Clin Orthop Relat Res (2012) 470:450–461
DOI 10.1007/s11999-011-2068-7

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

SYMPOSIUM: PAPERS PRESENTED AT THE ANNUAL MEETINGS OF THE HIP SOCIETY

A Short Tapered Stem Reduces Intraoperative Complications in Primary Total Hip Arthroplasty

Ryan G. Molli DO, Adolph V. Lombardi Jr MD, FACS, Keith R. Berend MD, Joanne B. Adams BFA, Michael A. Sneller BS

Published online: 5 October 2011

Abstract

Background While short-stem design is not a new concept, interest has surged with increasing utilization of less invasive techniques. Short stems are easier to insert through small incisions. Reliable long-term results including functional improvement, pain relief, and implant survival have been reported with standard tapered stems, but will a short taper perform as well?

Questions/purposes We compared short, flat-wedge, tapered, broach-only femoral stems to standard-length, double-tapered, ream and broach femoral stems in terms of intraoperative complications, short-term survivorship, and pain and function scores.

Patients and Methods We retrospectively reviewed the records of 606 patients who had 658 THAs using a less invasive direct lateral approach from January 2006 to March 2008. Three hundred sixty patients (389 hips) had standard-length stems and 246 (269 hips) had short stems. Age averaged 63 years, and body mass index averaged 30.7 kg/m^2. We recorded complications and pain and function scores and computed short-term survival. Minimum followup was 0.8 months (mean, 29.2 months; range, 0.8–62.2 months).

Results We observed a higher rate of intraoperative complications with the standard-length stems (3.1%; three trochanteric avulsions, nine femoral fractures) compared with the shorter stems (0.4%; one femoral fracture) and managed all complications with application of one or more cerclage cables. There were no differences in implant survival, Harris hip score, and Lower Extremity Activity Scale score between groups.

Conclusions Fewer intraoperative complications occurred with the short stems, attesting to the easier insertion of these devices. While longer followup is required, our early results suggest shortened stems can be used with low complication rates and do not compromise the survival and functional outcome of cementless THA.

One or more of the authors (AVL, KRB) receive royalties and institutional research support from and have consulting agreements with Biomet, Inc (Warsaw, IN, USA). One author (KRB) has consulting agreements with Salient Surgical Technologies (Portsmouth, NH, USA). One author (AVL) receives royalties from Innomed, Inc (Savannah, GA, USA).
All ICMJE Conflict of Interest Forms for authors and *Clinical Orthopaedics and Related Research* editors and board members are on file with the publication and can be viewed on request.

Each author certifies that his or her institution has 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.
This work was performed at Joint Implant Surgeons, Inc.

R. G. Molli, A. V. Lombardi Jr (✉), K. R. Berend, J. B. Adams, M. A. Sneller
Joint Implant Surgeons, Inc, 7277 Smith's Mill Road, Suite 200, New Albany, OH 43054, USA
e-mail: LombardiAV@joint-surgeons.com

A. V. Lombardi Jr, K. R. Berend
Department of Orthopaedics, The Ohio State University, Columbus, OH, USA

A. V. Lombardi Jr
Department of Biomedical Engineering, The Ohio State University, Columbus, OH, USA

R. G. Molli, A. V. Lombardi Jr, K. R. Berend
Mount Carmel Health System, New Albany, OH, USA

Level of Evidence Level III, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Although THA is continually noted as one of the most successful procedures performed by orthopaedic surgeons worldwide, current research and development continue to strive to improve on the biologic and mechanical designs of modern total hip prostheses. A multitude of published studies report overall survivorship of several standard-length tapered femoral components ranging from 94% to 100% at up to 20 years' followup [10–12, 17–20, 25, 27–29, 33, 35, 42, 43, 47, 52–55, 58–60]. We recently reported femoral implant survival rates of 98.6% at 5 years, 98.4% at 10 years, 97.1% at 15 years, and 95.5% at 20 years in 2000 standard-length tapered titanium porous plasma-sprayed femoral components (Mallory-Head® Porous [MHP]; Biomet, Inc, Warsaw, IN, USA) [43]. Cementless femoral fixation with tapered-geometry designs has evolved over the past several decades with a recent surge of interest in shorter stems.

Short stems are thought to preserve more native host bone and optimize proximal load transfer, and while not a novel concept, they have become increasingly utilized with the advent of less invasive surgery and rapid-recovery protocols [15, 24, 40, 56, 62, 66]. There are several proposed advantages of short stems, including easier insertion through smaller incisions and less invasive techniques, simpler femoral preparation with a "broach only" system, and their basic inherent bone-conserving nature allowing for more favorable conditions in the potential revision setting. Several studies have demonstrated overall survivorship of short stems ranging from 94% to 100% at up to 18 years' followup and incidences of thigh pain ranging from 0% to 4% [13, 15, 28, 33, 52, 54]. To justify using shorter tapered stems when more traditional standard-length tapered stems provide pain relief, restore function, and have high survivorship [9–11, 17–19, 25, 42, 43, 58, 60], it is important to show advantages with equal long-term survivorship and demonstrate similar intraoperative reproducibility with equivalent and/or decreased perioperative complications.

We therefore compared short, flat-wedge, tapered, broach-only femoral stems to standard-length, double-tapered, ream and broach femoral stems in terms of intraoperative and perioperative complications, short-term survivorship, and pain and function scores.

Present Address:
R. G. Molli
Orthopedic Institute of Michigan, 14555 Levan Road, Suite 116, Livonia, MI 48154, USA

Patients and Materials

Institutional review board approved informed consent for historical prospective clinical study was obtained from all patients undergoing THA. We performed a retrospective analysis from a query of our electronic medical record system (DocuMed, Inc, Ann Arbor, MI), revealing 879 consecutive patients (953 hips) who underwent primary THA from January 2006 through March 2008 by two surgeons (AVL, KRB). All patients were managed with a rapid-recovery protocol [8, 41]. The majority of cases (70%; 671 hips) were performed via a less invasive direct lateral approach (LIDL) [6], while a standard direct lateral approach was used in 10% (100 hips), and one surgeon (KRB) beginning in February 2007 used an anterior supine intermuscular approach in 182 hips (19%). To eliminate the possible confounding variable of different surgical approaches as an influence on complication incidence and functional outcome, only cases performed via the LIDL approach were included. Thirteen LIDL cases were excluded in which other femoral stem types were implanted: four cemented stems, six hydroxyapatite-coated stems, two modular stems with a porous proximal sleeve, and one device which was part of a US Food and Drug Administration (FDA) investigational feasibility study. Therefore, our cohort was 606 patients (658 hips) who underwent primary THA using tapered, titanium, porous plasma-sprayed femoral components inserted via a single LIDL approach (Table 1). There were a total of 51 staged bilateral procedures and one simultaneous bilateral procedure. In terms of operative side, 357 (54%) were right hips and 301 (46%) were left hips. A standard-length taper, the MHP femoral component, was implanted in 389 hips (59%), with 110 (28%) being a lateralized offset option. The MHP was introduced and has been used in our practice since 1984. The TaperLoc® stem (Biomet) was introduced in 1982, and a shortened version, the TaperLoc® Microplasty™ femoral component received FDA approval in 2005 and was introduced into clinical use in our practice in January 2006. The lateralized option became available in May 2007. The short stem was implanted in 269 hips (41%), with 173 (64%) being a lateralized offset option. The stem type for patients during the study period was chosen by the surgeons in a nonsystematic manner consistent with the typical process of trialing and implementing any newly available approved device into clinical use. The two groups were similar in age, body mass index, sex, and underlying diagnosis including rheumatoid arthritis. One surgeon (AVL) performed a higher proportion of arthroplasties within the short-stem group, because while the other surgeon (KRB) continued to use the short stem, he began to use the anterior supine intermuscular approach. More ceramic heads and fewer metal-on-metal bearings were used in the short stem group

