

Femoral stem migration after direct lateral and direct anterior total hip arthroplasty: a prospective cohort study

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Background: The direct lateral (DL) approach to total hip arthroplasty is more commonly used than the newer direct anterior (DA) approach. Both approaches use collared or collarless femoral stems. We sought to assess implant stability of stem designs implanted with the DL approach and compare outcomes from this cohort with those of a previously reported cohort of patients who underwent arthroplasty with a DA approach. We also sought to determine if early recovery influences differences in migration.

Methods: Patients underwent total hip arthroplasty using the DL or the DA approach and were randomized to receive either a collared or collarless, cementless femoral stem. On the day of surgery and at 6 follow-up visits through to 1 year, patients underwent supine radiostereometric imaging to track implant migration. At follow-up visits, patients performed an instrumented walking test to assess their functional ability and logged an average daily step count to assess their activity levels. We assessed whether patient function and activity were correlated with migration.

Results: Stem design did not have a significant effect on migration for the DL group ($p = 0.894$). Compared with the DA group, the DL group migrated significantly less for both collared ($p = 0.031$) and collarless ($p = 0.002$) stems. Migration was not correlated with function or activity at any time point ($p > 0.05$).

Conclusion: Most implant migration occurred from the day of surgery to 2 weeks after the operation and stabilized thereafter, suggesting adequate fixation and a low risk for aseptic loosening in both patient groups.

Contexte : La voie latérale directe (LD) est utilisée plus fréquemment pour effectuer une arthroplastie totale de la hanche (ATH) que la voie antérieure directe (AD), plus récente. Les 2 approches utilisent des tiges fémorales avec ou sans collerette. Nous avons évalué la stabilité des modèles de tiges implantés par voie LD et comparé les issues de cette cohorte à celles d'une cohorte de patients ayant déjà fait l'objet d'une étude qui avaient subi une arthroplastie par voie AD. Nous avons aussi cherché à déterminer si le début du rétablissement avait une influence sur des différences dans le risque de migration.

Méthodes : Des patients devant subir une arthroplastie par voie LD ou AD ont été répartis aléatoirement en 2 groupes : tiges fémorales sans ciment avec ou sans collerette. Le jour de l'intervention et durant 6 visites de suivi la première année, les patients ont subi un examen d'imagerie radiostéréométrique en décubitus visant à mesurer la migration de l'implant. Durant les visites de suivi, ils ont fait un test de marche instrumenté visant à évaluer leur capacité fonctionnelle et enregistré leur nombre moyen de pas quotidiens, ce qui permet d'évaluer leur niveau d'activité. Nous avons cherché à déterminer s'il y avait une corrélation entre la migration observée, et la capacité fonctionnelle et le niveau d'activité des patients.

Résultats : Le modèle de tige n'a pas eu d'effet significatif sur la migration pour le groupe LD ($p = 0,894$). Par contre, comparativement au groupe AD, on a enregistré chez les patients du groupe LD une migration significativement inférieure pour les tiges avec collerette ($p = 0,031$) et sans collerette ($p = 0,002$). Aucune corrélation n'a été observée entre la migration et la capacité fonctionnelle ou le niveau d'activité, peu importe le moment de l'évaluation ($p > 0,05$).

Conclusion : L'essentiel de la migration des implants est survenu dans les 2 semaines suivant l'intervention, puis le processus s'est stabilisé, ce qui semble indiquer une fixation adéquate et un faible risque de descellement aseptique dans les 2 groupes de patients.

Total hip arthroplasty (THA) is the only viable treatment for patients with end-stage osteoarthritis of the hip, and is successful and reliable in improving patients' quality of life, restoring function and alleviating pain.^{1,2} Over the last 5 years, the number of THA procedures performed in Canada has increased 17.4% to more than 58 000 annually.³ This continuous increase in THA procedures has placed an economic burden on health care systems. To help reduce costs and cope with this burden, demand exists to further optimize surgical pathways, implement rapid recovery programs and improve patient outcomes.^{4,5}

