ARTICLE IN PRESS

The Journal of Arthroplasty Vol. 00 No. 0 2012

A Fluoroscopic Grid in Supine Total Hip Arthroplasty

Improving Cup Position, Limb Length, and Hip Offset

Jeremy M. Gililland, MD, Lucas A. Anderson, MD, Shannon L. Boffeli, APRN, Christopher E. Pelt, MD, Christopher L. Peters, MD, and Erik N. Kubiak, MD

Abstract: We hypothesized that use of a novel fluoroscopic grid would decrease operative time and component positioning variability during anterior supine total hip arthroplasty (THA). We reviewed 99 anterior supine THAs: 39 using a fluoroscopic grid, and 60 using fluoroscopy alone. Goals were cup abduction of 40° ± 10° and limb length and hip offset within 10 mm of the contralateral side. Surgical time was decreased in the study group (79 vs 94 minutes, $P = .002$). In the study group, more components met the goal for cup abduction (97% vs 83%, $P = .046$), limb length (100% vs 88%, $P = .04$), hip offset (85% vs 67%, $P = .047$), and all 3 combined (82% vs 52%, $P = .002$). We demonstrated decreased component positioning variability during anterior supine THA with assistance of a fluoroscopic grid. **Keywords:** total hip arthroplasty, fluoroscopic grid, limb length.
© 2012 Elsevier Inc. All rights reserved.

Current rates of total hip arthroplasty (THA) are on the rise with demand expected to burgeon by 174% by 2030 [1]. Efficient methods with which to improve component positioning will become increasingly important to maximize both productivity and patient outcomes for the joint surgeon and the increasing number of general orthopedists that will be required to meet this demand.

Patient satisfaction, survivorship, and stability are all dependent on proper acetabular component positioning, limb-length equalization, and restoration of hip offset. Malpositioned acetabular components can result in increased dislocation rate, impingement, limited range of motion, increased osteolysis, increased polyethylene wear, and increased acetabular component migration [2-4]. Limb-length discrepancy after THA has been associated with nerve palsy, low back pain, abnormal gait, increased oxygen consumption and heart rate, and litigation [5, 6]. Failure to restore femoral offset has been tied to worsened gait and abductor function and increased component wear rates [7-10].

Current methods for intraoperative evaluation of component position, limb length, and offset include imaging with plain radiographs and fluoroscopy, the use of intraoperative mechanical devices, the use of anatomical landmarks, and computer navigation [2,11-14]. The anterior supine approach greatly simplifies the use of intraoperative fluoroscopy. However, although fluoroscopy is beneficial when compared with radiographs in that it provides real-time imaging, the field of view is too narrow to easily compare the operative hip with the contralateral side.

The purpose of our study was to evaluate an intraoperative fluoroscopic technique involving the use of a novel radiopaque grid in anterior supine THA. We hypothesized that the use of the grid would decrease component position variability including cup abduction, limb-length equalization, and restoration of hip offset when compared with the use of fluoroscopy alone. In addition, we hypothesized that the use of the fluoroscopic grid would also decrease operative time when compared with fluoroscopy alone.

Patients and Methods

We retrospectively reviewed 99 consecutive primary THAs in 86 patients performed by a single surgeon (EK) through an anterior supine approach on a fracture table (PROfx; Mizuho OSI, Union City, Calif). All THAs were

From the University of Utah, Department of Orthopaedic Surgery, Salt Lake City, Utah.
Submitted August 16, 2011; accepted March 15, 2012.
The Conflict of Interest statement associated with this article can be found at doi:10.1016/j.arth.2012.03.027.
Reprint requests. Jeremy M. Gililland, MD, Department of Orthopaedic Surgery, University of Utah School of Medicine, 590 Wakara Way Salt Lake City, Utah 84108.
© 2012 Elsevier Inc. All rights reserved.
0883-5403/0000-0000$36.00/0
doi:10.1016/j.arth.2012.03.027

