Outcomes of Minimally Invasive Anterolateral THA Are Not Superior to Those of Minimally Invasive Direct Lateral and Posterolateral THA

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Published online: 17 October 2012
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Abstract

Background There has been considerable interest in minimally invasive surgical (MIS) THA in recent years. The MIS anterolateral approach, or the MIS Watson-Jones approach, is a novel intermuscular abductor-sparing technique. Early reports from case series suggest the potential for superior function and reduced complications; however,

The institutions of the authors (NVG, SC, DSG, BAM, MT, AEG, CPD) have received funding from Zimmer, Inc (Warsaw, IN, USA). One or more of the authors (DSG, BAM, CPD) certify that each has received or may receive payments or benefits, during the study period, an amount in excess of \$10,000, from Zimmer, Inc. The remaining authors certify that they have no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

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The work was performed at the University of British Columbia (Vancouver, British Columbia, Canada), the University of Toronto (Toronto, Ontario, Canada), and McGill University (Montréal, Québec, Canada).

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the available information from clinical reports is inadequate to suggest surgeons should change from their accepted standard approach.

Questions/purposes We examined the potential superiority of this anterolateral approach, as judged by quality-of-life (QoL) measures, radiographic parameters, and complications, compared to limited-incision MIS direct lateral and MIS posterolateral approaches.

Methods We performed a prospective randomized controlled trial involving five surgeons at three centers, recruiting 156 patients undergoing primary THA to receive either the MIS anterolateral or the surgeon's preferred approach (direct lateral or posterolateral). For the 135 patients we report, we collected patient-reported WOMAC, SF-36, Paper Adaptive Test in 5 Domains of Quality of Life in Arthritis Questionnaire [PAT5D], and patient satisfaction scores. We recorded complications and evaluated radiographs for prosthetic component position, subsidence, and fracture. Minimum followup was 24 months (mean, 30 months; range, 24–42 months).

Results QoL and patient-reported satisfaction were similar between groups. Radiographic evaluation demonstrated no differences in acetabular component positioning; however, mean stem subsidence was 4.6 mm for the MIS anterolateral group and 4.1 mm for the alternate group, with differences observed among the three centers for stem subsidence and fracture. One center had increased rate of

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fracture requiring treatment and need for revision in the MIS anterolateral group.

Conclusions We found no superiority of the MIS anterolateral approach but observed intersite differences in painful stem subsidence and fracture. We have returned to the standard surgical approaches in use before the trial.

Level of Evidence Level I, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

Introduction

Over the past 50 years, primary THA has been one of the most successful orthopaedic interventions and one of the most cost-effective procedures at restoring patient quality of life (QoL) [14]. In the United States, surgeons perform in excess of 300,000 primary THA procedures annually, with this number expected to increase to an estimated 572,000 procedures by 2030 [9]. With the advent of minimally invasive surgery (MIS), many surgeons and stakeholders in healthcare delivery turned to MIS techniques for THA, with the hope they would improve function, expedite recovery, and reduce healthcare expenditure. MIS THA techniques include a variety of approaches, selected with the intent of reducing the soft tissue trauma associated with surgery through shorter incisions than those in traditional approaches. Two of the common MIS THA approaches in North America are the MIS posterolateral (PL) and the MIS direct lateral (DL), which are adapted from the standard PL approach and the standard DL transgluteal approach to the hip [16]. An alternative MIS technique that has gained interest in Europe and more recently North America is the MIS anterolateral (AL) approach (or MIS Watson-Jones approach) [15]. While it is an adaptation of the standard Watson-Jones approach, it has gained support at some centers recently [2, 15] due to its relative sparing of the abductors, posterior capsule, and external rotators, which may permit early recovery and reduced risk of dislocation.

While Bertin and Röttinger [2] and Röttinger [15] reported the MIS AL approach to be reliable and associated with low risk of complications and excellent clinical results, these two reports are uncontrolled case series, which cannot evaluate for superiority over the more widely accepted MIS PL and MIS DL techniques. Given the determinants of recovery and outcome after THA are multifactorial and recognizing the reported outcomes of MIS techniques may be influenced by selection bias, reporting bias, and other sources of error or confounding, it is preferable to consider a randomized controlled trial (RCT) to evaluate any new approach before considering one MIS technique superior to another. A prospective RCT

provides the investigator with the most robust study design to control the potential biases and confounding and to evaluate for causation rather than association.