The direct lateral (DL) surgical approach is the preferred method for THA for about 42% of orthopedic surgeons worldwide.⁶ The DL approach provides good exposure of the femur and acetabulum, and has a low risk for dislocations. However, the intramuscular nature of the DL approach may lead to greater postoperative pain and longer hospital stays or rehabilitation times.⁷ In recent years, the direct anterior (DA) approach has increased in popularity for its muscle-sparing nature, leading to a faster recovery, less postoperative pain and an earlier discharge from the hospital.^{8,9} However, the steep learning curve and decreased surgical view of the femur associated with the DA approach may lead to complications such as risk of fracture and dislocation.^{6,9,10} Studies have also reported a higher rate of aseptic loosening associated with the DA approach, possibly owing to the greater likelihood of using an undersized stem.¹⁰⁻¹²

Although some femoral stem migration is common and acceptable throughout recovery, substantial and continuous early migration can predict loosening of the femoral component and implant failure.^{13,14} Collared stem designs can provide greater stability and are associated with less migration than collarless designs.^{13,15} Radiostereometric analysis (RSA) is recognized as the gold standard for tracking implant migration and can detect implant movement with an accuracy of 0.2 mm for translations and 0.5° for rotations.^{14,16,17} Radiostereometric analysis plays an important role in evaluating stem fixation after THA and can be used to compare outcomes between different stem designs and surgical approaches.

The purpose of the present study was to evaluate implant stability between stem designs after primary THA using the DL approach, and to compare outcomes in this cohort to those of a previously reported cohort of patients who underwent the DA approach.¹⁸ We hypothesized that the collared stem design would mitigate migration compared with the collarless design, and that patients who underwent the DL approach would have less implant migration than those who underwent the DA approach. We also hypothesized that recovery of patient functional abilities and level of activity would influence femoral stem migration.

METHODS

Study design and participants

We included patients undergoing unilateral primary THA. Patients were prescreened and excluded based on the following criteria: symptomatic contralateral hip osteoarthritis, revision or bilateral THA, a body mass index greater than 40, cognitive defects or neuromuscular disorders that would prevent a walking test, inability to understand English and living more than 100 km from our institution given the frequent follow-up visits required for the study. Eligible patients were recruited and provided written informed consent before participation.

Using an expertise-based approach,^{19,20} patients recruited for this study underwent THA using either the DL approach or the DA approach depending on their surgeon referral. Two fellowship-trained arthroplasty surgeons performed all the operations; 1 surgeon (E.M.V.) performed all the DL surgeries and another (B.A.L.) performed all the DA surgeries. Before their surgery, we randomized patients within each surgical approach group to receive either a collared or collarless Corail cementless femoral stem (DePuy Synthes) using block randomization with concealed envelopes. As required for each patient, the surgeon could choose to use a standard or a high-offset stem, along with either a 28 mm, 32 mm or 36 mm cobalt-chromium femoral head. All patients received a Pinnacle cup, with AltrX highly crosslinked acetabular liner (DePuy Synthes) as the acetabular component. To enable tracking of implant migration with RSA, a minimum of 6 tantalum beads (diameter 1 mm) were inserted into the cortical bone of the proximal femur intraoperatively.

We recruited patients in both surgical approach groups concurrently and followed an identical protocol. We have previously reported on the differences in migration and clinical outcomes between stem designs for the DA cohort.¹⁸ Here, we report the differences in outcomes between stem designs for the DL cohort and perform further analyses to compare outcomes between the DL and DA cohorts.

Radiographic analysis

Each patient underwent an RSA exam in a supine position within 24 hours after their surgery, before they were discharged from the hospital. Follow-up RSA exams were conducted at 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months and 1 year after surgery. Patients were consistently positioned at each exam with a uniplanar calibration cage (RSA Biomedical) used to define the coordinate system. We used model-based RSA software (RSACore) to analyze radiographs. We defined positive translation

directions as proximal translation in the y-axis, medial translation in the x-axis and anterior translation in the z-axis. We defined positive rotation directions as internal rotation about the y-axis, anterior tilt about the x-axis and valgus rotation about the z-axis.