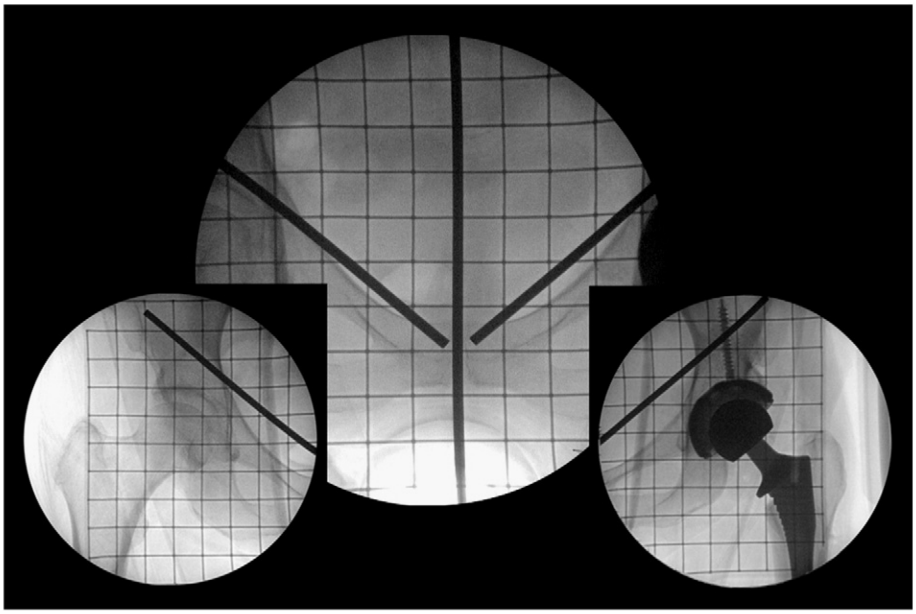

Fig. 1. Fluoroscopic images with grid in place to aid in assessing limb length, hip offset, and acetabular component abduction.

performed using cementless femoral and acetabular components with the use of either a ceramic or metal-on-polyethylene bearing. In the study group, 39 THAs were performed in 35 patients between September 22, 2010, and August 5, 2011, with the use of fluoroscopy and a novel radiopaque grid fixed to the operative table made up of 1-cm squares and 40° abduction angles (Fig. 1). This allows improved intraoperative assessment of cup abduction, limb length, and hip offset. This group consisted of 11 men (31%) and 23 women (69%). In the control group, 60 THAs were performed in 51 patients between July 1, 2009, and January 25, 2011, with the use of fluoroscopy alone. This group consisted of 27 men (53%) and 25 women (47%). The exclusion criteria for this study were the following: revision THAs, THAs done through any approach other than the anterior supine approach, any anterior supine THAs done without the use of fluoroscopy, and any patient without an adequate postoperative anteroposterior pelvis film as defined below. No patients were recalled specifically for this study; all data were obtained from medical records. We had approval of our institutional review board.

The study group consisted of more women than the control group (69% vs 47%, P = .048). There was a significant difference between the groups in terms of weight (72 vs 85 kg, P = .004) and body mass index (BMI) (26 vs 29 kg/m^2, P = .01). There were no differences between the 2 groups in terms of age or height. There were no differences between the groups in terms of presenting diagnosis (Table 1).

Our intraoperative fluoroscopy protocol with and without the grid was similar. We first obtained an anteroposterior pelvis image centered over the symphysis and adjusted the rainbow and tilt until we had an adequate image in which the coccyx was centered and within 2 cm of the top of the pubic symphysis. We next adjusted the contralateral extremity longitudinal boot traction until the ischial tuberosities were parallel to the grid coordinate system (this step was not performed when the grid was not used.) We then saved our final central image. Next, the fluoroscopy unit was telescoped into position, and an anteroposterior image was saved of the contralateral hip. This image was then transferred to the opposing screen on the fluoroscopy unit and was used for comparison when assessing the operative hip. The fluoroscopy unit was then telescoped into position over the operative hip. In this position, fluoroscopic imaging was obtained while reaming and impacting the acetabular component as well as when trialing with various component combinations (Fig. 1).