Table 1. Characteristics of standard-length taper and short taper stem groups

Characteristic	Standard-length stem group	Short-stem group	p value
Patients (number)	360	246	
Primary hips (number)	389	269	
Time period	January 2006 to March 2008	January 2006 to March 2008	
Average age (years)	63 (20–89)	63 (27–91)	0.532
Average body mass index (kg/m^2)	31.0 (17–66)	30.1 (19–60)	0.101
Sex			0.130
Male	185 (51%)	111 (45%)	
Female	175 (49%)	135 (55%)	
Preoperative diagnosis			0.119
Osteoarthritis	323 (83%)	209 (78%)	
Avascular necrosis	21 (5%)	27 (10%)	
Developmental dysplasia	16 (4%)	12 (5%)	
Posttraumatic arthritis	8 (2%)	6 (2%)	
Rheumatoid arthritis	10 (3%)	3 (1%)	
Legg-Calvé-Perthes disease	7 (2%)	1	
Acute fracture	3 (1%)	4 (2%)	
Slipped capital femoral epiphysis	1	3 (1%)	
Psoriatic arthritis	0	2 (1%)	
Failed ORIF (degeneration)	0	1	
Failure resurfacing (cup migration)	0	1	
Surgeon			0.000
AVL	250 (64%)	215 (80%)	
KRB	139 (36%)	54 (20%)	
Head material			0.027
Cobalt-chromium	381 (98%)	233 (95%)	
BIOLOX® delta ceramic	8 (2%)	13 (5%)	
Acetabular component*			0.023
Magnum™ (Biomet)	261 (67%)	158 (59%)	
RingLoc® (Biomet)	105 (18%)	99 (37%)	
Regenerex® (Biomet)	5 (1%)	10 (4%)	
Trabecular Metal® (Zimmer)	12 (3%)	2 (1%)	
Trident® Tritanium® (Stryker)	2	0	
C2a-Taper™ (Biomet)	4 (1%)	0	
Femoral component offset			0.044
Standard offset	279 (72%)	173 (64%)	
Lateralized offset	110 (28%)	96 (36%)	

* Manufacturers included: Biomet, Inc, Warsaw, IN, USA; Zimmer, Inc, Warsaw, IN, USA; and Stryker Orthopaedics, Mahwah, NJ, USA; ORIF = open reduction and internal fixation; AVL = Adolph V. Lombardi, Jr; KRB = Keith R. Berend.

as ceramic heads became available in larger sizes and awareness increased regarding adverse reactions to metal-on-metal. More lateralized option stems were required in the short-stem group because the standard offset neck shaft angle of that device is more valgus (138° versus 136.5°) than the standard-length taper standard offset neck. The minimum followup for the standard-length group was 0.8 months (average, 30.9 months; range, 0.8–61.2 months) and the minimum followup for the short-stem group was 0.9 months (average, 26.9 months; range, 0.9–62.2 months). Twenty-six patients (28 hips) died within the study period at an average of 22 months postoperatively, with none related to the arthroplasty procedure and no THA failures. Two of the patients who died had not returned for a post-operative evaluation. Of the surviving patients, 74% (469) had minimum 2-year followup. Four living patients, with two from each group, did not return for clinical evaluation and could not be located. Clinical data from all patients

Fig. 1 The MHP femoral component, introduced in 1984, is a double-tapered titanium stem with a proximal porous plasma-sprayed surface applied circumferentially around the stem. The middle section is grit-blasted and the distal section has a matte finish. The device is available in 14 standard offset sizes with a neck angle of 136.5°, diameters from 6 to 19 mm, and lengths from 135 to 180 mm, and 10 lateralized offset sizes with a neck angle of 131.5°, diameters from 8 to 17 mm, and lengths from 145 to 180 mm. (Reproduced with permission of Joint Implant Surgeons, Inc, New Albany, OH.)

Fig. 2 The TaperLoc® Microplasty™ femoral component is a tapered, titanium, porous plasma-sprayed device available with either standard or lateralized offset and in 13 sizes, with diameters ranging from 5 to 25 mm and lengths ranging from 95 to 135 mm. The neck shaft angle is 138° for both standard and lateralized offset options, with lateralization achieved by shifting the trunnion medially. (Reproduced with permission of Joint Implant Surgeons, Inc, New Albany, OH.)

were included. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs.

The MHP femoral component is a titanium collarless stem with a proximal-to-distal taper in both the coronal and sagittal planes (double taper) and three separate surface finishes (Fig. 1). The proximal 1/3 is plasma-sprayed with titanium alloy, the midsection is grit-blasted, and the distal surface is a smooth satin finish. The system requires both reaming and broaching. The design features fins proximally that engage the cortical-cancellous junction to resist rotational moments about the implant in the proximal femur. There are seven different neck length options available and a lateralized neck offset option that allows for increased abductor tension and hip stability without lengthening of the limb.

The TaperLoc® Microplasty™ femoral component is a titanium collarless stem with a flat, tapered-wedge geometry (3° medial to lateral taper) with a proximal, titanium, porous plasma-sprayed surface (Fig. 2). This is a broach-only system. The collarless feature allows for optimal component seating and enhanced rotational stability. There are seven neck length options, and a lateralized neck offset option is available.