We used anteroposterior radiographs to evaluate stem fit in the femoral canal. As per the standard practice of each surgeon, immediate postoperative radiographs were assessed for the DL group and intraoperative radiographs were assessed for the DA group. The discrepancy in radiograph timing is a generalized difference, as intraoperative imaging is routinely used with the DA surgical technique.^{21,22} We used the femoral head size to calibrate the measurements. We assessed stem fit in the femoral canal using the canal fill ratio (CFR), calculated at halfway from the shoulder to the tip of the stem. We considered a CFR of less than 80% as an undersized stem.²³ To characterize femoral bone quality, we analyzed preoperative anteroposterior radiographs for both patient groups. Using the Dorr method, explained in a previous article,¹⁸ we measured the canal-to-calcar ratio (CCR) and used it to categorize patients as Dorr type A (CCR < 0.5), B (CCR 0.5–0.75) or C (CCR > 0.75).²⁴

Additional measures

We obtained patient demographic information from the hospital's database. At preoperative, 3-month postoperative and 1-year postoperative clinic appointments, patients completed the Short-Form 12, Western Ontario and McMaster Universities Osteoarthritis Index and University of California Los Angeles Activity Score questionnaires. Clinicians also completed the Harris Hip Score evaluation for each patient at these visits.

To assess patient function, patients completed 3 trials of the timed-up-and-go (TUG) functional performance test at their follow-up visits at 2 weeks, 4 weeks, 6 weeks, 3 months, 6 months and 1 year after surgery. Patients were instructed to begin the test in a seated position, stand and walk to a marked target 3 m away, turn around, walk back to the chair and sit down. For the duration of the TUG tests, patients wore a previously validated, wearable sensor system that automatically extracted time to test completion.²⁵ We used the average total time to complete the TUG test across the 3 trials as the overall measure of patient function, where less time to complete the test suggested greater function. To assess patient activity, each patient was given a wrist-worn activity tracker (Fitbit Flex 2) at their preoperative clinic appointment. We asked patients to wear their activity tracker for at least a 7-day period leading up to each postoperative follow-up visit. We calculated an average daily step count from each 7-day period.^{26,27}

Statistical analysis

We completed all statistics using Prism version 8.2.1 (GraphPad Software) and reported data as means with ranges or standard deviations. We used unpaired Student *t* tests to compare age, body mass index, questionnaire scores and CFR between surgical approach groups and a Fisher exact test to detect a difference in sex, implant details and Dorr type. We used a mixed-effects model with Sidak multiple comparison tests to compare femoral stem migration between patient groups over time. We used the Pearson correlation coefficient to correlate migration with function and activity for each patient group at all time points. Statistical significance was set at a *p* value of 0.05 or less.

We defined femoral stem migration as the primary outcome of this study. Based on a previous study of cementless femoral stem RSA at our centre, to detect a difference in migration of 0.4 mm with 80% power, a significance of 0.05 and a standard deviation of 0.45 mm, we required a sample size of 20 per group.²⁸ To allow for a 20% dropout rate, we increased the target recruitment to 24 per group. The target recruitment was met and completed for the DA group. Given supplier issues for the RSA marker beads during the COVID-19 pandemic, we halted recruitment for the DL group (which was contemporaneous to the DA group but proceeded more slowly). We completed an interim analysis of migration, comparing between the DL and DA groups, and found 95% power for collarless stems and 77% power for collared stems, which we deemed adequate given the unusual extenuating circumstances inhibiting further recruitment.

Ethics approval

This prospective cohort study was approved by our institutional research ethics board and registered with ClinicalTrials.gov (NCT03558217).

RESULTS

A total of 79 patients were recruited, including 30 who underwent the DL approach and 49 who underwent the DA approach (Figure 1). There were no differences in demographics (Table 1) or patient-reported outcomes (Table 2) between surgical groups. There was a difference in the femoral stem offset between groups, with patients in the DL group receiving fewer high-offset stems than patients in the DA group (*p* = 0.024). Radiographically, there were no differences in CFR (*p* = 0.740) or Dorr classification for bone quality (*p* = 0.545) between the DL and DA groups.

Within the DL group, 13 patients received a collared stem and 17 patients received a collarless stem. There

