Intraoperative Femur Fracture is Associated with Stem and Instrument Design in Primary Total Hip Arthroplasty

Keith R. Berend MD, Adolph V. Lombardi Jr. MD, FACS

Published online: 13 April 2010
© The Association of Bone and Joint Surgeons® 2010

Abstract

Background Intraoperative proximal femoral fracture is a risk in total hip arthroplasty (THA) with cementless stems with reported rates of 1.5–27.8%. Certain designs or designs associated with certain types of instrumentation may have higher rates.

Questions/purposes We compared the incidence of proximal femoral fracture with two stem and instrument design systems.

Methods We retrospectively reviewed 425 patients (457 hips) undergoing primary THAs using a supine, muscle-sparing approach between February 2007 and April 2009. In 439 cases, a monoblock, broach-only, tapered wedge design stem was used with a single low-profile cutting blade (cutting) calcar mill. Eighteen proximally modular,

broach-only, tapered wedge design stems were used with a calcar mill with multiple deep cutting teeth (toothed).

Results There were no proximal femoral fractures among the 439 hips using the cutting mill and two intraoperative proximal femur fractures in 18 hips using the toothed mill. Both fractures occurred during calcar milling when the cutting teeth engaged the bone, resulting in a torque of the broach.

Conclusions Given the high intraoperative proximal femur fracture rate using the toothed design, and the absence of fractures using the cutting design, we caution against the use of the toothed style. The overall rate using a flat, wedge, tapered design (two of 457 hips or 0.4%) is lower than that associated with previously published designs. Fracture appears directly related to instrumentation.

Level of Evidence Level III, retrospective comparison study. See Guidelines for Authors for a complete description of Levels of Evidence.

Two of the authors (KRB, AVL) received research funding, royalties, and consulting income from Biomet, Inc. The authors have full control over all primary data and agree to allow the journal to review the data if requested.

Each author certifies that his or her institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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

K. R. Berend, A. V. Lombardi Jr.
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

Introduction

The goal of primary THA is to provide pain relief and long-term survivorship. With the burgeoning interest and published long-term survival better than 90% of cementless THA, more cementless THAs are being performed each year [11, 12]. Intraoperatively, with cementless THA it is important to achieve immediate component stability to reduce early micromotion and encourage bony ingrowth or ongrowth [12]. This involves a tight proximal fill with anatomic medullary components, a tight wedge fit with tapered prostheses, or a “scratch fit” in the diaphysis with extensively coated stems. In this quest for component stability, fracture of the proximal femur can occur. Although not exclusive to uncemented femoral components, the

incidence of intraoperative femoral fracture is higher with these designs than in cemented THA with reported rates from 1.5% to as high as 27.8% in cementless THA [3, 4, 10, 13, 14, 16].

We previously reported a 4.4% risk of intraoperative fracture using a relatively long, double-tapered, cementless femoral component. By identifying these intraoperative cracks, and treating them with cerclage wires or cables, we identified no patients with aseptic failure at 2 to 16 years followup [2]. Although no negative impact on survival or revision rates was associated with these intraoperative fractures, they were associated with increased cost and operative time. There is also the risk that these fractures are inadvertently missed intraoperatively, are not treated with cerclage techniques, and may result in subsequent postoperative periprosthetic fracture requiring revision. Therefore, efforts should be pointed to avoiding these fractures through implant design and instrumentation.

We therefore (1) compared the intraoperative fracture rates using two similar femoral stem designs that use different instrumentation for proximal femoral preparation; (2) report how they were treated; and (3) compared the rate of fractures using a flat-wedge, tapered stem with that of a longer double-tapered cementless device.

