, $p = 0.0024$). Correlation coefficient for HHS was weakly correlated with thigh pain ($r = -0.39804$, $p < 0.001$).

Discussion

Short stem cementless femoral components were developed to preserve metaphyseal bone by proximal load transfer, simplify insertion in less invasive exposures, and potentially limit thigh pain. The use of short femoral stems has increased over the last decade [49]. Although the preservation of metaphyseal bone and ease of insertion may seem intuitive, what remains unresolved with short stem designs is whether they can achieve comparable functional and radiographic results to standard length stems in the long term and also maintain a low frequency of thigh pain. We therefore evaluated a series of patients who received one short femoral stem design in an attempt to answer these questions. Although functional and radiographic results were generally satisfactory, there was a concerning proportion of patients who reported thigh pain in our series.

Table 1. Comparison of cohort demographics

Demographic	Conventional stem*	Short stem
Total number of patients (number of hips)	88 (100)	238 (261)
Average age at index surgery (years; range)	62 (25–90)	64 (21–91)
Sex, percent of patients (percent of hips)	Male 42 (40)	Male 44 (44)
	Female 58 (60)	Female 56 (56)
Average body mass index (kg/m^2; range)	30 (18–60)	30 (16–56)
Preoperative diagnosis, percent of hips (number of hips)	Osteoarthritis 79 (88)	Osteoarthritis 100 (260)
	Avascular necrosis 5 (8)	Avascular necrosis 0.4 (1)
	Rheumatoid arthritis 2 (2)	
	Protrusio 1 (1)	
	Nonunion/malunion 1(1)	

* Goetz et al. [16].

Table 2. Summary of short stem studies

Study	Implant name	Implant design	Number of hips	Average postoperative HHS	Thigh pain	Average age (years)	Average followup (years)	Stem revisions for aseptic loosening
Ghera and Pavan [13]	Proxima (DePuy International Ltd, Leeds, UK)	Wedge femoral neck sparing short stem	50	91	0	70	2	0 (0%)
Lazovic and Zigan [26]	Metha (B. Braun Aesculap, Tuttlingen, Germany)	Modular femoral neck sparing short stem	55	92	2	48	1	0 (0%)
Molli et al. [29]	Taperloc Microplasty (Biomet, Inc, Warsaw, IN, USA)	Tapered flat-wedge short stem	269	83	NR	63	2	0 (0%)
Morales de Cano et al. [30]	GTS (Biomet, Inc)	Tapered short stem with elliptic-octagon cross-section	81	Merle d'Aubigne score: 16	0	65	1	0 (0%)
Morrey [31]	Mayo (Zimmer International, Warsaw, IN, USA)	Short stem with high valgus neck	20	98	0	NR	2	1 (5%)
Morrey et al. [32]	Mayo (Zimmer International)	Double tapered short stem modular neck	159	90.4	0	51	6	3 (2%)
Patel et al. [35]	Shortened version of Citation (Stryker Orthopaedics, Mahwah, NJ, USA)	Anatomic off-the-shelf short stem	65	88	0	75	3	0 (0%)
Patel et al. [34]		Anatomic custom short stem	69	96	0	56	6	0 (0%)
Pipino et al. [37]	Biodynamic (Howmedica, Mahwah, NJ, USA)	Anatomic femoral neck sparing with collar	44	37% excellent, 45% good	6	63	13–17	0 (0%)
Rohrl et al. [39]	CFP (Waldemar Link, Hamburg, Germany)	Modular femoral neck sparing short stem	26	93	NR	54	2	0 (0%)
Santori and Santori [41]		Custom high-neck resection short stem	129	95	0	51	8	0 (0%)
Falez et al .[10]	Mayo (Zimmer International)	Double-tapered short stem modular neck	160	NR	0	64	5	2 (1%)
Briem et al. [5]	CFP (Waldemar Link)	Modular femoral neck sparing short stem	155	96	0	60	6	1 (1%)
Kress et al. [25]	CFP (Waldemar Link)	Modular femoral neck sparing short stem	84	92	NR	58	7	1 (2%)
Gustke [18]	Fitmore (Zimmer, Inc, Warsaw, IN, USA)	Proximally coated curved trochanter-sparing	500	NR	NR	67	1	0
Wittenberg et al. [50]	Metha (B. Braun Aesculap)	Proximally coated partial collum with neck-preserving osteotomy	250	97	NR	60	5	3 (2%)
Thorey et al. [47]	Metha (B. Braun Aesculap)	Proximally coated partial collum with neck preserving osteotomy	151	90	0 severe thigh pain	56	6	2 (2%)
Kendoff et al. [23]	CFP (Waldemar Link)	Modular femoral neck sparing short stem	149	93	NR	64	12	4 (4%)