We therefore evaluated the hypothesis that the MIS AL approach is superior in terms of (1) function (WOMAC, 24 months postoperatively), (2) recovery (WOMAC, 3 months postoperatively), (3) QoL (SF-36) and patient utility (Paper Adaptive Test in 5 Domains of Quality of Life in Arthritis Questionnaire [PAT5D]), (4) patient-reported satisfaction [10], (5) radiographic component position (acetabular cup anteversion/abduction angle, femoral stem varus/valgus, subsidence), and (6) complications (deep venous thrombosis, nerve injury, infection, wound hematoma, fracture), compared to the traditional MIS approaches (DL, PL).

Patients and Methods

After hospital and institutional ethics review and approval of our study protocol, we performed a prospective RCT involving five surgeons at three centers and recruited 156 patients undergoing primary THA to receive either the MIS AL approach or the surgeon's preferred approach (DL or PL) between 2005 and 2008. During the study period, we treated 587 patients with THA. Inclusion criteria for the study were indication for hip arthroplasty due to osteoarthritis or avascular necrosis, age of 19 to 75 years, willingness to adhere to the short-stay program, home environment supportive of early discharge to home, and ability to give informed consent. We excluded 431 patients who did not meet the inclusion criteria and had one or more of the following: inflammatory arthritis, disabling arthritis in any other joint, one or more activity-modifying comorbidities, obesity (BMI > 30), or previous fracture/osteotomy/internal fixation involving the index hip. Patients were randomly assigned to receive THA using the MIS AL technique or the alternate MIS technique. Randomization was performed through a computer-generated randomization code, stratified by surgeon and site, in permuted blocks of 2 and 4. Patients were blinded to their group allocation and the surgeon notified. All ward nursing and rehabilitation staff members were blinded to group assignment, and patients were treated with identical patient care map, anesthesia protocol, postoperative pain management, rehabilitation program, and discharge criteria. The statistician and radiographic evaluator were also blinded to group assignment. Before randomization, 12 patients (four MIS AL, eight alternate MIS) withdrew from the trial, and after randomization but before the first followup questionnaire, an additional nine patients (four MIS AL, five alternate MIS) withdrew, leaving a total of 135 patients (69 MIS AL, 66 alternate MIS [40 MIS DL, 26

MIS PL]) from the three centers (Vancouver site, 93; Toronto site, 36; Montréal site, six) for comparison with complete baseline parameters and followup measures at the desired time intervals. The minimum followup was 24 months (mean, 30 months; range, 24–42 months).

Sample size was calculated to detect an 8-point difference in WOMAC (normalized 0- to 100-point scale) between two groups, which is the minimum perceptible difference in WOMAC and represents an effect size of 0.5. For an alpha of 0.05, using a two-tailed superiority design, with a correlation coefficient of 0.5 for repeated-measures ANOVA, we calculated a sample size of 130 patients (65 patients/group) for an 80% power. Estimating up to 20% withdrawal or attrition, we established a recruitment goal of 156 patients.

Patients completed a preoperative interview and questionnaire documenting age, sex, BMI, comorbidity, and QoL (WOMAC [1], SF-36 [17], PAT5D [8]). Patients were similar between groups in terms of demographic parameters (Table 1) and preoperative disease-specific, generic, and utility QoL measures (WOMAC, SF-36, PAT5D). There were no crossovers or protocol violators.

After a learning curve, which included a hands-on course and a combined number of 95 cases, five specialized hip surgeons at three academic centers participated in the study. Before commencing the study, an expert panel of hip arthroplasty surgeons was used to define the so-called learning curve for the MIS AL procedure. To participate in the study, it was agreed the surgeon should participate in a hands-on cadaveric course, assist in an MIS AL surgery, and perform a minimum of 10 AL THAs. Participating surgeons performed either the MIS AL technique or an alternate MIS technique (surgeon's usual standard MIS DL or PL). This was done so as to preserve the real-world pragmatic comparison of the MIS AL technique to the surgeon's usual MIS technique in keeping with a clinical effectiveness trial rather than an efficacy trial. All surgeons contributed a minimum of six patients to the study. Aggregate analyses were performed on QoL and satisfaction data. Aggregate and intersite analyses were performed on radiographic results and complications.