We used the same surgical approach for every case in this series: the LIDL approach [6], a less invasive modification of the direct lateral approach previously described by Frndak et al. [23] (Fig. 3). We performed preoperative templating in each case to assist in determining component size (both femoral and acetabular) and the appropriate neck resection level. The LIDL approach utilized a more oblique skin incision centered over the tip of the greater trochanter and angled from anterodistally to posteroproximally. The surgeons then incised the fascia lata in line with the skin incision, with minimal undermining between the subcutaneous fat and fascia lata to minimize dead space. The assistants then simultaneously abducted and slowly externally rotated the leg as the surgeon began taking down the anterior-most insertional fibers of the gluteus medius from distal to proximal beginning at the vastus ridge. At this stage, dissection was performed with electrocautery to

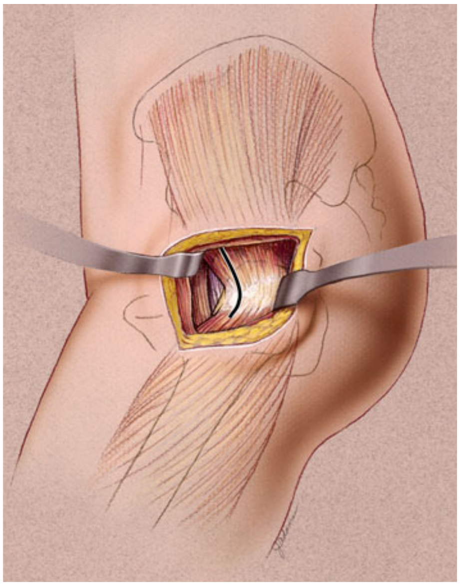

Fig. 3 The LIDL approach to the hip is performed by elevating the gluteus medius insertion along with the capsule in one continuous soft tissue sleeve from the anterior aspect of the trochanter. The origin of the vastus lateralis is left intact and dissection proceeds anterior and medial below the vastus muscle. (Reproduced with permission of Joint Implant Surgeons, Inc, New Albany, OH.)

allow for hemostasis. The anterior aspect of the vastus lateralis was incised in line with its fibers to allow for one continuous sleeve to be elevated off of the anterior femur. Working proximally toward the anterior-proximal-most tip of the greater trochanter, the fibers of the gluteus medius were split at an angle of 45° and bluntly dissected in an anterior and proximal direction for a few centimeters, directly in line with the femoral neck. A blunt Homan-type retractor was then placed deep to the gluteus medius, exposing the anterior-most fibers of the gluteus minimus and anterior hip capsule. The capsule was incised proximally along the superior aspect of the femoral neck, possibly including a small portion of the gluteus minimus tendon. This generally corresponded to a 1 o'clock position in a right hip. Then, the femoral head was resected and standard acetabular and femoral preparation was performed with either the standard-length or short tapered instrumentation and implants. We encountered a femoral or trochanteric fracture during femoral preparation in 13 patients; in these patients, we stabilized the fracture with one or more cerclage cables or wires [9].

We allowed patients full weightbearing as tolerated with a walker or crutches immediately postoperatively and advised them to progress to a cane and eventually without any ambulatory assistance once they were pain-free and without a limp.

We saw patients at approximately 6 weeks postoperatively and yearly thereafter, unless a problem arose in which case patients were seen as soon as possible. At each clinical examination, radiographs were obtained, including an AP view of the pelvis and a lateral view of the involved hip. In addition, a standard physical examination was performed, including evaluation of the wound and strength assessment of the involved hip. Pain, deformity, ROM, and function were rated using the Harris hip score (HHS) [26] and activity level rated using the Lower Extremity Activity Scale (LEAS) of Saleh et al. [61]. We reviewed perioperative records for incidence of intraoperative complications, operative times, and estimated blood loss; and discharge and office notes for hemoglobin level at discharge, length of acute stay, discharge disposition, implant-related complications, and need for further surgery. Intraoperative records were available for all THAs. Discharge notes were available for 95%.

We used chi square analysis to compare difference in incidence of intraoperative complications between the two groups. We used a two-tailed Student's t test to compare differences in mean HHSs, pain scores, and LEAS scores between the two groups.

Results

More intraoperative complications (fractures) occurred when the standard-length tapers (n = 12; 3.1%) were implanted compared with the short tapers (n = 1; 0.4%). The location of these fractures utilizing the Mallory classification [9, 46] were three trochanteric avulsions, seven Type I femoral fractures, and two Type III fractures within the standard-length stem group. One Type I femoral and two of the trochanteric avulsions were in patients with rheumatoid arthritis. The fracture in the short-stem group was a Type I femoral fracture in a patient with rheumatoid arthritis (Table 2). Other complications within the standard-length stem group included four acetabular revisions (three for loosening, one for metal sensitivity) (1.0%), one temporary (< 12 hours) sciatic nerve palsy (0.2%), and one chronic sciatic nerve palsy (0.2%). Other complications in the short-stem group included two acetabular revisions (0.7%), one for cup migration and one for acetabular fracture/cup protrusion. There was no difference in incidence of complications between the two surgeons.

We observed two stem failures requiring revision, one from each group for an overall incidence of stem failure for any reason of 0.26% in the standard-length stem group and 0.37% in the short-stem group. There were no patients with aseptic loosening in either group. The first failure was a periprosthetic femur fracture in the standard-length stem group, which we identified 2 weeks after the primary procedure (Fig. 4). We revised the patient to a larger MHP stem with cerclage cables and she was doing well at latest

Table 2. Results for standard-length taper and short taper stem groups

Parameter	Standard-length stem group	Short-stem group	p value
Intraoperative complications (number)	12 (3.1%)	1 (0.4%)	0.013
Avulsion of trochanter	3	0	
Femoral fracture Type I	7	1	
Femoral fracture Type II	0	0	
Femoral fracture Type III	2	0	
Average operative time (minutes)	69.5	67.4	0.162
Average estimated blood loss (mL)	146.8	140.9	0.332
Average hemoglobin at discharge (g/dL)	11.1	11.0	0.328
Average length of acute stay (days)	2.1	2.0	0.184
Discharge disposition (number)			0.181
Not available	21 (5.4%)	15 (5.6%)	
Home	263 (67.6%)	189 (70.3%)	
Home with home health or therapy	14 (3.6%)	15 (5.6%)	
Home with outpatient therapy	2 (0.5%)	4 (1.5%)	
Skilled nursing facility	87 (22.4%)	44 (16.4%)	
Transferred to acute care	2 (0.5%)	2 (0.7%)	
Average clinical preoperative (points)			
HHS pain (0–44)	13.8	13.0	0.077
HHS total (0–100)	50.0	49.9	0.980
LEAS score (1–18)	9.1	9.3	0.772
Average clinical at 6 weeks postoperatively (points)			
HHS pain (0–44)	37.6	38.5	0.181
HHS total (0–100)	75.8	75.4	0.674
LEAS score (1–18)	7.7	7.8	0.784
Average clinical at most recent followup (points)			
HHS pain (0–44)	38.5	38.0	0.496
HHS total (0–100)	83.8	83.1	0.570
LEAS score (1–18)	10.1	9.8	0.384
Reoperations (number)	5 (1.3%)	6 (2.2%)	0.156
Incision and débridement, wound issue	0	3 (1.1%)	0.068
Cup revision, loosening	3 (0.8%)	2 (0.7%)	0.347
Cup revision, metal sensitivity	1	0	0.591
Stem revision, fracture	1	0	0.591
Full revision, sepsis	0	1	0.409

HHS = Harris hip score; LEAS = Lower Extremity Activity Scale.

followup. The second patient was in the short-stem group and had continued pain, radiolucencies around the femoral component on plain radiographs, and a bone scan with increased uptake, suggesting aseptic loosening versus infection. Laboratory analysis demonstrated elevated erythrocyte sedimentation rate and C-reactive protein 19 months after the index procedure and we performed a radical débridement with antibiotic spacer placement. The patient subsequently underwent reimplantation with a standard-length stem and revision acetabular component and was doing well at most recent followup.