Patients and Methods

Through a retrospective review of our Institutional Review Board-approved arthroplasty database we identified all 425 patients with 457 primary THAs, performed by one surgeon (KRB) using one of two stem designs and one of two types instruments for proximal femoral preparation from February 2007 and April 2009. In 439 hips, a monoblock, tapered, wedge design stem was used (Taperloc, Biomet, Inc, Warsaw, IN). The instrument platform includes a broach-only design and a calcar mill for proximal femoral preparation that uses a single low-profile cutting blade (cutting design; Fig. 1). In 18 hips we used a proximally modular, tapered, wedge design stem (M/L Taper with Kinectiv™ Technology; Zimmer, Inc, Warsaw IN). We used this stem when during templating we identified substantial anteversion, a short varus neck, or a long valgus neck; in these cases we believe modularity would be beneficial. The instrument system uses a broach-only stem and a calcar mill with multiple deep cutting teeth (toothed design; Fig. 2). The minimum clinical and radiographic followup time was 6 weeks (mean, 9 months; range 6 weeks to 31 months). No patients were lost to followup.

All procedures were performed using the modified Smith-Petersen interval with the patient in the supine position on a standard radiolucent operating table. Both stem and instrument designs use nearly identical

Fig. 1 The cutting-design calcar mill for proximal femoral preparation is shown (Biomet, Inc, Warsaw, IN).

Fig. 2 The toothed-design calcar mill for proximal femoral preparation is shown (Zimmer, Inc, Warsaw, IN).

instrumentation platforms with the exception of the calcar mill for proximal femoral preparation. A box osteotome is used to open the proximal femur, a starter awl is used to open the medullary canal and lateralize the implant, and then sequentially larger broaches are used to prepare the femoral canal. Once size of the stem has been confirmed using fluoroscopy, the neck resection is finalized using a calcar mill. Fractures were identified and treated intraoperatively at the time of milling the proximal femur.

All patients walked a minimum of 30 feet the day of surgery with assistance and supervision of a physical therapist, using a walker or crutches. Weight bearing as tolerated was allowed for all patients regardless of fracture as previously described [2].

Routine postoperative protocols allowed for discharge postoperative day 1 or 2 when physical therapy goals were

met and the patient was medically cleared. Followup was performed at 6 weeks and annually thereafter and included a routine history and physical examination. Radiographic evaluation at followup included an anteroposterior view of the pelvis and both hips, and a frog-leg lateral of the operative hip. One of two of us (KRB, AVL) examined all postoperative radiographs for obvious subsidence, failure of ingrowth (complete radiolucent line), or extensive mechanical failure. No specific radiographic classification system was utilized, simply objective lack of above mentioned failure modes. Lack of subjective subsidence or failure of ingrowth was assumed indicative of fracture healing. All patients had minimum 6-week radiographs to determine early failure and the two fracture cases had 10 and 13 months followup.

We previously reported an intraoperative fracture rate of 4.4% (58 cases) in 1520 primary THA using a cementless double-tapered, ream and broach stem design (Mallory-Head Porous, Biomet, Inc.) that used a ream and broach operative technique and identical proximal femoral preparation cutting mill to that used here [2]. We examined the difference in proportions of fractures between the two groups and between our previously published experience with a different stem design and the current designs with statistical evaluation using Fisher's exact test for 2×2 chi square contingency tables.

Results

We intraoperatively identified two fractures in the 457 hips, an incidence of 0.4%. Neither of these fractures occurred during the first 250 hips and both occurred with the toothed design. During femoral broaching, no apparent calcar cracks occurred in any hip. During calcar milling, a higher proportion ($p = 0.001$) of intraoperative fractures occurred in the hips in which we used a toothed design compared to those with the cutting design: two fractures in 18 hips versus none in 439, respectively.

Both fractures were type-2, minimally displaced calcar fractures extending to the level of the lesser trochanter and treated with a single cerclage cable [2]. The broach was removed and a cable passed proximal to the lesser trochanter. After tightening the cable, trial reduction with the broach was performed to confirm fracture stability. Final implants were inserted in a standard fashion. All patients were managed with weightbearing as tolerated and routine postoperative protocol as noted. At most recent followup, neither stem associated with an intraoperative fracture demonstrated subsidence and the patients are without hip related symptoms.

The fracture rate was lower ($p = 0.001$) in the current series of 457 primary THAs performed with a flat-wedge

tapered stem design and utilizing broach only instrumentation compared to the historical series of 1520 primary THAs using a cementless double-tapered, ream and broach stem design (0.4% versus 4.4%).