Table 1. Patient demographics

Variable	MIS AL approach	Alternate MIS approaches	p value
Female (%)	63	69	0.77
Male (%)	37	31	0.77
BMI*	25.1 (2.9)	25.5 (3.4)	0.65
Comorbidities*	4.04 (2.7)	3.81 (3.1)	0.38
Age (years)*	62.1 (9.6)	61.3 (13.1)	0.92

* Values are expressed as mean, with SD in parentheses; MIS = minimally invasive surgery; AL = anterolateral.

Surgical technique was standardized across the participating centers. The MIS AL technique was performed as per Bertin and Röttinger [2] and Röttinger [15], the MIS DL technique was performed reflecting anteriorly the anterior $\frac{1}{3}$ of the gluteus medius and minimus followed by anatomic suture repair of the musculotendinous flap, and the MIS PL approach was performed using anatomic capsulotendinous repair of the short external rotators and posterior hip capsule. We used the M/L Taper stem, 28- or 32-mm CoCr femoral heads, Trilogy[®] cup, and Longevity[®] polyethylene liner (all Zimmer Inc, Warsaw, IN, USA). Anesthesia protocols using spinal or epidural anesthesia, postoperative multimodal analgesia, and accelerated short-stay care maps were standardized and utilized at all centers for study patients.

Patients were mobilized on the day of surgery and received daily physiotherapy (minimum of 30 minutes supervised physiotherapy session plus one or two sessions of self-administered exercise) until discharged. Physiotherapy protocols included full weightbearing, unrestricted abductor strengthening, gait retraining, and instruction of safe self-administered exercise protocols.

Patients were assessed at intervals of 1, 2, 3, 4, 6, 12, and 24 months postoperatively. We collected WOMAC and PAT5D scores at all intervals, SF-36 scores at 3, 6, 12, and 24 months, and patient satisfaction [10] at 24 months. The questionnaire of Mahomed et al. [10] is a scale designed to assess satisfaction with joint arthroplasty. Patients answer four questions: patients' overall satisfaction with surgery (global), extent of pain relief (pain), ability to perform home or yard work (function), and ability to perform recreational activities (recreation). The scale score is the mean of the scores from the individual items, ranging from 25 (least satisfied) to 100 (most satisfied). Patients also completed questionnaires regarding complications, including readmission to hospital, reoperation or revision surgery, dislocation, infection, or treatment for hematoma or infection. Furthermore, all hospital and clinic charts and records were reviewed for readmissions and complications.

One hundred thirty-four of the 135 retained patients had complete radiographic series for review. While all patients received an immediate postoperative AP pelvis radiograph in the operating room and then a complete AP and lateral of the hip before discharge, one patient was discharged early (before completing the AP and lateral of the hip). The additional images were obtained at 3-month followup. A single, blinded, independent orthopaedic surgeon who was not one of the operating surgeons in the study (SC) reviewed all radiographs from all centers. Radiographs were reviewed for component position (acetabular cup anteversion/abduction angle, femoral stem varus/valgus, and subsidence [Fig. 1]) using the techniques of Widmer

Fig. 1 A radiograph shows the subsidence measurement method in a patient from the MIS AL group, with symptomatic subsidence of greater than 10 mm requiring revision hip arthroplasty.

[18] and Faisal et al. [4], and measurements were completed using digital techniques adjusting for magnification. While other techniques are commonly used for precise measurement of component migration, subsidence, or loosening (ie, roentgen stereophotogrammetric analysis or Ein-Bild-Röntgen-Analyse), we did not have these techniques in use at our study centers at the time of the study. It is important to recognize the radiographic determination of component placement and subsidence was a secondary outcome in our study and the primary outcome was clinical. We attempted to minimize error and bias by using a single, blinded radiographic reviewer, using digital images, and adjusting for magnification differences, techniques widely used in other studies reporting on MIS THA prosthetic component status. While it is possible our measurement technique may be associated with measurement error or bias, the blinded nature of the measurements should result in it being nondifferential in nature and it should not adversely affect the conclusion of our comparative radiographic results.