Table 2. continued

Study	Implant name	Implant design	Number of hips	Average postoperative HHS	Thigh pain	Average age (years)	Average followup (years)	Stem revisions for aseptic loosening
Hutt et al. [22]	CFP (Waldemar Link)	Modular femoral neck-sparing short stem	75	91	NR	52	10	0
Stulberg and Dolan [44]		Custom metaphyseal-engaging ultrashort stem	65	93	NR	56	3	0
Toth et al. [48]	Proxima (DePuy International Ltd, Leeds, UK)	Wedge femoral neck-sparing short stem	41	88	0	49	2	0
Kim et al. [24]	Proxima (DePuy International Ltd)	Wedge femoral neck-sparing short stem	144	96	0	54	5	0
Hagel et al. [19]	Mayo (Zimmer International)	Double-tapered short stem modular neck	316	93.6	NR	NR	NR	5
Goebel and Schultz [15]	Mayo (Zimmer International)	Double-tapered short stem modular neck	30	Merle d'Aubigne score: 18	NR	57	7	3
Synder et al. [46]	Metha (B. Braun Aesculap)	Proximally coated partial collum with neck-preserving osteotomy	30	97	0	43	1	0
Schmidutz et al. [42]	Metha (B. Braun Aesculap)	Proximally coated partial collum with neck-preserving osteotomy	80	96	NR	55	3	0
Ender et al. [7]	CUT (ESKA Implants, Lübeck, Germany)	Neck-sparing	123	NR	3 requiring revision	53	5	7 (5%)
Gill et al. [14]	CFP (Waldemar Link)	Modular femoral neck-sparing short stem	79	88% excellent or good	1 requiring revision	52	5	0
Pons [38]	CFP (Waldemar Link)	Modular femoral neck-sparing short stem	138	92	NR	58	3	0
Cinotti et al. [6]	IPS (DePuy, Warsaw, IN, USA)	Metaphyseal anatomic portion, a pronounced lateral flare, proximal porous coating	84	88	5 (8%) no revisions	68	Minimum 9 years	0
Sperati and Ceri [43]	Tri-Lock BPS (DePuy)	Proximally coated tapered wedge	101	NR	0	69	2	1 (1%)

HHS = Harris hip score; NR = not reported.