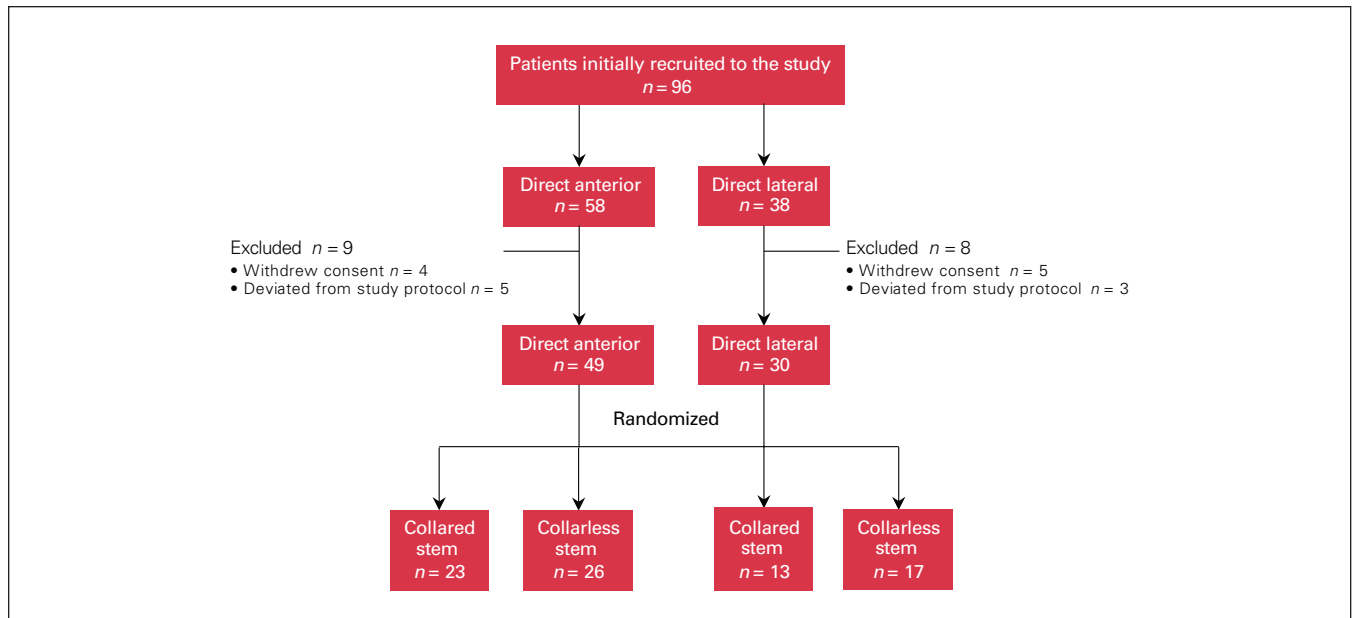


Fig. 1: Flow diagram showing study group allocation.

Characteristic	No. of patients*		p value
	Direct anterior n = 49	Direct lateral n = 30	
Sex			0.353
Female	20	16	
Male	29	14	
BMI, mean (range)	29.21 (22–38.9)	27.52 (17.3–36.2)	0.125
Age, yr, mean (range)	64.57 (44–85)	66.00 (41–85)	0.481
Femoral stem size (mm)			0.694
8 (115)	2	2	
9 (130)	1	0	
10 (140)	3	2	
11 (145)	12	7	
12 (150)	11	12	
13 (155)	8	4	
14 (160)	8	2	
15 (165)	2	0	
16 (170)	2	1	
Femoral stem offset			0.024
Standard	25	23	
High	24	7	
Femoral head size, mm			0.720
28	1	0	
32	15	10	
36	33	20	
Dorr classification			0.545
Type A	6	2	
Type B	42	27	
Type C	1	0	
Canal fill ratio, %, mean (range)	81.03 (54.55–94.44)	80.44 (63.64–94.44)	0.740

BMI = body mass index.

was no difference in migration along the y-axis between stem designs (Table 3 and Figure 2, $p = 0.894$). The only significant difference of implant movement between stem designs in the DL group was the varus–valgus rotation about the z-axis ($p = 0.044$), where collared stems rotated more toward varus tilt and collarless stems rotated more into valgus (Figure 3).

Comparing the DL group to the previously reported DA group, surgical approach did have a significant effect on migration for both collared (Table 4, $p = 0.031$) and collarless stem designs (Table 5, $p = 0.002$). From the day of surgery to the 2-week follow-up examination, collared stems within the DL group migrated significantly less than collared stems in the DA group (Figure 4A, mean difference 0.786 mm, $p = 0.020$). Similarly, in the first 2 weeks after surgery, collarless stems in the DL group migrated less than collarless stems in the DA group (Figure 4B, mean difference 3.136 mm, $p = 0.001$). After the 2-week visit, there were no differences in migration between the DL and DA groups, and stem designs in both surgical groups remained stable through to 1 year after surgery. Furthermore, there was also a difference in internal rotation about the y-axis between surgical groups for both collared ($p = 0.004$) and collarless stems and ($p = 0.040$), with the DA group rotating into greater retroversion than the DL group (Figure 5).