We performed descriptive and comparative analyses using SAS® Version 9.2 (SAS Institute Inc, Cary, NC, USA). Repeated-measures ANOVA was performed with QoL measure (WOMAC, SF-36, PAT5D) as outcome

variable, adjusting for baseline status, for their respective analyses. F tests with 95% CIs were performed at latest recovery (24 months postoperatively) and early recovery (3 months postoperatively). We tested for normality by group using the Kolmogorov-Smirnov test. Variables not demonstrating normality ($p < 0.05$) were analyzed using two-sample Wilcoxon rank-sum tests and variables demonstrating normality were analyzed using two-sample t-tests. Patient satisfaction demonstrated normality and was analyzed using the two-sample t-test. Radiographic outcomes of cup abduction, anteversion, and stem position met the criteria for normality and were analyzed with t-tests. Stem subsidence failed the test for normality and was evaluated with the Wilcoxon rank-sum test. To evaluate the potential for outliers to adversely affect the interpretation of this outcome, boxplots were constructed and sensitivity analyses performed by way of repeating the analyses excluding outliers. Complications including fractures are categorical variables and were evaluated using the chi-square test and Fisher's exact test.

Results

We found no differences ($p > 0.05$) between MIS AL and the comparison group at latest recovery (24 months postoperatively) and early recovery (3 months postoperatively) as measured by WOMAC. Furthermore, we did not detect any differences ($p > 0.05$) between groups in SF-36, PAT5D utility, or patient satisfaction scores (Table 2). In both groups, we observed improvements across all QoL scores from preoperative values, and patients reported high levels of satisfaction with their outcome at 2 years.

Radiographic analyses demonstrated no differences ($p > 0.05$) in acetabular anteversion (anterior opening), acetabular abduction (lateral opening), or femoral varus/valgus alignment at the Vancouver site (Table 3) and at the Toronto and Montréal sites (Table 4). The Vancouver center, with three surgeons participating in the study, observed more subsidence ($p < 0.007$) in stems inserted through the MIS AL approach (4.2 mm) than in stems inserted through the alternate MIS approaches (2.2 mm) (Table 3). In addition, the MIS AL group had two patients with symptomatic subsidence of greater than 10 mm for which they underwent revision hip arthroplasty (Fig. 2).

Four patients in the MIS AL group sustained a fracture intraoperatively (two large trochanteric fractures treated with cable with or without plate fixation, two small trochanteric fractures not treated) (Fig. 3). Four patients in the alternate MIS group sustained a trochanteric fracture (one treated with cable fixation, three small not treated). One patient in the MIS AL group developed a deep venous thrombosis, and one patient developed a minor wound

Table 2. Quality of life outcomes

Measure	MIS AL approach	Alternate MIS approaches	p value
Preoperative (baseline)			
WOMAC (points)			
Global	49.1 (18.2)	48.0 (17.9)	0.70
Function	48.1 (18.2)	47.0 (18.7)	0.71
Pain	47.7 (18.2)	48.1 (18.2)	0.88
Stiffness	43.4 (17.1)	44.8 (17.8)	0.66
Postoperative (3 months)			
WOMAC (points)			
Global	82.4 (11.9)	79.8 (16.7)	0.35
Function	82.7 (12.9)	79.7 (17.4)	0.32
Pain	86.6 (12.0)	83.8 (15.9)	0.31
Stiffness	69.2 (19.5)	70.1 (21.3)	0.82
Postoperative (24 months)			
WOMAC (points)			
Global	92.1 (10.4)	90.6 (12.9)	0.47
Function	92.1 (11.4)	90.8 (11.2)	0.55
Pain	94.0 (5.0)	91.6 (8.9)	0.24
Stiffness	86.4 (16.3)	85.5 (18.4)	0.78
SF-36 (points)			
Mental	53.3 (9.7)	55.3 (7.3)	0.67
Physical	50.4 (6.9)	50.8 (8.3)	0.77
PAT5D (points)	0.89 (0.1)	0.90 (0.9)	0.80
Satisfaction (points)			
Global	91.8 (16.8)	87.1 (25.6)	0.30
Pain	92.3 (16.5)	89.4 (20.2)	0.43
Function	89.8 (26.7)	91.9 (17.7)	0.56
Recreation	88.1 (14.7)	88.7 (16.3)	0.94

Values are expressed as mean, with SD in parentheses; MIS = minimally invasive surgery; AL = anterolateral; PAT5D = Paper Adaptive Test in 5 Domains of Quality of Life in Arthritis Questionnaire.

hematoma. There were no dislocations or infections (Table 5).