Between groups, there were no differences in preoperative or postoperative HHSs or LEAS scores at 6 weeks and most recent followup (Table 2).

Discussion

There has been much evidence demonstrating standard-length, tapered, titanium, porous plasma-sprayed components perform well in the short, mid, and long term [10–12, 17–20, 25, 27–29, 33, 35, 42, 43, 47, 52–55, 58–60]. With

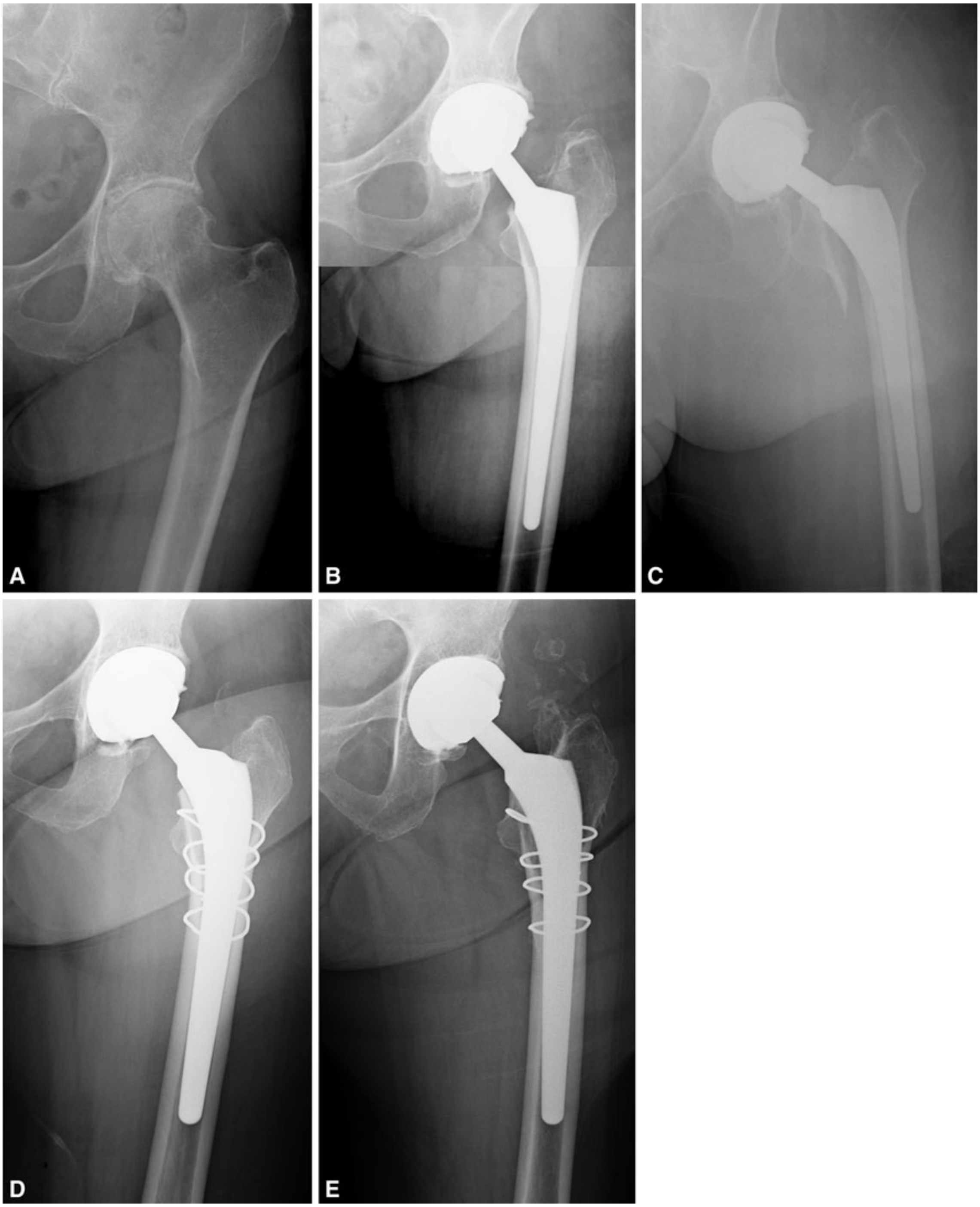

Fig. 4A–E (**A**) A preoperative radiograph of the left hip of a 79-year-old female patient who presented with severe pain and discomfort secondary to osteoarthritis shows severe joint space narrowing, sclerosis, and osteophyte and cyst formation. (**B**) An immediate postoperative radiograph shows treatment of cementless primary left THA with an 11- by 160-mm standard-length taper stem with lateralized offset and a 36-mm cobalt-chromium head with +6-mm neck articulated against highly crosslinked polyethylene. (**C**) At 2 weeks postoperative, the patient presented emergently with severe pain. A radiograph reveals a periprosthetic femoral fracture. (**D**) The patient's femoral component was revised to a 14- by 175-mm standard-length tapered stem with lateralized offset, and the bone was secured with five cerclage cables. (**E**) A radiograph at 3 years after revision shows well-fixed components in satisfactory position and alignment. The patient had a HHS of 94 at latest followup.

recent interest in less invasive surgery through smaller incisions, shorter cementless stems have been popularized and utilized to achieve femoral fixation [15, 24, 40, 56, 62, 66]. We therefore compared the intraoperative and perioperative complication rate, short-term survival, and preoperative and postoperative HHSs and LEAS scores for

Table 3. Published studies reporting incidence of intraoperative femoral, trochanteric, and ankle fractures during primary THA