We did not observe any correlation between migration and patient functional ability (defined as total TUG test time) or between migration and patient activity (defined as average daily step count) for the DL and DA groups at any time point, regardless of collared or collarless stem design (Table 6; $p > 0.05$ for all correlations).

Table 2: Questionnaire results of direct anterior and direct lateral groups

Questionnaire	Mean score (range)		p value
	Direct anterior	Direct lateral	
SF-12 mental			
Pre-operation	55.31 (36.52–69.32)	56.53 (26.19–70.35)	0.549
3 mo postoperation	58.27 (39.97–66.94)	57.82 (32.55–67.15)	0.769
1 yr postoperation	57.59 (35.38–67.37)	56.46 (27.55–64)	0.506
SF-12 physical			
Pre-operation	33.50 (20.44–57.29)	33.47 (17.54–52.78)	0.992
3 mo postoperation	48.00 (28.49–59.11)	46.40 (30.67–56.82)	0.454
1 yr postoperation	51.59 (23.36–59.78)	51.81 (34.34–58.56)	0.918
WOMAC pain			
Pre-operation	52.35 (25–100)	49.64 (30–75)	0.466
3 mo postoperation	87.61 (55–100)	88.13 (60–100)	0.878
1 yr postoperation	92.33 (30–100)	97.61 (85–100)	0.118
WOMAC function			
Pre-operation	48.47 (11.76–89.71)	51.94 (25–98.5)	0.411
3 mo postoperation	86.35 (45.59–100)	86.03 (58.82–100)	0.923
1 yr postoperation	93.09 (27.94–100)	94.31 (72.06–100)	0.730
WOMAC total			
Pre-operation	49.83 (15.94–89.37)	48.69 (27.76–79.50)	0.750
3 mo postoperation	84.72 (51.11–100)	84.37 (68.25–100)	0.908
1 yr postoperation	91.35 (22.94–100)	94.27 (73.95–100)	0.419
UCLA Activity Score			
Pre-operation	5.45 (2–9)	5.30 (2–10)	0.743
3 mo postoperation	6.55 (4–9)	6.25 (3–9)	0.389
1 yr postoperation	7.24 (4–10)	7.08 (3–10)	0.687
HHS pain			
Pre-operation	22.04 (10–30)	21.43 (10–30)	0.681
3 mo postoperation	42.44 (30–44)	43.00 (40–44)	0.524
1 yr postoperation	42.58 (20–44)	44.00	0.300
HHS function			
Pre-operation	30.08 (10–40)	28.61 (16–42)	0.326
3 mo postoperation	44.54 (22–47)	43.19 (32–47)	0.375
1 yr postoperation	44.61 (30–47)	44.55 (35–47)	0.970
HHS total			
Pre-operation	57.83 (35–76)	56.44 (31–80)	0.608
3 mo postoperation	97.95 (91–100)	94.80 (81–100)	0.064
1 yr postoperation	97.27 (77–100)	97.55 (88–100)	0.890

HHS = Harris Hip Score; SF-12 = Short-Form 12; UCLA = University of California Los Angeles; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

DISCUSSION

As one of the most common interventions for musculo-skeletal disorders, there is continuous demand to further improve patient outcomes, minimize patient recovery times and lower health care costs after THA. With the growing popularity of minimally invasive surgeries, surgical approach has become a topic of debate. A network meta-analysis from Putananon and colleagues²⁹ investigated the DA, DL, direct posterior and direct posterior-2 approaches and compared their postoperative outcomes and complications. In terms of complications such as dislocation, infection and fracture, the DL approach followed the posterior approach for fewest complications, and the DA approach had the most complications of the 4 approaches. Further, Petis and colleagues²¹ conducted a literature review and reported on various large studies that followed patients who underwent THA with different surgical approaches. This showed low dislocation rates associated with both the DA and DL approach and a higher dislocation rate associated with the posterior approach.²¹ Eto and colleagues¹² concluded that the DA approach has higher rates of aseptic loosening and, consequently, a higher early revision rate than the DL and posterior approaches. Sheth and colleagues³⁰ reported no increased risk in early revisions for loosening between surgical groups. We investigated the stability of 2 stem designs implanted with the DL approach and further examined how surgical approach affected implant migration. We also evaluated whether patient functional ability and activity level influenced implant migration after THA.