Discussion

There has been considerable interest in MIS THA in recent years. The MIS AL approach, or the MIS Watson-Jones approach, is a novel intermuscular abductor-sparing technique. While the MIS DL and PL approaches have proven popular in North America, they both have potential drawbacks in so far as the DL approach is a transgluteal approach and therefore may adversely affect abductor function and the PL approach violates the posterior hip capsule, which may be associated with increased risk of dislocation. The MIS AL approach provides the surgeon

Table 3. Radiographic outcomes: Vancouver site

Variable	MIS AL approach	Alternate MIS approaches	p value
Cup anteversion (°)	18.35 (7.96)	19.55 (8.14)	0.482
Cup abduction (°)	42.13 (5.99)	43.95 (4.76)	0.117
Stem position (°)	−0.59 (1.51)	−0.55 (1.32)	0.931
Stem subsidence (mm)	4.2 (3.88)	2.2 (1.87)	0.007

Values are expressed as mean, with SD in parentheses; MIS = minimally invasive surgery; AL = anterolateral.

Table 4. Radiographic outcomes: Toronto and Montréal sites

Variable	MIS AL approach	Alternate MIS approaches	p value
Cup anteversion (°)	15.64 (11.70)	16.00 (9.40)	0.921
Cup abduction (°)	41.88 (5.98)	38.05 (6.42)	0.123
Stem Position (°)	−0.61 (0.90)	−0.58 (1.10)	0.911
Stem subsidence (mm)	4.8 (3.94)	7.15 (4.31)	0.110

Values are expressed as mean, with SD in parentheses; MIS = minimally invasive surgery; AL = anterolateral.

with a so-called abductor-sparing hip approach, which preserves the posterior hip capsule and short external rotators. Early case series reported by Bertin and Röttinger [2] and Röttinger [15] suggest excellent clinical results and few complications. Our goal was to compare the MIS AL approach to a surgeon's usual MIS approach with the methodologic rigor of a prospective RCT. We therefore evaluated the hypothesis that the MIS AL approach is superior in terms of (1) function (WOMAC, 24 months postoperatively) (2) recovery (WOMAC, 3 months postoperatively), (3) QoL (SF-36) and patient utility (Paper Adaptive Test in 5 Domains of Quality of Life in Arthritis Questionnaire [PAT5D]), (4) patient-reported satisfaction [10], (5) radiographic component position (acetabular cup anteversion/abduction angle, femoral stem varus/valgus, subsidence), and (6) complications (deep venous thrombosis, nerve injury, infection, wound hematoma, fracture), compared to the traditional MIS approaches (DL, PL).

There are some limitations to our study. First, we calculated sample size using QoL measures and made WOMAC our primary outcome measure of interest. It is possible that subtle differences in clinical or gait performance exist between these MIS approaches and we were unable to detect differences due to lack of precision, responsiveness, or ceiling effects attributable to such an outcome measure. However, we believe we selected outcomes that are relevant, reflect disease-specific and generic QoL, and are likely to detect any major effect that a surgical approach has on these parameters. In addition, the

Fig. 2A–B Radiographs of the femoral stem in a female patient in the MIS AL group show subsidence of greater than 10 mm (A) postoperatively and (B) at 12-month followup.