Table 1. Patient Demographics and Presenting Diagnoses

	Grid (n = 35)	Nongrid (n = 51)	P
Age (y)	63 (17)	63 (14)	.81
Gender*	11 M (31%)	27 M (53%)	.048
	23 F (69%)	25 F (47%)	
Height (cm)	167 (10)	171 (13)	.14
Weight (kg)	72 (16)	85 (21)	.004
BMI (kg/m^2)	26 (5)	29 (5)	.01
Osteoarthritis*	31 (79%)	41 (68%)	.22
Posttraumatic arthritis*	4 (10%)	13 (22%)	.14
Avascular necrosis*	3 (8%)	5 (8%)	>.99
Perthes*	1 (3%)	0 (0%)	.39
Postinfectious arthritis*	0 (0%)	1 (2%)	>.99

Data are presented as means with standard deviations in parentheses.
* These are binary variables and are thus presented as absolute numbers with percentages in parentheses. Presenting diagnoses percentages are calculated with respect to the total number of THAs in each group (n = 39 in grid group, n = 60 in nongrid group).

Using an adequate postoperative anteroposterior plane radiographs of the pelvis as defined by the legs positioned in 15° of internal rotation and with the coccyx centered within 2 cm of the pubic symphysis, 2 independent readers (JG and LA) blinded to patient grouping measured the cup abduction, limb-length inequality, and hip offset difference compared with the contralateral limb. We measured limb length as the perpendicular distance from the transteardrop line to the apex of the lesser trochanter [15]. We used the method described by Dastane et al [16] to measure hip offset, which is the femoral offset added to the horizontal position of the center of rotation (COR) of the hip. We decided to measure hip offset in lieu of femoral offset because femoral offset does not represent the true displacement of the femur from the pelvis because this displacement is influenced by both femoral offset and COR [16]. Femoral offset was measured as the distance perpendicular to the anatomical axis of the femur from the center of the femoral head to the anatomical axis of the femur (Fig. 2). The position of the COR was measured as a distance parallel to the transteardrop line from the teardrop to the center of the acetabulum or acetabular component (Fig. 2). Interobserver differences were noted and remeasured and reconciled by consensus.

The surgeon's goal for the cup abduction angle was 40° ± 10° (the safe zone). For limb length and hip offset, the surgeon desired to be within 10 mm of the contralateral side. For each THA being evaluated, the measurements obtained were compared with each respective goal, and a binary value of in or out of the desired zone was given for abduction angle, limb-length inequality, and hip offset difference. Ideally, a well-placed THA would be within all 3 of our goal zones, and we therefore performed 1 final evaluation of the measurements and gave each hip a binary value of in or out for all goals. We did not measure component version because we do not feel that the grid helps guide version.

Along with obtaining demographic information, records were reviewed for operative start time and end time, allowing us to calculate elapsed surgical time for each case.

Data were analyzed by an independent statistician using commercially available software (STATA Version 11; StataCorp, College Station, Tex). Student *t* test was used for comparing the continuous variables: elapsed surgical time, age, height, weight, and BMI. The χ^2 test was used to compare all binary variables if the expected frequencies were all greater than 5. Fisher exact test was used to compare those binary variables where the expected frequencies were not adequate for the χ^2 test.