We found that stem design did not affect migration for patients who underwent the DL approach, as both designs were remained stable through to 1 year after surgery. The same was not noted for the DA approach, as we previously reported that stem design did have a significant effect on migration, particularly in the first 2 weeks after surgery.¹⁸ Further, collared stems rotated more toward varus and the collarless stems rotated toward valgus ($p = 0.043$) in the DL group; however, the amount of rotation was less than 1° . This small amount of motion is not clinically important as varus or valgus malalignment is defined as 5° or more.³¹

The internervous and intermuscular nature of the DA approach has been reported to result in less postoperative pain and a quicker recovery; however, there are concerns about possible increased rates of intraoperative complications, given challenges with femoral exposure.^{32,33} A study by Rivera and colleagues¹⁰ tested the hypothesis that surgeons' knowledge of increased risk of complication may interfere with appropriate stem sizing and concluded that the possibility of using an undersized stem is 3 times more likely with the DA approach. Stem undersizing is a documented risk factor for aseptic loosening as it affects primary stability and results in greater micromotion and implant migration.³⁴ When comparing surgical approach

Table 3: Translations and rotations of femoral stems of the direct lateral group, from the day of surgery to 1 year after surgery

Plane	Collared stems, mean ± SD						Collarless stems, mean ± SD						p value
	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	
Translation, mm													
x	-0.04 ± 0.14	0.01 ± 0.17	-0.05 ± 0.16	-0.06 ± 0.16	-0.08 ± 0.19	-0.02 ± 0.19	-0.01 ± 0.33	-0.01 ± 0.26	0.02 ± 0.24	0.001 ± 0.20	0.04 ± 0.22	0.01 ± 0.28	0.765
y	-0.20 ± 0.31	-0.23 ± 0.31	-0.20 ± 0.30	-0.25 ± 0.32	-0.16 ± 0.29	-0.23 ± 0.30	-0.08 ± 0.69	-0.21 ± 0.71	-0.19 ± 0.63	-0.23 ± 0.68	-0.29 ± 0.76	-0.23 ± 0.69	0.894
z	-0.13 ± 0.32	-0.04 ± 0.33	-0.24 ± 0.31	-0.19 ± 0.28	-0.10 ± 0.18	0.04 ± 0.27	-0.06 ± 0.42	-0.18 ± 0.27	-0.12 ± 0.36	-0.14 ± 0.41	-0.12 ± 0.32	-0.09 ± 0.38	0.981
Rotation, °													
x	0.10 ± 0.38	0.35 ± 0.52	0.07 ± 0.39	0.17 ± 0.44	0.03 ± 0.49	-0.05 ± 0.31	0.30 ± 0.65	0.12 ± 0.59	0.20 ± 0.60	0.20 ± 0.49	0.25 ± 0.56	0.22 ± 0.69	0.638
y	-0.24 ± 0.89	0.17 ± 1.14	-0.59 ± 0.98	-0.49 ± 1.01	-0.64 ± 1.01	-0.43 ± 0.84	-0.40 ± 0.82	-0.56 ± 0.50	-0.83 ± 1.74	-0.58 ± 1.21	-0.88 ± 0.78	-0.55 ± 1.14	0.465
z	-0.18 ± 0.28	-0.24 ± 0.43	-0.21 ± 0.45	-0.13 ± 0.51	-0.15 ± 0.54	-0.06 ± 0.54	0.13 ± 0.18	0.10 ± 0.16	0.06 ± 0.19	0.15 ± 0.20	0.16 ± 0.18	0.11 ± 0.23	0.044

SD = standard deviation.