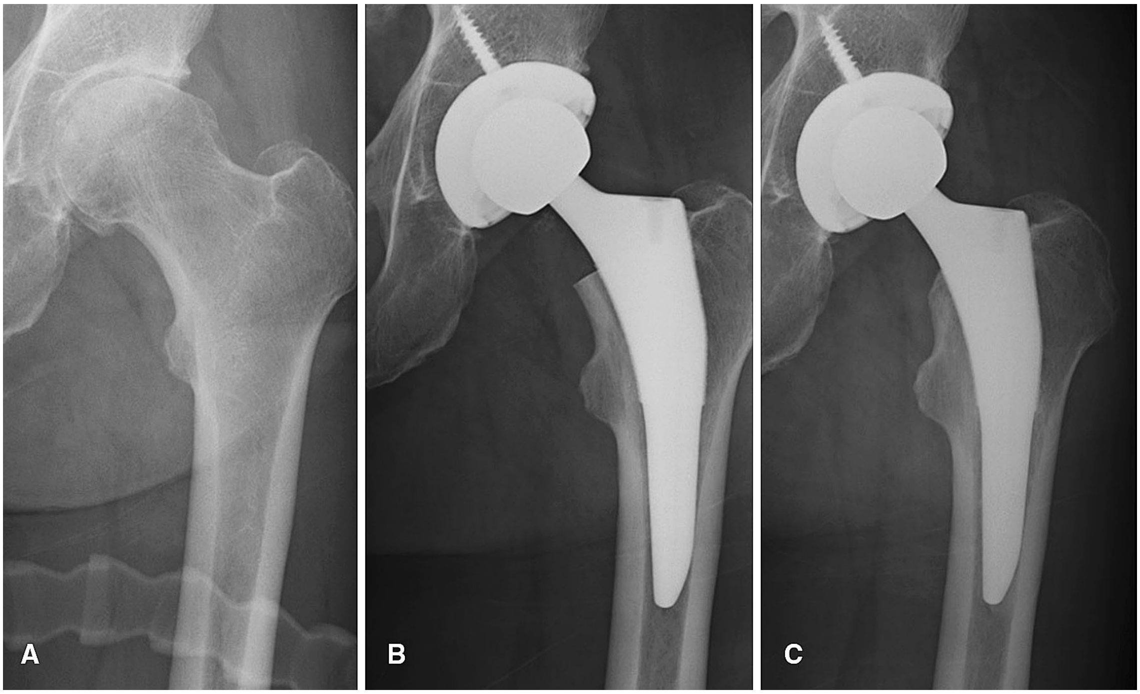

Fig. 3A–C This is an example of a 71-year-old man who underwent THA at age 68 years with the following clinical scores at most recent followup: 100, 75, and 83 on the WOMAC pain, stiffness, and function scores, respectively; a HHS of 94; SF-36 Physical and Mental scores of 52 and 62, respectively; a Tegner of 2; and a UCLA score of 6. (**A**) On the left is a preoperative AP radiograph. (**B**) A 6-week postoperative AP radiograph is shown. (**C**) On the right is a 3-year final followup AP radiograph.

This study has a number of limitations. This is a single surgeon's case series; the surgeon could be making an unrecognized systematic technical error that could adversely impact the results seen here, or conversely his results using this stem may not be generalizable to other surgeons with less experience. The HHS and thigh pain survey were administered using the most convenient means for the patient. This included options to take the survey on the Internet, over the phone, or in person in the clinic, if possible. Although patients were asked specifically if they had "thigh pain," hip pain, trochanteric bursitis, or abductor tendonitis, lumbar spine radicular pain and thigh pain may be hard for some patients to differentiate. A single author (RLA) administered the surveys, defining thigh pain as any pain below the hip/groin and above the knee. Additionally, the study is relatively short term, especially for a THA followup, and thigh pain may modulate over time. The author who performed all of the operations only used this implant for approximately 4 years. This study follows the first 22 months of the 4-year period. After the enrollment of this study was concluded, four stems failed to become successfully ingrown. This finding and the increased thigh pain ultimately led to the author abandoning its use. Finally, this study has similar limitations as all other radiographic studies of THA, including inter- and intraobserver variability of radiographic measurements. However, all radiographic findings were agreed on by two observers (JJC, RLA). We also acknowledge that determining the amount of stress shielding is somewhat problematic because of the variability of radiographic quality and observer interpretations. However, we used an established grading system that evaluates patterns of bone remodeling.