Study	Number of patients	Number of hips	Cohort description*	Number of intraoperative fractures
Andrew et al. [1] (1986)	400	400	Isoelastic cementless stem (Mathys) of polyacetyl resin	92 femoral (23%)
				19 trochanteric (4.8%)
Jensen and Repta [31] (1987)	36	36	Judet cementless stem (Stryker)	10 femoral (27.8%)
				3 trochanteric (8.3%)
Fitzgerald et al. [22] (1988)	NA	499	PCA® (Stryker), Harris-Galante® (Zimmer), BIAS® (Zimmer), Omnifit® (Stryker)	17 (3.5%)
Mallory et al. [46] (1989)	267	309	Cementless 1982 to 1986, MHP (Biomet), PCA® (Stryker), AML® (DePuy), Autophor (Smith and Nephew), CDH Tri-Lock® (DePuy)	34 (11.0%)
Schwartz et al. [64] (1989)	NA	1318	AML® cementless stem (DePuy)	39 (3.0%)
Stuchin [65] (1990)	72	79	Cementless	16 (20.3%)
Cracchiolo et al. [16] (1992)	34	40	Cementless, rheumatoid arthritis	3 (8.1%)
Martell et al. [48] (1992)	111	121	Harris-Galante® cementless stem (Zimmer)	10 (8.3%)
Au [3] (1994)	23	25	Isoelastic cementless stem (Mathys)	7 (28%)
Toni et al. [68] (1994)	NA	61	Lord straight-stemmed cementless (Benoist Girard)	11 (18%)
		111	AnCA™ standard cementless (Wright)	2 (1.8%)
		223	AnCA™ short cementless (Wright)	3 (1.3%)
Bargar et al. [4] (1998)	62	62	Cementless, performed without computer guidance	3 (4.8%)
	65	65	Cementless, performed with ROBODOC® (Curexo)	1 (0%)
Liu et al. [38] (1998)	NA	493	Primary, performed 1972 to 1996	12 (2.4%)
Loehr et al. [39] (1999)	15	21	Cementless, rheumatoid arthritis	1 (4.8%)
Schramm et al. [63] (2000)	94	107	CLS® (Zimmer)	8 (7.5%)
Berend et al. [9] (2004)	NA	1320	MHP cementless stem (Biomet), standard direct lateral approach	58 (4.4%)
Cameron [14] (2004)	NA	679	S-ROM® cementless stem (Depuy)	47 (6.9%)
Parvizi et al. [59] (2004)	121	129	TaperLoc® cementless stem (Biomet)	3 (2.3%)
Matta et al. [50] (2005)	437	494	Minimally invasive single-incision anterior approach on orthopaedic table, cementless stems	6 femoral (1.2%)
				3 trochanteric (0.6%)
				3 ankle (0.3%)
Asayama et al. [2] (2006)	50	50	Cementless, standard direct lateral approach	0 (0%)
	52	52	Cementless, limited direct lateral approach	2 (3.8%)
Laffosse et al. [36] (2006)	NA	42	Minimally invasive anterolateral approach, large-diameter femoral heads	4 femoral (9.5%)
				4 trochanteric (9.5%)
	NA	58	Standard posterior approach, 28-mm heads	1 femoral (1.7%)
Lerch et al. [37] (2007)	NA	1216	Bicontact® cementless stem (B Braun)	42 (3.5%)
Lu et al. [44] (2007)	60	63	Minimally invasive two-incision approach	2 (3.2%)
Fernandez-Fernandez et al. [21] (2008)	NA	117	Meridian® cementless stem (Stryker)	13 (11.1%)
Mainard [45] (2008)	42	42	Cementless straight stem, nonnavigated	1 (2.4%)
	42	42	Cementless straight stem, navigated	0 (0%)
Masonis et al. [49] (2008)	NA	300	Minimally invasive direct anterior approach with fluoroscopic assistance	3 (1.0%)
McGrory et al. [51] (2008)	115	115	Minimally invasive posterior approach	1 (0.9%)
Thilleman et al. [67] (2008)	NA	39,478	Primary osteoarthritis, Danish registry 1995 to 2005	519 (1.3%)

Table 3. continued

Study	Number of patients	Number of hips	Cohort description*	Number of intraoperative fractures
Ghera and Pavan [24] (2009)	65	65	Proxima® cementless stem (DePuy UK)	1 (1.5%)
Benum and Aamodt [5] (2010)	191	191	Custom CAD-CAM cementless stem (SCP), direct lateral approach	2 (1.0%)
Berend and Lombardi [7] (2010)	NA	439	Monoblock, cementless, broach only, tapered-wedge stem, prepared with low-profile cutting blade calcar mill	0 (0%)
	NA	18	Modular, cementless, broach only, tapered-wedge stem prepared with deep-toothed cutting calcar mill	2 (11.1%)
Palutsis et al. [57] (2010)	181	200	Minimally invasive two-incision approach, cementless VerSys® MidCoat (Zimmer), M/L Taper (Zimmer)	4 femoral (2%)† 14 trochanteric ≤ 2 cm (7%) 2 trochanteric > 2 cm (1%)
Jewett and Collis [32] (2011)	NA	800	Minimally invasive anterior approach with aid of fracture table	19 trochanteric (2.4%) 4 femoral (0.5%)
Molli et al. (2011)	360	389	MHP (Biomet), less invasive direct lateral approach	9 femoral (2.3%) 3 trochanteric (0.8%)
	246	269	TaperLoc® Microplasty™ (Biomet), less invasive direct lateral approach	1 femoral (0.4%)
Total		50,538		1064 (2.1%)

* Manufacturers included: Mathys Ltd Bettlach, Bettlach, Switzerland; Stryker Orthopaedics, Mahwah, NJ; Zimmer, Inc, Warsaw, IN; Smith and Nephew, Inc, Memphis TN; DePuy Orthopaedics, Inc, Warsaw, IN; Benoist Girard, Bagneux, France; Wright Medical Technology, Inc, Arlington, TN; Curexo Technology Corp, Sacramento, CA; B Braun, Melsungen, Germany; DePuy International Ltd, Leeds, UK; Scandinavian Customized Prostheses (SCP), Trondheim, Norway; †there were four additional early postoperative femoral fractures in this series; NA = not available; PCA® = Porous Coated Anatomic; BIAS® = Biologic Ingrowth Anatomic System; MHP = Mallory-Head® porous; AML® = Anatomic Medullary Locking; CDH = congenital dysplasia of the hip; AnCA = Anatomic Ceramic Arthroplasty; CLS® = Cementless Self-locking; S-ROM® = Sivash Range of Motion; CAD-CAM = computer-aided design and computer-aided manufacture.

pain and function between groups receiving standard-length double-tapered stems and shorter, flat-wedge, "microplasty" tapered stems.

Our study does contain several limitations. First, although both stems are titanium, porous plasma-sprayed, tapered designs, they are two completely different stems, not just a shorter version of the standard-length stem. The standard-length stem requires both reaming and broaching, while the short stem is a broach-only system. This extra-preparation and geometric design may influence the tendency for the standard-length stem to have a higher fracture risk [9, 40, 59, 63]. Second, the short-term followup for this study was a limiting factor in terms of comparing differences in survivorship and functional outcomes. Third, although this was not the intent of this study, there was no specific analysis of radiographs with regard to positioning and sizing of stems, although studies have shown stem position is not correlated with increased incidence of early component failure [11, 34].