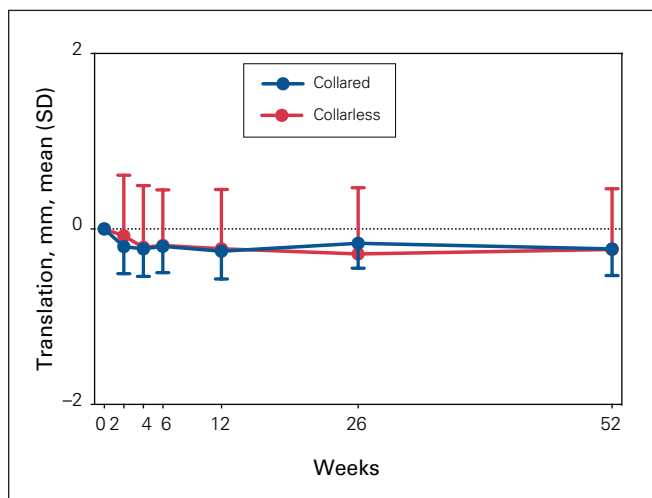


Fig. 2: Migration (y-axis translation) between collared and collarless stems in the direct lateral group ($p = 0.894$), from day of surgery until 1 year after surgery. SD = standard deviation.

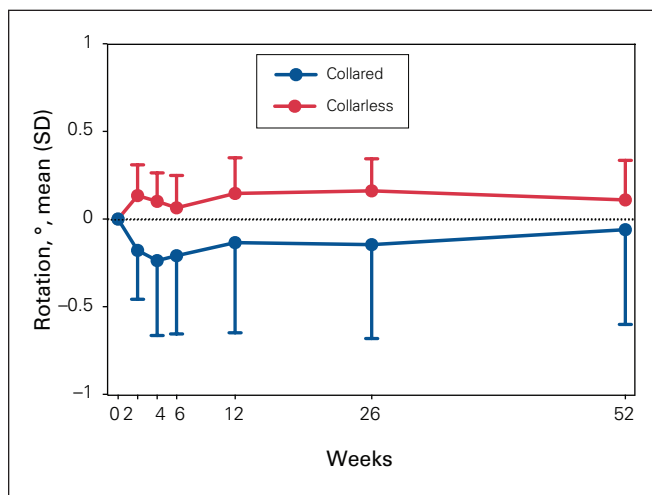


Fig. 3: Varus–valgus rotation (z-axis rotation) between collared and collarless stems in the direct lateral group ($p = 0.043$), from day of surgery until 1 year after surgery. SD = standard deviation.

groups, we found that the DA group had greater implant migration for both collared and collarless stems than the DL group, though radiographic analysis did not differ in the stem canal fill measured between groups. Most implant migration occurred between the day of surgery and the 2-week follow-up examination for both groups, with the collared stem design significantly reducing the migration in the first 2 weeks within the DA group. Implant migration stabilized from 2 weeks through to 1 year after surgery, suggesting adequate stem fixation and a low risk for aseptic loosening. We did not observe continuous stem migration with either surgical approach or stem design, which would have indicated a risk of early loosening.^{14,16} This is in keeping with a retrospective review of the Corail stem at this institution, which found no difference in the overall revision rate between approaches but a greater absolute number of revisions owing to aseptic loosening for the DA approach.³⁵

In addition to differences in migration between surgical groups, there was also a rotational difference across the y-axis, which, like migration, mostly occurred from the day of surgery to 2 weeks postoperation. Both collared and collarless stem designs in the DA group rotated significantly more toward retroversion than stems in the DL group ($p = 0.004$ and $p = 0.040$, respectively); however, the average at all time points was less than 5° .

As a secondary objective, we investigated the possibility that an early recovery may be a factor that increases the magnitude of migration. The DA approach is associated with an earlier recovery and we observed that femoral stems in the DA group had greater migration early on than the DL group.^{1,21} However, our results showed there was no correlation between migration and patient functional ability or activity level in all groups at all time points through to 1 year after surgery. This suggests that patients who had greater functional ability and higher

Table 4: Translations and rotations of collared femoral stems by surgical approach, from the day of surgery to 1 year after surgery