Thigh pain was substantial and moderate or severe in 9% of patients (9% of hips) who received this stem. The same surgeon earlier reported his experience using a conventional length cementless stem [16] with similar demographics to this group (Table 1). The patient-reported frequency of moderate or severe thigh pain (21 of 238 hips [9%]) using this short tapered stem was much greater than that reported with the standard length tapered stem (one of 100 hips [1%]) [16]. Our reported thigh pain is also higher than that reported in another followup study using the same femoral stem by Sperati and Ceri [43]. In their observational study, they reported minimal thigh pain but no description of the data collected was given. It is unclear whether their patients were specifically queried regarding presence, location, and severity of thigh pain, which might explain the difference in findings. Only five of the studies of short stems reviewed (Table 2) reported any thigh pain at all [6, 7, 14, 26, 37]. Two studies reported thigh pain requiring revision surgery [7, 14]. Cinotti et al. reported that three of the five cases of thigh pain in their series appeared to be unrelated to the THA procedure [6]. Pipino et al. [37] reported six cases of thigh pain but five of them resolved within 1 year. Nam et al. reported pain of any type in a young, active patient population receiving THA and surface replacement arthroplasty (SRA) [33]. They reported 10% of their population with anterior thigh pain, 8% with lateral thigh pain, and 5% with posterior thigh pain in the THA group. These numbers are not directly comparable to our study because they allowed patients to select more than one area of thigh pain on clinical surveys and also used a scale from 0 to 5 with specific descriptors of pain. Nam et al. theorized that the THA population has a higher prevalence of thigh pain than the SRA group because the patients undergoing SRA retain a more physiologic stress transfer [33]. We theorize that the thigh pain seen in our study may be related to the modulus mismatch between the stem tip and bone at the high stress subtrochanteric region of the femur and we are designing future experiments in the biomechanics laboratory to test this hypothesis. Because this is a short-term followup, there is the possibility that a subset of the thigh pain may resolve on its own similar to the Pipino et al. study, but in a later timeframe [37].

At a minimum 2-year followup, our clinical results showed no femoral components were revised for aseptic loosening. There was one femoral revision for thigh pain and one femoral revision for infection. Two patients showed stable fibrous fixation. These results are comparable or superior to other short stem reports in terms of revision frequency and HHS outcomes at short-term followup [5–7, 10, 13–15, 18, 19, 22–26, 29–32, 34, 35, 37–39, 41–44, 46–48, 50].

The radiographic results using this stem are comparable to conventional length cementless THA in terms of fixation and revision. The short stem and the traditional length stem demonstrated similar results in the author's (DDG) practice in terms of femoral fixation: 99% bone ingrowth for the short stem and 99% for the traditional length stem [16]. Femoral stress shielding was mild in 64% (135 hips), moderate in 0.5% (one hip), and severe in no hips using this short stem. The conventional length stem previously reported showed mild stress shielding in 58%, moderate in 11%, and severe in 3% of hips. Kress et al. found a similar rate of stress shielding in a short femoral stem reporting 36% and 26% of hips having stress shielding in Gruen Zones 1 and 7, respectively [25]. The senior author (DDG) had consistent radiographic results with this short stem construct (Fig. 3). The metaphyseal loading of the short stem may be contributing to the preservation of the bone at the proximal end of the femur.

Younger patients reported more thigh pain than older patients. This finding corroborates the study by Nam et al. that showed a high percentage of young patients undergoing THA experiencing pain [33]. Presumably, younger patients are more active and put more stress on the implant than older, sedentary patients.

At 2- to 4-year followup of this ML taper short stem (DePuy Tri-Lock Bone Preservation Stem), patients reported considerably more thigh pain than the same surgeon's experience with a more conventional length stem. With 9% of patients describing moderate or severe thigh pain, the senior author discontinued his use of this stem. Although the thigh pain was concerning, it must be noted that patients did report excellent return to function and 99% of stems obtained bone ingrowth with minimal stress shielding. Further studies with longer followup, larger cohorts, and multiple surgeons are needed to corroborate these concerns, but in the interim, the primary surgeon has returned to a conventional length stem in primary THA.

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