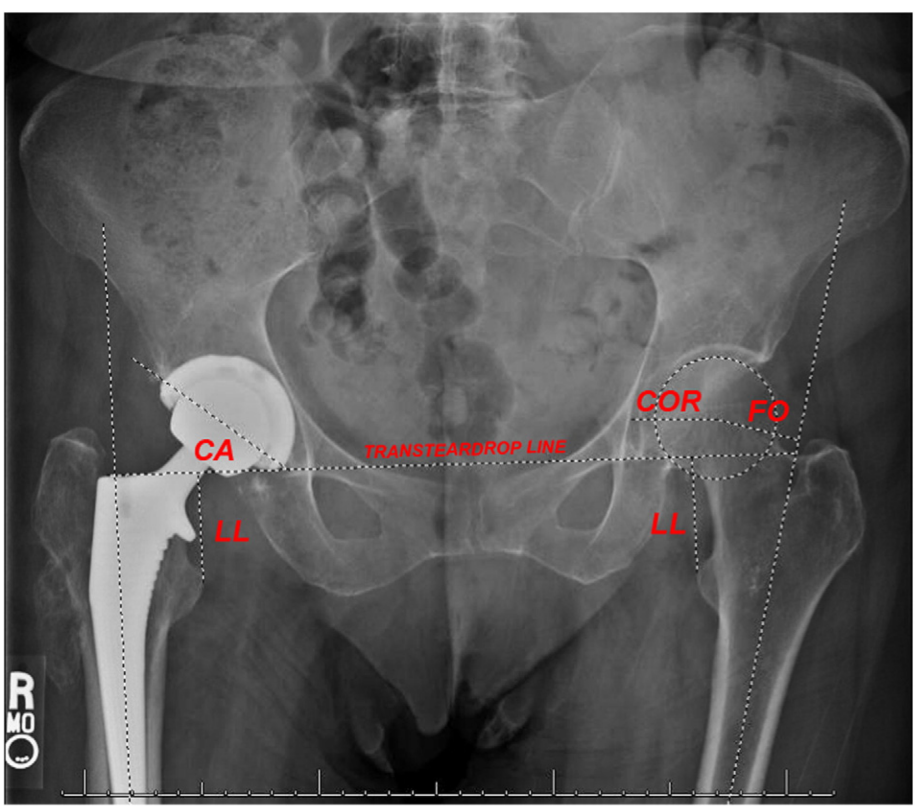

Fig. 2. Postoperative anteroposterior pelvis radiograph used to measure cup abduction (CA), limb-length (LL) difference, and hip offset difference (COR + femoral offset [FO]).

Of the demographic data evaluated, potential confounders were identified as sex, height, weight, BMI, a diagnosis of osteoarthritis, and a diagnosis of posttraumatic arthritis because the *P* values for these variables were either significant or nonsignificant but less than .25. A multivariable linear regression controlling for these potential confounders was performed for the continuous variable of elapsed surgical time.

Results

There were significantly more acetabular components within the safe zone of cup abduction (30°-50°) in the study group (97% vs 83%, *P* = .046). With the use of the grid, significantly more THAs had restoration of limb length to within 10 mm of the contralateral extremity (100% vs 88%, *P* = .04). Hip offset restoration to within 10 mm of the contralateral extremity was also significantly higher with use of the grid (85% vs 67%, *P* = .047). Finally, with the use of the grid, there were significantly more THAs meeting all 3 goals of cup abduction within the safe zone, limb-length restoration, and hip offset restoration (82% vs 52%, *P* = .002) (Table 2).

Mean elapsed surgical time was statistically significantly less (adjusted *P* = .002) in the grid group, with a mean operative time of 79 minutes compared with 94 minutes in the control group and an adjusted elapsed surgical time difference of 14 minutes when controlling for potential confounders (Table 2).

Discussion

Because patient satisfaction, survivorship, and stability are all dependent on proper acetabular component positioning, limb-length equalization, and restoration of hip offset, efficient methods with which to improve these factors are of paramount importance. In anterior supine THA, fluoroscopy is commonly used as a tool for intraoperative assessment of component positioning. However, the fluoroscopic method frequently described involves printing an image taken of the trial components in position, and superimposing this image on a printed image of the contralateral hip attempting to overlap the radiographic landmarks of the pelvis and the femur to compare length and offset [12]. This technique has been shown in a large series to yield excellent results in terms of acetabular component positioning and limb-length restoration [12]. We desired to simplify this process and developed the grid as a fluoroscopic adjunct to obtain comparable results in component positioning with improved efficiency.

We found that the use of the grid with intraoperative fluoroscopy compared with the use of fluoroscopy alone decreased component position variability in terms of cup abduction, limb-length equalization, and restoration of hip offset. In a recently published large registry series evaluating cup positioning in THA and hip resurfacing procedures, cup abduction was found to fall within the safe zone in only 63% of cases. This study found that lower surgeon volume, minimally invasive surgical approaches, and patient obesity were independent predictors of cup malpositioning [17]. However, Matta et al [12] showed excellent radiographic results in component positioning with the use of fluoroscopy in their experience of 494 anterior supine THAs; 96% of acetabular components were found within the safe zone for cup abduction, and limb lengths were within 11 mm of the contralateral side in 99% of their hips. In this study, Matta et al [12] also stated that unlike most minimally invasive surgical approaches, the anterior supine approach could be done on any patient and did not require selection of qualified patients based on body habitus. Our results in the grid group compare favorably with the results of Matta in that 97% of our acetabular components were within the safe zone for abduction and 100% of our THAs had limb lengths within 10 mm of the contralateral side. In a recent study by Dastane et al, the concept of *hip offset* was defined as the combination of femoral offset and cup COR. They describe hip offset as a more important measure than femoral offset because in THA the cup COR is changed and femoral offset no longer represents the displacement of the femur from the pelvis. In this study, they were able to restore the hip offset to within 6 mm of the contralateral side in 95% of 82 THAs with the assistance of computer navigation [16]. We had similar results in that we were able to restore our hip offset within 10 mm of the contralateral side in 85% of our THAs with the use of the grid.