We found a higher incidence of intraoperative femoral and trochanteric fracture with standard-length stems (3.1%) than with short stems (0.4%), which are both within the range of findings reported in other studies of primary cementless THA (Table 3). While these numbers are lower than previous reports of intraoperative fracture with tapered designs, which range from 1.6% to 7% [9, 59, 63], our study demonstrates this particular design of shorter stem does have a lower incidence of intraoperative femur fracture when compared with a standard-length stem. The literature is a bit conflicting when looking at overall outcomes of THAs after intraoperative fractures. Thillemann et al. [67] have shown an overall cumulative failure rate of 0.9% within the first 6 months for patients without intraoperative femoral fractures versus 3.4% for patients with associated intraoperative femoral fractures. The highest cumulative failure rates in that study were 5.7% for the patients when they had osteosynthesis compared to 1.5% in the intraoperative fractures treated nonoperatively [67]. The decision to treat certain intraoperative fractures without osteosynthesis is likely due to less severe fracture morphology with more inherent stability with distal stem fixation [67]. In contrast, we previously reported excellent long-term survival of MHP femoral components after intraoperative fracture with immediate cerclage wire or cable fixation (100% femoral component survival at up to 16 years) [9]. In another experimental study comparing a standard-length, cementless, tapered stem (CLS® Spotorno®; Zimmer, Inc, Warsaw, IN, USA) with a shorter, tapered stem (Mayo®; Zimmer), the authors observed a nonsignificant trend toward lower fracture resistance with the short-stemmed design [30]. This same study showed a much lower average amount of subsidence before fracture in the short stem (7.9 mm) versus the standard-length stem (13.9 mm) [30]. Although these reports show conflicting data, our experience with these two particular stem designs suggests the shorter stems are an equally efficacious alternative to the standard-length stems. While the shorter stems may make the procedure technically easier and more amenable to less invasive approaches, our data also demonstrate a decreased risk of intraoperative fracture when shorter stems are used.

The overall stem survivorship at most recent followup with stem revision for any reason as the end point was 99.7%, with only two of 658 stems needing revision for any reason. We performed no revisions for aseptic loosening or failure of ingrowth, for an early rate of stable fixation of 100%. Although this study was predominately designed to compare the intraoperative complication rates between standard-length and short tapered stems, our short-term survival is encouraging. We previously reported a 98.6% overall stem survivorship at 5 years (98.4% at 10 years, 97.1% at 15 years, and 95.5% at 20 years) with the MHP femoral prosthesis, all performed via a direct lateral approach, with stem revision for any reason as the end point [43]. In the same study, stem survivorship, when looking only at aseptic loosening as reason for failure, was 99.4% at 5 years and 99.3% at 10, 15, and 20 years [43]. Further followup is needed to compare the long-term durability in clinical practice of these two devices in terms of survival and patient function and activity level.

With regard to postoperative pain and function scores, no differences in the HHS pain and total scores and LEAS scores were seen between the two groups at the 6-week or most recent followup visit. Both groups saw relatively equivalent improvements in their HHS pain and total scores postoperatively when compared with preoperative levels (Table 2).

In conclusion, the TaperLoc® Microplasty™ femoral stem appears to be a safe and reliable alternative to a more traditional standard-length double-tapered stem (Fig. 5).

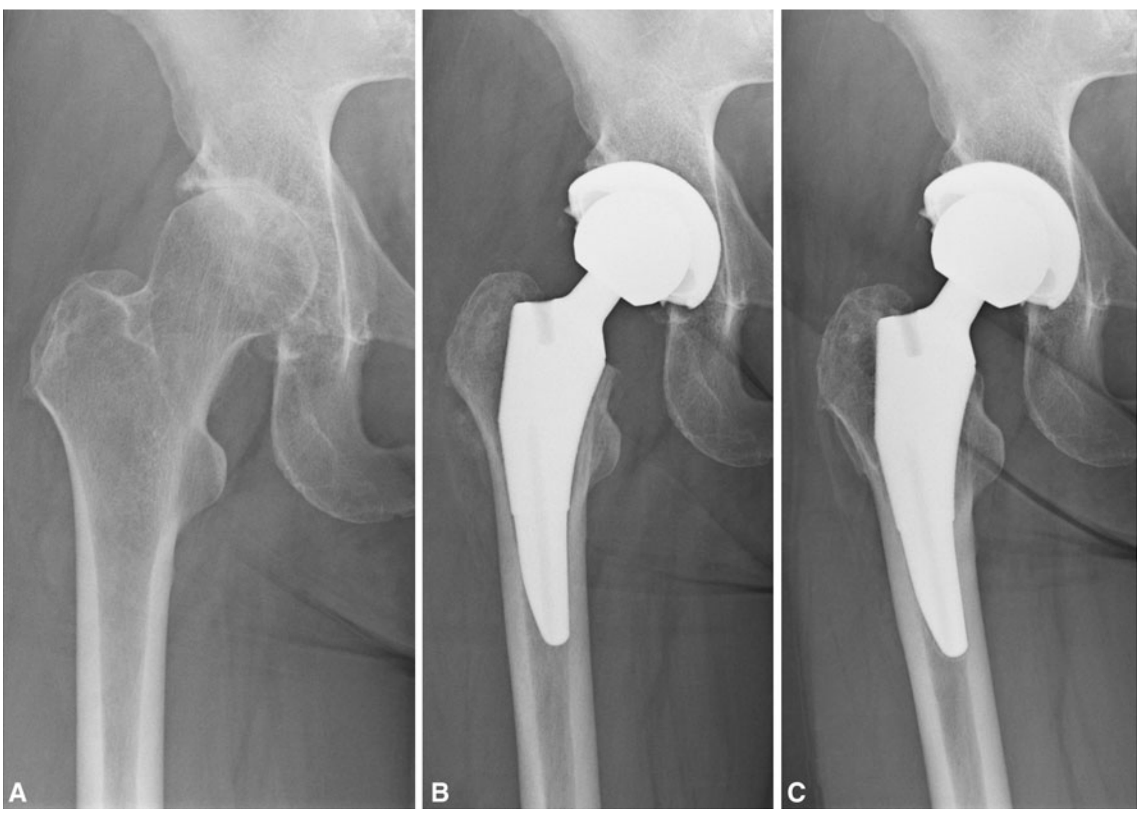

Fig. 5A–C (**A**) A preoperative radiograph of the left hip of a 64-year-old female patient who presented with severe pain and discomfort secondary to osteoarthritis shows severe joint space narrowing, sclerosis, and osteophyte and cyst formation. (**B**) A postoperative radiograph at 6 weeks shows treatment of cementless primary left THA with a 10- by 105-mm short taper stem and a 36-mm BIOLOX® delta ceramic-on-highly-crosslinked polyethylene articulation (Ceramtec AG, Plochingen, Germany). (**C**) A radiograph at 4 years postoperatively shows well-fixed components in satisfactory position and alignment. The patient had a HHS of 96.5 at latest followup.

The risk of major intraoperative complications, particularly iatrogenic femoral fracture, was less with this short stem, making it an attractive alternative to more traditional stems. Although overall stem survivorship in the literature with traditional stems is exceptional, the nearly eight times higher risk of intraoperative fracture associated with these stems in this study certainly lends to more fracture-friendly stem options being sought. Short stems do not appear to compromise either femoral fixation or short-term clinical results and will likely continue to be utilized as many more surgeons and patients seek less invasive techniques for THA. Future studies focused on long-term survivorship and durability of these "short stems" will be important in determining their continued use in THA.