Fig. 3A–B Radiographs show a greater trochanteric fracture (A) preoperatively and (B) after fixation with cable and plate.

fact that we used patient-reported outcomes as our primary outcome of interest reduces the risk of interviewer bias or data measurement bias adversely affecting our outcome. Second, we included two distinctly different MIS approaches in the same comparison group of the trial (DL, PL). We did not compare the MIS AL technique to standard incision but rather to current and relevant MIS DL and PL approaches. While this may make it difficult to determine how the MIS AL approach compares to the MIS PL approach alone or to the MIS DL approach alone from our data, we determined this was less of a priority than

Table 5. Complications

Complication	Number of patients	
	MIS AL approach	Alternate MIS approaches
Deep venous thrombosis	1	0
Nerve injury	0	0
Infection	0	0
Wound hematoma	1	0
Fracture	4 (2 required fixation)	4 (1 required fixation)

MIS = minimally invasive surgery; AL = anterolateral.

establishing superiority of the MIS AL technique in comparison to the best alternative technique that the surgeon already had mastered. We believe this is a more pragmatic and real-world comparison and renders our results more generalizable to the community of orthopaedic surgeons than to one particular technique of MIS arthroplasty. While it would have been possible to perform this RCT as a noninferiority or equivalence study, our core group of researchers (inclusive of surgeons and statistician) considered the case series data and reports from other surgeons to suggest they would not consider an alternate MIS THA technique unless it demonstrated superiority on major outcome variables such as clinical results, patient satisfaction, or complications. Therefore, we designed this trial to evaluate for superiority, using a two-tailed design. An additional strength of this study is that is a blinded, multicenter prospective RCT, which did not allow for imbalances in baseline characteristics or data reporting, recording, or measurement to influence our reported outcomes. Furthermore, blinding the patients, ward nurses, and rehabilitation personnel minimized the potential for external factors to affect the patient's perspective of their own status and outcome as reported on their questionnaires.

Our findings refute the hypothesis that the MIS AL approach has superior results in comparison to the alternate MIS DL and PL approaches. First, our study demonstrates no difference in patient-reported, disease-specific QoL at latest recovery (WOMAC, 24 months postoperatively).

We also found no differences at early recovery (WOMAC, 3 months postoperatively), nor did we observe differences in generic QoL (SF-36) or patient-reported utility score (PAT5D). The patients reported similar satisfaction scores as measured on global satisfaction and across domains of satisfaction. Our results on patient-reported QoL compare favorably to other recent RCTs reported in the literature (Table 6). Inaba et al. [7] randomized 102 patients to receive MIS AL or MIS DL and did not detect any difference in QoL (WOMAC, SF-36) at

Table 6. Comparison with published literature

Study	Year	Number of patients	Followup (months)	Stem type	Number of MIS AL THAs	Number of comparison MIS THAs	Disease-specific QoL comparison	Generic QoL comparison	Number of fractures	Number of revisions
Inaba et al. [7]	2011	102	12	Cementless	52	50 MIS DL	HHS* and WOMAC*	SF-36*	1 (MIS AL)	0
Martin et al. [11]	2011	79	12	Cemented	42	41 standard DL	HHS* and PMA*	SF-36*	None	0
Current study	2012	135	24	Cementless	69	66 (40 MIS DL, 26 MIS PL)	WOMAC*	SF-36*	8 (4 MIS AL, 4 MIS DL)	2 (MIS AL)

* No significant difference between groups; MIS = minimally invasive surgery; AL = anterolateral; DL = direct lateral; PL = posterolateral; QoL = quality of life; HHS = Harris hip score; PMA = Postel-Merle d'Aubigné.

1 year postoperatively. Martin et al. [11] randomized 79 patients (83 hips) to MIS AL or MIS DL and observed no difference in QoL (Postel-Merle d'Aubigné, SF-36) at 1 year postoperatively. It appears our study, together with the two RCTs cited, demonstrates results that are good but not superior to their respective comparison groups.