We found significantly shorter operative times in the grid group compared with the use of fluoroscopy alone. In a prospective randomized clinical study by Kalteis et al [13], acetabular component abduction was evaluated

Table 2. Goal Zone and Surgical Time Results

THAs Within Goals			
Goal	Grid (n = 39)	Nongrid (n = 60)	*P*
Cup abduction goal (30°-50°)	38 (97%)	50 (83%)	.046
Limb-length goal (±10 mm)	39 (100%)	53 (88%)	.04
Hip offset goal (±10 mm)	33 (85%)	40 (67%)	.047
Within all 3 goals	32 (82%)	31 (52%)	.002

Surgical times	Grid (n = 39)	Nongrid* (n = 60)	Adjusted Mean Difference†	*P*†
Elapsed surgical time (min)	79 (74-84)	94 (89-100)	14 (6-23)	.002

Data are presented as absolute numbers with percentages in parentheses.

* Data presented as means with 95% confidence intervals in parentheses.

† Adjusted for sex, height, weight, BMI, osteoarthritis, and posttraumatic arthritis in a multivariable linear regression model. *P* value for the adjusted mean difference from the linear regression model.

after freehand placement as compared with the assistance of computed tomography (CT)–based and imageless navigation systems. Navigation was found to improve cup abduction from 45% in the safe zone with freehand technique to 83% and 93% with imageless navigation and CT-based navigation, respectively. However, the operative time was increased by 8 minutes with imageless navigation and by 17 minutes with CT-based navigation [13]. We found similar improvement in acetabular component abduction as we improved from 83% in the safe zone with fluoroscopy alone to 97% with the use of the grid. However, unlike the Kalteis et al study, we did not find increased operative time with the use of the grid compared with fluoroscopy alone. Although it is difficult to retrospectively assess the effect of the grid on operative efficiency, we do believe that the grid has the potential to improve efficiency over fluoroscopy alone for several reasons. First, it allows for a simple comparison of limb length and hip offset compared with the contralateral side and requires less fluoroscopic images to be obtained because the grid provides a static frame of reference from image to image. In addition, it can be used to evaluate the direction of reaming and the cup abduction in real time while reaming and impacting the cup, respectively. This allows for accurate placement of the cup without having to go back and adjust for malposition seen with trialing images. Of note, the use of the fluoroscopic grid does require placing this device on the fracture table preoperatively. Anecdotally, this only adds approximately 1 minute to the preoperative setup because the grid is quickly centered via the perineal posthole and secured to the table with Velcro.

There are several limitations to our study. First, our study was retrospective without any randomization. Although there was some overlap in dates of surgery between the groups, a greater percentage of the nongrid THAs were performed during an earlier period in this surgeon's experience with anterior supine THA. Increased surgeon experience may be a confounder when evaluating accuracy of component positioning and operative efficiency. However, we did not include the first 20 anterior supine THA performed by the surgeon, as a surgeon's first 10 anterior supine hips have been shown to reflect the learning curve related to complications [18]. In addition, we performed a separate analysis comparing the last 5 patients from each group to validate whether our exclusion of the first 20 cases was effective in decreasing the potential bias from increased surgeon experience. This analysis did not yield any statistically significant differences between these 2 subgroups, but this would be expected because of the limited numbers of 5 patients per group. However, the grid subgroup did have more hips meeting the goal for abduction (100% vs 40%), limb-length restoration (100% vs 80%), and all 3 goals combined (60% vs 20%), whereas the nongrid subgroup had more hips meeting the goal for hip offset restoration (80% vs 60%). The mean elapsed surgical time was shorter in the grid subgroup (75 vs 102 minutes). Other than hip offset, the differences between these subgroups were quite similar to those seen in Table 2 for the larger groups, and we feel that these findings validate our assumption that our cases beyond the first 20 were outside of the learning curve.