Discussion

Intraoperative periprosthetic femoral fractures are well described, being noted as major challenges as early as 1975 [19]. With the increasing use of cementless technology in THA, a concomitant increase in intraoperative femoral fracture has been seen [2, 5, 18, 20, 21]. We therefore compared the rates of intraoperative proximal femur fracture using two similar stem designs with two proximal femoral preparation devices, reported how these are treated, and compared the rate of intraoperative femur fracture with that of a previously published stem design.

We acknowledge several limitations. First, we had a small number of patients in whom we used a toothed broach. This may represent a bias with greater experience using the cutting device and there may be a learning curve associated with the toothed mill. However, the surgeon has extensive experience with flat-wedge, tapered stem designs and the instrumentation systems are nearly identical in terms of femoral preparation with the exception of the proximal femoral mill. We therefore believe it unlikely that less experience with the toothed mill would explain the difference in fracture rates. Rather, we presume the design of the instrumentation is the cause of fracture. Second, we do not have minimum 1-year followup on all patients in this study group. This report describes an intraoperative event, and we cannot ensure whether the event influenced the long-term survival of the implant. However, we previously reported that identifying and treating a proximal calcar fracture intraoperatively does not affect the long-term survival of the femoral implant [2].

A number of studies suggest a nondisplaced or minimally displaced proximal femur fracture can be treated with cerclage techniques without affecting the survivorship [4, 7, 10, 14, 16]. At 2 to 16 years followup (average, 7.6 years) of intraoperative proximal femoral fractures in association with a tapered, cementless THA, secured with a cerclage technique, we have previously reported no effect on fixation or implant survivorship [2]. Fractures involving other tapered, cementless designs have also been reported and successfully treated [8, 11, 12, 20]. This is in contrast to a canine fracture model in which the fractures had a negative impact on bone ingrowth despite adequate fixation with cerclage wire [17]. We noted two fractures out of 18 cases in which a toothed mill was used for proximal femoral preparation and no fractures in which a mill with a single cutting blade was utilized in 439 THAs. Both

patients with fractures in the current series had an uneventful postoperative course but with short-term followup.

Cerclage techniques with wire or cable increase the hoop stress resistance of the proximal femur and reduce the risk of crack propagation, which explains the success of cerclage cabling in cementless THA [8, 9]. Despite this success and lack of major negative impact on the eventual outcome of primary THA, there are increased costs and increased operative time associated with the use of cables [15]. Additionally, although the overall postoperative results seem unaffected, there can be considerable risk associated with wiring or cabling the femur such as nerve or vascular injury [1].

The general design of the flat-wedged, tapered titanium stems used in this series was associated with a 0.4% incidence of intraoperative femur fracture. Excluding the group in which the toothed mill was used for calcar preparation, there were no intraoperative fractures. This is in contradistinction to our previous report of 4.4% using a different stem design [2]. Clearly, stem design is intimately associated with the risk of intraoperative fracture revealing a 10-fold lower risk when a broach-only, tapered, wedge-shaped design is used.

Previous authors have noted an increase in intraoperative fractures with the advent of minimally invasive or muscle-sparing approaches for THA with one report citing a 6.5% rate during the early learning curve [6]. We identified no fractures occurring in the first 250 cases; only with the use of the toothed calcar mill did intraoperative fractures occur. As noted, a bias may exist if the milling device itself requires a learning curve, but we do not believe this to be the situation based on extensive experience with similar stem designs. As opposed to previous reports of fracture associated with muscle-sparing approaches, these fractures occurred when the toothed broach engaged the proximal femur, catching the bone, and applying violent torque to the broach. This torque caused the proximal femur to break and appeared to be unrelated to surgical approach. While the proximal milling devices were most strikingly different in terms of the bone cutting surfaces (toothed versus cutting [Figs. 1, 2]), there were also differences in the length of engagement of the mill onto the broach. The cutting mill incorporates a spring-loaded tube, which may allow the mill to be correctly centered on the broach and slowly applied to the calcar surface with some resistance from the spring. In contrast, the toothed device utilizes a short female connection that offers limited distance to ensure the device is correctly centered and no resistance from a spring mechanism.