References

1. Andrew TA, Flanagan JP, Gerundini M, Bombelli R. The isoelastic, noncemented total hip arthroplasty: preliminary experience with 400 cases. *Clin Orthop Relat Res*. 1986;206:127–138.
2. Asayama I, Kinsey TL, Mahoney OM. Two-year experience using a limited-incision direct lateral approach in total hip arthroplasty. *J Arthroplasty*. 2006;21:1083–1091.
3. Au MK. Isoelastic total hip replacement: clinical evaluation of prosthetic isoelasticity. *J Formos Med Assoc.* 1994;93:497–502.
4. Bargar WL, Bauer A, Börner M. Primary and revision total hip replacement using the Robodoc system. *Clin Orthop Relat Res.* 1998;354:82–91.
5. Benum P, Aamodt A. Uncemented custom femoral components in hip arthroplasty: a prospective clinical study of 191 hips followed for at least 7 years. *Acta Orthop.* 2010;81:427–435.
6. Berend KR, Lombardi AV Jr. Total hip arthroplasty via the less invasive anterolateral abductor splitting approach. *Semin Arthroplasty*. 2004;15:87–93.
7. Berend KR, Lombardi AV Jr. Intraoperative femur fracture is associated with stem and instrument design in primary total hip arthroplasty. *Clin Orthop Relat Res.* 2010;468:2377–2381.
8. Berend KR, Lombardi AV Jr, Mallory TH. Rapid recovery protocol for peri-operative care of total hip and total knee arthroplasty patients. *Surg Technol Int*. 2004;13:239–247.
9. Berend KR, Lombardi AV Jr, Mallory TH, Chonko DJ, Dodds KL, Adams JB. Cerclage wires or cables for the management of intraoperative fracture associated with a cementless, tapered femoral prosthesis: results at 2 to 16 years. *J Arthroplasty*. 2004;19(Suppl 2):17–21.
10. Berend KR, Lombardi AV, Mallory TH, Dodds KL, Adams JB. Cementless double-tapered total hip arthroplasty in patients 75 years of age and older. *J Arthroplasty*. 2004;19:288–295.
11. Berend KR, Mallory TH, Lombardi AV Jr, Dodds KL, Adams JB. Tapered cementless femoral stem: difficult to place in varus but performs well in those rare cases. *Orthopedics*. 2007;30:295–297.
12. Bourne RB, Rorabeck CH. A critical look at cementless stems: taper designs and when to use alternatives. *Clin Orthop Relat Res*. 1998;355:212–223.
13. Burt CF, Garvin KL, Otterberg ET, Jardon OM. A femoral component inserted without cement in total hip arthroplasty: a study of the Tri-Lock component with an average ten-year duration of follow-up. *J Bone Joint Surg Am*. 1998;80:952–960.
14. Cameron HU. Intraoperative hip fractures: ruining your day. *J Arthroplasty*. 2004;19(4 Suppl 1):99–103.
15. Chen HH, Morrey BF, An KN, Luo ZP. Bone remodeling characteristics of a short-stemmed total hip replacement. *J Arthroplasty.* 2009;24:945–950.
16. Cracchiolo A 3rd, Severt R, Moreland J. Uncemented total hip arthroplasty in rheumatoid arthritis diseases: a two- to six-year follow-up study. *Clin Orthop Relat Res*. 1992;277:166–174.
17. Ellison B, Berend KR, Lombardi AV Jr, Mallory TH. Tapered titanium porous plasma-sprayed femoral component in patients aged 40 years and younger. *J Arthroplasty*. 2006;21(Suppl 2):32–37.
18. Emerson RH Jr, Head WC, Emerson CB, Rosenfeldt W, Higgins LL. A comparison of cemented and cementless titanium femoral components used for primary total hip arthroplasty: a radiographic and survivorship study. *J Arthroplasty*. 2002;17:584–591.
19. Emerson RH Jr, Head WC, Higgins LL. Clinical and radiographic analysis of the Mallory-Head femoral component in revision total hip arthroplasty: a minimum 8.8-year and average eleven-year follow-up study. *J Bone Joint Surg Am*. 2003;85:1921–1926.
20. Emerson RH Jr, Sanders SB, Head WC, Higgins L. Effect of circumferential plasma-spray porous coating on the rate of femoral osteolysis after total hip arthroplasty. *J Bone Joint Surg Am*. 1999;81:1291–1298.
21. Fernandez-Fernandez R, García-Elias E, Gil-Garay E. Peroperative fractures in uncemented total hip arthroplasty: results with a single design of stem implant. *Int Orthop.* 2008;32:307–313.
22. Fitzgerald RH Jr, Brindley GW, Kavanagh BF. The uncemented total hip arthroplasty: intraoperative femoral fractures. *Clin Orthop Relat Res*. 1988;235:61–66.
23. Frndak PA, Mallory TH, Lombardi AV Jr. Translateral surgical approach to the hip: the abductor muscle "split." *Clin Orthop Relat Res*. 1993;295:135–141.
24. Ghera S, Pavan L. The DePuy Proxima hip: a short stem for total hip arthroplasty. Early experience and technical considerations. *Hip Int.* 2009;19:215–220.
25. Gosens T, van Langelaan EJ, Tonino AJ. Cementless Mallory-Head HA-coated hip arthroplasty for osteoarthritis in hip dysplasia. *J Arthroplasty*. 2003;18:401–410.
26. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am*. 1969;51:737–755.
27. Head WC, Mallory TH, Emerson RH Jr. The proximal porous coating alternative for primary total hip arthroplasty. *Orthopedics.* 1999;22:813–815.
28. Hozack W, Gardiner R, Hearn S, Eng K, Rothman R. Taperloc femoral component: a 2–6-year study of the first 100 consecutive cases. *J Arthroplasty*. 1994;9:489–493.
29. Hozack WJ, Rothman RH, Eng K, Mesa J. Primary cementless hip arthroplasty with a titanium plasma sprayed prosthesis. *Clin Orthop Relat Res*. 1996;333:217–225.
30. Jakubowitz E, Seeger JB, Lee C, Heisel C, Kretzer JP, Thomsen MN. Do short-stemmed-prostheses induce periprosthetic fractures earlier than standard hip stems? A biomechanical ex-vivo study of two different stem designs. *Arch Orthop Trauma Surg*. 2009;129:849–855.
31. Jensen JS, Retpen JB. Failures with the Judet noncemented total hip. *Acta Orthop Scand*. 1987;58:23–26.
32. Jewett BA, Collis DK. High complication rate with anterior total hip arthroplasties on a fracture table. *Clin Orthop Relat Res*. 2011;469:503–507.
33. Keisu KS, Orozco F, Sharkey PF, Hozack WJ, Rothman RH, McGuigan FX. Primary cementless total hip arthroplasty in octogenarians: two to eleven-year follow-up. *J Bone Joint Surg Am*. 2001;83:359–363.
34. Khalily C, Lester DK. Results of a tapered cementless femoral stem implanted in varus. *J Arthroplasty*. 2002;17:463–466.