A second limitation is that our study reflects 1 surgeon's experience at an academic center. Use of the grid by additional surgeons will be necessary to prove that these favorable results associated with use of the grid are reproducible in the hands of surgeons with varying levels of experience and THA volume.

Another limitation of our study was the asymmetric demographics between the groups with more men with higher BMIs in the nongrid group. We feel that the difference in gender distribution is simply an anomaly, and we are not aware of any potential confounding effects that this may have had on our findings. The difference in BMI is concerning for confounding as Callanan et al [17] found obesity (compared with BMI's in normal and overweight range) along with minimally invasive surgical approaches and surgeons with low THA volume to be independent risk factors for acetabular component malpositioning. However, their study did not include specifically break out the anterior supine approach nor did it mention intraoperative fluoroscopy as a real-time safe guard. In addition, Matta et al [12], in their study of anterior THAs using intraoperative fluoroscopy, reported consistent component positioning regardless of body habitus.

In conclusion, we have demonstrated reduced variability in component positioning and reduced operative times for anterior supine THA performed with intraoperative fluoroscopy coupled with a novel radiopaque grid. Given the importance of accuracy in THA component positioning, we recommend the use of this simple and effective supplement to anterior supine THA.

References

1. Kurtz S, Ong K, Lau E, et al. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780.
2. Parratte S, Argenson JNA. Validation and usefulness of a computer-assisted cup-positioning system in total hip arthroplasty. A prospective, randomized, controlled study. J Bone Joint Surg Am 2007;89:494.
3. Kennedy JG, Rogers WB, Soffe KE, et al. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. J Arthroplasty 1998;13:530.
4. Lewinnek GE, Lewis JL, Tarr R, et al. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am 1978;60:217.

5. Clark CR, Huddleston HD, Schoch EP, et al. Leg-length discrepancy after total hip arthroplasty. J Am Acad Orthop Surg 2006;14:38.
6. Gurney B, Mermier C, Robergs R, et al. Effects of limb-length discrepancy on gait economy and lower-extremity muscle activity in older adults. J Bone Joint Surg Am 2001;83-A:907.
7. Charles MN, Bourne RB, Davey JR, et al. Soft-tissue balancing of the hip. The role of femoral offset restoration. J Bone Joint Surg 2004;86:1078.
8. Devane PA, Horne JG. Assessment of polyethylene wear in total hip replacement. Clin Orthop Relat Res 1999;59.
9. Sakalkale DP, Sharkey PF, Eng K, et al. Effect of femoral component offset on polyethylene wear in total hip arthroplasty. Clin Orthop Relat Res 2001;125.
10. Little NJ, Busch CA, Gallagher JA, et al. Acetabular polyethylene wear and acetabular inclination and femoral offset. Clin Orthop Relat Res 2009;467:2895.
11. Archbold HAP, Mockford B, Molloy D, et al. The transverse acetabular ligament: an aid to orientation of the acetabular component during primary total hip replacement: a preliminary study of 1000 cases investigating postoperative stability. J Bone Joint Surg Br 2006;88:883.
12. 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.
13. Kalteis T, Handel M, Bäthis H, et al. Imageless navigation for insertion of the acetabular component in total hip arthroplasty: is it as accurate as CT-based navigation? J Bone Joint Surg Br 2006;88:163.
14. Berend KR, Sporer SM, Sierra RJ, et al. Achieving stability and lower-limb length in total hip arthroplasty. J Bone Joint Surg Am 2010;92:2737.
15. Ranawat C. Correction of limb-length inequality during total hip arthroplasty. J Arthroplasty 2001;16:715.
16. Dastane M, Dorr LD, Tarwala R, et al. Hip offset in total hip arthroplasty: quantitative measurement with navigation. Clin Orthop Relat Res 2010;469:429.
17. Callanan MC, Jarrett B, Bragdon CR, et al. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. Clin Orthop Relat Res 2011;469:319.
18. Berry DJ, Berger RA, Callaghan JJ, et al. Minimally invasive total hip arthroplasty. Development, early results, and a critical analysis. Presented at the annual meeting of the American Orthopaedic Association, Charleston, South Carolina, USA, June 14, 2003. In: The Journal of bone and joint surgery American volume. 2235. 2003