The flat-wedge tapered titanium stem appears well suited for use in muscle-sparing, minimally invasive

THA. The typical rate of proximal femoral fractures that have been seen with cementless tapered stems has not been observed in over 400 cases. Instead, differences in instrumentation design, namely the design of the calcar mill, appears to be associated with intraoperative fracture. We advise against the use of this toothed style of mill.

Acknowledgments We thank Joanne Adams, BFA for her contributions to the data collection and review for this report.

References

1. Aleto T, Ritter MA, Berend ME. Case report: superficial femoral artery injury resulting from cerclage wiring during revision THA. *Clin Orthop Relat Res.* 2008;466:749–753.
2. 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.
3. Berry DJ. Management of periprosthetic fractures: the hip. *J Arthroplasty.* 2002;17:11–13.
4. Duncan CP, Masri BA. Fractures of the femur after hip replacement. *Instr Course Lect.* 1996;44:293–304.
5. Fitzgerald RH Jr, Brindley GW, Kavanagh BF. The uncemented total hip arthroplasty. Intraoperative femoral fractures. *Clin Orthop Relat Res.* 1988;235:61–66.
6. Graf R, Azizbaig-Mohajer M. Minimally invasive total hip replacement with the patient in the supine position and the contralateral leg elevated. *Oper Orthop Traumatol.* 2006;18:317–329.
7. Greidanus NV, Mitchell PA, Masri BA, Garbus DS, Duncan CP. Principles of management and results of treating the fractured femur during and after total hip arthroplasty. *Instr Course Lect.* 2003;52:309–322.
8. Herzwurm PJ, Walch J, Pettine KA, Ebert FR. Prophylactic cerclage: a method of preventing femur fracture in uncemented total hip arthroplasty. *Orthopedics.* 1992;15:143–146.
9. Incavo SJ, DiFazio F, Wilder D, Howe JG, Pope M. Longitudinal crack propagation in bone around femoral prosthesis. *Clin Orthop Relat Res.* 1991;272:175–180.
10. Kyle RF, Crickard GE. Hip arthroplasty: management problems; periprosthetic fractures associated with total hip arthroplasty. *Orthopedics.* 1998;21:982–984.
11. Mallory TH, Lombardi AV Jr, Leith JR, Fujita H, Hartman JF, Capps SG, Kefauver CA, Adams JB, Vorys GC. Minimal 10-year results of a tapered cementless femoral component in total hip arthroplasty. *J Arthroplasty.* 2001;16:49–54.
12. Mallory TH, Lombardi AV Jr, Leith JR, Fujita H, Hartman JF, Capps SG, Kefauver CA, Adams JB, Vorys GC. Why a taper? *J Bone Joint Surg Am.* 2002;84(Suppl 2):81–89.
13. Moroni A, Faldini C, Piras F, Giannini S. Risk factors for intraoperative femoral fractures during total hip replacement. *Ann Chir Gynaecol.* 2000;89:113–118.
14. Reis MD. Hip arthroplasty: management problems; periprosthetic fractures: early and late. *Orthopedics.* 1997;20:789–800.
15. Ritter MA, Lutgring JD, Davis KE, Berend ME, Meding JB. A clinical, radiographic, and cost comparison of cerclage techniques: wires vs cables. *J Arthroplasty.* 2006;21:1064–1067.

16. Schmidt AH, Kyle RF. Periprosthetic fractures of the femur. *Orthop Clin.* 2002;33:143–152.
17. Schutzer SF, Grady-Benson J, Jasty M, O'Connor DO, Bragdon C, Harris WH. Influence of intraoperative femoral fractures and cerclage wiring on bone ingrowth into canine porous coated femoral components. *J Arthroplasty.* 1995;10: 823–829.
18. Schwartz JT Jr, Mayer JG, Engh CA. Femoral fracture during non-cemented total hip arthroplasty. *J Bone Joint Surg Am.* 1989;71:1135–1142.
19. Scott RD, Turner RH, Leitzes SM, Aufranc OE. Femoral fractures in conjunction with total hip replacement. *J Bone Joint Surg Am.* 1975;57:494–501.
20. Sharkey PF, Hozack WJ, Booth RE Jr, Rothman RH. Intraoperative femoral fractures in cementless total hip arthroplasty. *Orthop Rev.* 1992;21:337–342.
21. 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.