35. Kim YH. Long-term results of the cementless porous-coated anatomic total hip prosthesis. *J Bone Joint Surg Br*. 2005;87:623–627.
36. Laffosse JM, Chiron P, Accadbled F, Molinier F, Tricoire JL, Puget J. Learning curve for a modified Watson-Jones minimally invasive approach in primary total hip replacement: analysis of complications and early results versus the standard-incision posterior approach. *Acta Orthop Belg*. 2006;72:693–701.
37. Lerch M, Windhagen H, von Lewinski G, Thorey F. [Intraoperative femoral fractures during the implantation of the cementless BiCONTACT stem: a matched-pair analysis of 84 patients] [in German]. *Z Orthop Unfall.* 2007;145:574–578.
38. Liu Y, Lu S, Liu B. [The reason and management of intraoperative femur fracture during hip arthroplasty] [in Chinese]. *Zhonghua Wai Ke Za Zhi.* 1998;36:93–95.
39. Loehr JF, Munzinger U, Tibesku C. Uncemented total hip arthroplasty in patients with rheumatoid arthritis. *Clin Orthop Relat Res*. 1999;366:31–38.
40. Lombardi AV Jr, Berend KR, Adams JB. A short stem solution: through small portals. *Orthopedics*. 2009;32(9). doi: 10.3928/01477447-20090728-09.
41. Lombardi AV Jr, Berend KR, Adams JB. A rapid recovery program: early home and pain free. *Orthopedics*. 2010;33(9):656. doi: 10.3928/01477447-20100722-38.
42. Lombardi AV Jr, Berend KR, Mallory TH. Hydroxyapatite-coated titanium porous plasma spray tapered stem: experience at 15 to 18 years. *Clin Orthop Relat Res*. 2006;453:81–85.
43. Lombardi AV Jr, Berend KR, Mallory TH, Skeels MD, Adams JB. Survivorship of 2000 tapered titanium porous plasma-sprayed femoral components. *Clin Orthop Relat Res*. 2009;467:146–154.
44. Lu ML, Chou SW, Yang WE, Senan V, Hsieh PH, Shih HN, Lee MS. Hospital course and early clinical outcomes of two-incision total hip arthroplasty. *Chang Gung Med J*. 2007;30:513–520.
45. Mainard D. Navigated and nonnavigated total hip arthroplasty: results of two consecutive series using a cementless straight hip stem. *Orthopedics*. 2008;31(10 Suppl 1).
46. Mallory TH, Kraus TJ, Vaughn BK. Intraoperative femoral fractures associated with cementless total hip arthroplasty. *Orthopedics*. 1989;12:231–239.
47. Marshall AD, Mokris JG, Reitman RD, Dandar A, Mauerhan DR. Cementless titanium tapered-wedge femoral stem: 10- to 15-year follow-up. *J Arthroplasty*. 2004;19:546–552.
48. Martell JH, Galante JO, Pierson RH, Jacobs JJ, Rosenberg AG, Maley M. Clinical experience with primary cementless total hip arthroplasty. *Chir Organi Mov*. 1992;77:383–396.
49. Masonis J, Thompson C, Odum S. Safe and accurate: learning the direct anterior total hip arthroplasty. *Orthopedics*. 2008;31(12 Suppl 2).
50. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. *Clin Orthop Relat Res*. 2005;441:115–124.
51. McGrory BJ, Finch ME, Furlong PJ, Ruterbories J. Incision length correlates with patient weight, height, and gender when using a minimal-incision technique in total hip arthroplasty. *J Surg Orthop Adv*. 2008;17:77–81.
52. McLaughlin JR, Lee KR. Total hip arthroplasty with an uncemented femoral component: excellent results at ten-year follow-up. *J Bone Joint Surg Br*. 1997;79:900–907.
53. McLaughlin JR, Lee KR. Total hip arthroplasty in young patients: 8- to 13-year results using an uncemented stem. *Clin Orthop Relat Res*. 2000;373:153–163.
54. McLaughlin JR, Lee KR. The outcome of total hip replacement in obese and non-obese patients at 10- to 18-years. *J Bone Joint Surg Br*. 2006;88:1286–1292.
55. McLaughlin JR, Lee KR. Total hip arthroplasty with an uncemented tapered femoral component. *J Bone Joint Surg Am*. 2008;90:1290–1296.
56. Morrey BF. Short-stemmed uncemented femoral component for primary hip arthroplasty. *Clin Orthop Relat Res*. 1989;249:169–175.
57. Palutsis RS, Sheridan KC, Wasielewski RC. One surgeon's experience with the 2-incision technique for total hip arthroplasty. *J Arthroplasty*. 2010;25:71–75.
58. Park MS, Choi BW, Kim SJ, Park JH. Plasma spray-coated Ti femoral component for cementless total hip arthroplasty. *J Arthroplasty*. 2003;18:626–630.
59. Parvizi J, Keisu KS, Hozack WJ, Sharkey PF, Rothman RH. Primary total hip arthroplasty with an uncemented femoral component: a long-term study of the Taperloc stem. *J Arthroplasty*. 2004;19:151–156.
60. Reitman RD, Emerson R, Higgins L, Head W. Thirteen year results of total hip arthroplasty using a tapered titanium femoral component inserted without cement in patients with type C bone. *J Arthroplasty*. 2003;18(Suppl 1):116–121.
61. Saleh KJ, Mulhall KJ, Bershadsky B, Ghomrawi HM, White LE, Buyea CM, Krackow KA. Development and validation of a lower-extremity activity scale: use for patients treated with revision total knee arthroplasty. *J Bone Joint Surg Am*. 2005;87:1985–1994.
62. Santori FS, Santori N. Mid-term results of a custom-made short proximal loading femoral component. *J Bone Joint Surg Br*. 2010;92:1231–1237.
63. Schramm M, Keck F, Hohmann D, Pitto RP. Total hip arthroplasty using an uncemented femoral component with taper design: outcome at 10-year follow-up. *Arch Orthop Trauma Surg*. 2000;120:407–412.
64. Schwartz JT Jr, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. *J Bone Joint Surg Am*. 1989;71:1135–1142.
65. Stuchin SA. Femoral shaft fracture in porous and press-fit total hip arthroplasty. *Orthop Rev*. 1990;19:153–159.
66. Stulberg SD, Dolan M. The short stem: a thinking man's alternative to surface replacement. *Orthopedics*. 2008;31:885–886.
67. Thillemann TM, Pedersen AB, Johnsen SP, Søballe K. Inferior outcome after intraoperative femoral fracture in total hip arthroplasty: outcome in 519 patients from the Danish Hip Arthroplasty Registry. *Acta Orthop*. 2008;79:327–334.
68. Toni A, Ciaroni D, Sudanese A, Femino F, Marraro MD, Bueno Lozano AL, Giunti A. Incidence of intraoperative femoral fracture: straight-stemmed versus anatomic cementless total hip arthroplasty. *Acta Orthop Belg*. 1994;60:43–54.