While it appears all MIS approaches we evaluated resulted in similar cup and stem orientation, we observed greater stem subsidence and a risk of revision for subsidence-related reasons in comparison to the alternate MIS approaches at the one center that contributed the largest number of patients to the study. We believe this may be attributed to the additional technical challenges related to femoral canal visualization, instrumentation, and final component placement. While exposure and adequate visualization of the femoral canal may be the norm for the majority of patients who receive the MIS AL technique, our data suggest a small proportion of such patients will receive a stem that may be undersized or not completely seated due to the additional challenges in exposing the femoral canal. All participating surgeons attended an educational course and cadaveric training using the same instrumentation and implants, had completed a minimum of 10 cases, and were confident they were beyond the learning curve before performing the procedures on study patients. While some subsidence may be considered normal for a tapered stem, two of these patients developed symptomatic subsidence and fibrous fixation for which they underwent revision hip arthroplasty. Both of these patients were in the MIS AL group and no cases of symptomatic fibrous fixation were identified in the MIS DL group. All participating surgeons use the M/L Taper stem as their primary stem for the majority of THAs and have not reported subsidence of stem or failure of ingrowth to be issues in their routine use of this device. We attribute the increased subsidence seen in this study across the study population to incomplete fit and fill of the canal due to a

Fig. 4 Boxplots compare subsidence by surgical approach (1 = MIS AL; 2 = MIS DL, MIS PL) in combined sites. Box = interquartile range (25%–75%); horizontal line in box = median; + = mean; whiskers = range of values to a maximum of 1.5 times the value of the interquartile range; open circles = outliers.

compromised view of the femoral canal associated with the MIS approaches. The participating surgeons have all adapted their approaches now to use a minimal-incision technique; however, all now report using the smallest reasonable incision that permits adequate visualization and instrumentation rather than a predetermined maximal length of skin incision (ie, 10.2 cm). To assess the potential for outliers to affect our data, we illustrated the subsidence data on boxplots (Fig. 4). In sensitivity analyses in which we reran subsidence analyses excluding the outliers, our results did not change.

In comparing our results to the published literature, it is evident there is substantial heterogeneity in the literature to date on MIS hip approaches and their effect on clinical outcome. Ogonda et al. [12] was among the first to report no difference arising from the MIS PL approach in comparison to the standard approach in an adequately powered prospective RCT. After that report, Woolson et al. [19] questioned the merits of MIS THA techniques. Dorr et al. [3] reported improved pain scores after the MIS PL

approach versus standard approach in a small RCT; however, they were not able to blind their patients or study personnel and did not report on QoL outcomes or other validated measures of patient-reported function. Other RCTs to date have not provided any compelling data to justify a change in surgical approach [5–7, 13]. Reininga et al. [14] completed a qualitative and systematic review of the literature on MIS THA in 2010, evaluating for validity, bias, and methodologic quality of the study design. They concluded there are few studies of high quality and there is little evidence to support superiority of an MIS technique over comparison groups in those studies.

One site participating in our trial identified an additional unique risk of subsidence and a subsidence-related need for early revision that is uniquely attributed to the new MIS AL surgical approach. While we acknowledge we did not see the same magnitude of these complications at the other participating sites, it is important to recognize fewer cases were performed at those sites. Fracture and painful subsidence are relatively infrequent complications, and therefore it may take larger numbers of study patients at those sites to observe similar outcomes or complications that are relatively infrequent in occurrence. Our results pertaining to component orientation suggest no difference in comparison to the reports from Martin et al. [11] and Inaba et al. [7]. However, our observation of increased risk of subsidence in the MIS AL group differed from other RCTs recently reported in the literature. Martin et al. [11] did not identify problematic cases of subsidence or fracture and Inaba et al. [7] observed only one calcar fracture in the MIS AL group. This difference may be related to intersurgeon differences in technique, instrumentation, or component insertion or may be due to differences in implant characteristics. Our study used a tapered titanium stem while Martin et al. [11] used a cemented stem and Inaba et al. [7] used a cementless stem different from that used in our study. Given that a number of potential contributing factors are involved in creating one such complication and that these are relatively rare complications in relatively small RCTs, more studies are necessary to determine whether these complications are truly attributable to the surgical approach.

In summary, we failed to demonstrate superiority with the MIS AL approach and in fact observed an increased risk of site-specific complications requiring revision with this approach. We believe it is important to advise the surgical community to proceed with caution when considering new surgical approaches, which may create greater technical challenges and may compromise visualization increasing the risk of fracture or painful subsidence. All of us have returned to our preferred minimal-incision approaches in use before this study, and the MIS AL approach evaluated in this study is no longer in use at the respective centers. In fact, in the absence of superiority

data from any MIS RCT, we no longer advocate MIS approaches and we use common sense in the use of the smallest possible incision that is compatible with easy visualization and the least possible surgical trauma to the patient.

Acknowledgments We thank Daphné Savoy for her assistance in the preparation of this manuscript and Abdul Aziz for his participation with patient followup and data collection for this study.

References

1. Bellamy NF, Buchanan WW, Goldsmith CH, Campbell JF, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol*. 1988;15:1833–1840.
2. Bertin KC, Röttinger H. Anterolateral mini-incision hip replacement surgery: a modified Watson-Jones approach. *Clin Orthop Relat Res*. 2004;429:248–255.
3. Dorr LD, Maheshwari AV, Long WT, Wan Z, Sirianni LE. Early pain relief and function after posterior minimally invasive and conventional total hip arthroplasty: a prospective randomized, blind study. *J Bone Joint Surg Am*. 2007;89:1153–1160.
4. Faisal M, Thomas G, Young SK. Subsidence of the Corail femoral component in the elderly: a retrospective radiological review. *Hip Int*. 2011;21:325–329.
5. Foucher KC, Wimmer MA, Moision KC, Hildebrand M, Berli MC, Walker MR, Berger RA, Galante JO. Time course and extent of functional recovery during the first postoperative year after minimally invasive total hip arthroplasty with two different surgical approaches—a randomized controlled trial. *J Biomechanics*. 2011;44:372–378.
6. Goosen JH, Kollen BJ, Castelein RM, Kuipers BM, Verheyen CC. Minimally invasive versus classic procedures in total hip arthroplasty. *Clin Orthop Relat Res*. 2011;469:200–208.
7. Inaba Y, Kobayashi N, Yukizawa Y, Ishida T, Iwamoto N, Saito T. Little clinical advantage of modified Watson-Jones approach over modified mini-incision direct lateral approach in primary total hip arthroplasty. *J Arthroplasty*. 2011;26:1117–1122.
8. Kopec JA, Sayre EC, Davis AM, Badley EM, Abrahamowicz M, Sherlock L, Williams JL, Anis AH, Esdaile JM. Assessment of health-related quality of life in arthritis: conceptualization and development of five item banks using item response theory. *Health Qual Life Outcomes*. 2006;4:33.
9. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007;89:780–785.
10. Mahomed N, Gandhi R, Daltroy L, Katz JN. The self-administered patient satisfaction scale for primary hip and knee arthroplasty. *Arthritis*. 2011;2011:591253.
11. Martin R, Clayson PE, Troussel S, Fraser BP, Docquier PL. Anterolateral minimally invasive total hip arthroplasty: a prospective randomized controlled study with a follow-up of 1 year. *J Arthroplasty*. 2011;26:1362–1372.
12. Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, O'Brien S, Beverland D. A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes: a prospective, randomized, controlled trial. *J Bone Joint Surg Am*. 2005;87:701–710.
13. Popischill M, Kranzl A, Attwenger B, Knahr K. Minimally invasive compared with traditional transgluteal approach for total hip arthroplasty. *J Bone Joint Surg Am*. 2010;92:328–337.

14. Reininga IH, Zijlstra W, Wagenmakers R, Boerboom AL, Huijbers BP, Groothoff JW, Bulstra SK, Stevens M. Minimally invasive and computer-navigated total hip arthroplasty: a qualitative and systematic review of the literature. *BMC Musculoskelet Disord.* 2010;11:92.
15. Röttinger H. [The MIS anterolateral approach for THA] [in German]. *Orthopäde.* 2006;35:710–715.
16. Toms A, Duncan CP. The limited incision, anterolateral, intermuscular technique for total hip arthroplasty. *Inst Course Lect.* 2006;55:199–203.
17. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992;30:473–483.
18. Widmer KH. A simplified method to determine acetabular cup anteversion from plain radiographs. *J Arthroplasty.* 2004;19:387–390.
19. Woolson ST, Mow CS, Syquia JF, Lannin JV, Shurman DJ. Comparison of primary total hip replacement performed with a standard incision or a mini-incision. *J Bone Joint Surg Am.* 2004;86:1353–1358.