Plane	Direct anterior, mean ± SD						Direct lateral, mean ± SD						p value
	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	
Translation, mm													
x	-0.06 ± 0.27	-0.09 ± 0.31	0.08 ± 0.37	0.08 ± 0.40	-0.01 ± 0.40	0.04 ± 0.36	-0.04 ± 0.14	0.01 ± 0.17	-0.05 ± 0.16	-0.06 ± 0.16	-0.08 ± 0.19	-0.02 ± 0.19	0.643
y	-0.99 ± 1.03	-1.30 ± 1.42	-1.40 ± 1.89	-1.52 ± 1.99	-1.51 ± 1.97	-1.47 ± 2.04	-0.20 ± 0.31	-0.23 ± 0.31	-0.20 ± 0.30	-0.25 ± 0.32	-0.16 ± 0.29	-0.23 ± 0.30	0.031
z	-0.30 ± 0.50	-0.28 ± 0.42	-0.30 ± 0.71	-0.14 ± 0.49	-0.39 ± 0.61	-0.27 ± 0.51	-0.13 ± 0.32	-0.04 ± 0.33	-0.24 ± 0.31	-0.19 ± 0.28	-0.10 ± 0.18	0.04 ± 0.27	0.219
Rotation, °													
x	0.21 ± 0.52	0.05 ± 0.47	-0.08 ± 0.69	0.16 ± 0.83	0.28 ± 0.79	0.18 ± 0.79	0.10 ± 0.38	0.35 ± 0.52	0.07 ± 0.39	0.17 ± 0.44	0.03 ± 0.49	-0.05 ± 0.31	0.895
y	-1.89 ± 1.88	-2.25 ± 2.06	-1.74 ± 1.82	-1.69 ± 1.46	-2.35 ± 2.05	-1.85 ± 1.36	-0.24 ± 0.89	0.17 ± 1.14	-0.59 ± 0.98	-0.49 ± 1.01	-0.64 ± 1.01	-0.43 ± 0.84	0.004
z	-0.11 ± 0.37	-0.09 ± 0.36	-0.07 ± 0.51	-0.19 ± 0.38	-0.10 ± 0.49	-0.08 ± 0.46	-0.18 ± 0.28	-0.24 ± 0.43	-0.21 ± 0.45	-0.13 ± 0.51	-0.15 ± 0.54	-0.06 ± 0.54	0.747

SD = standard deviation.

Table 5: Translations and rotations of collarless femoral stems by surgical approach, from the day of surgery to 1 year after surgery

Plane	Direct anterior, mean ± SD						Direct lateral, mean ± SD						p value
	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	2 wk	4 wk	6 wk	12 wk	26 wk	52 wk	
Translation, mm													
x	0.20 ± 0.64	0.21 ± 0.71	0.18 ± 0.71	0.25 ± 0.74	0.27 ± 0.69	0.17 ± 0.79	-0.01 ± 0.33	-0.01 ± 0.26	0.02 ± 0.24	0.001 ± 0.20	0.04 ± 0.22	0.01 ± 0.28	0.321
y	-3.21 ± 3.21	-3.61 ± 3.31	-3.71 ± 3.39	-3.62 ± 3.47	3.72 ± 3.44	3.66 ± 3.57	-0.08 ± 0.69	-0.21 ± 0.71	-0.19 ± 0.63	-0.23 ± 0.68	-0.29 ± 0.76	-0.23 ± 0.69	0.002
z	-0.61 ± 0.88	-0.74 ± 1.08	-0.75 ± 1.05	-0.69 ± 1.10	-0.63 ± 1.07	-0.49 ± 1.02	-0.06 ± 0.42	-0.18 ± 0.27	-0.12 ± 0.36	-0.14 ± 0.41	-0.12 ± 0.32	-0.09 ± 0.38	0.064
Rotation, °													
x	0.51 ± 0.62	0.36 ± 0.62	0.31 ± 0.74	0.36 ± 0.98	0.45 ± 0.67	0.65 ± 0.87	0.30 ± 0.65	0.12 ± 0.59	0.20 ± 0.60	0.20 ± 0.49	0.25 ± 0.56	0.22 ± 0.69	0.250
y	-2.70 ± 4.22	-3.10 ± 4.25	-3.47 ± 4.51	-3.04 ± 4.43	-3.34 ± 4.30	-3.53 ± 4.39	-0.40 ± 0.82	-0.56 ± 0.50	-0.83 ± 1.74	-0.58 ± 1.21	-0.88 ± 0.78	-0.55 ± 1.14	0.040
z	0.36 ± 1.39	0.27 ± 1.46	0.45 ± 1.59	0.47 ± 1.45	0.39 ± 1.45	0.46 ± 1.58	0.13 ± 0.18	0.10 ± 0.16	0.06 ± 0.19	0.15 ± 0.20	0.16 ± 0.18	0.11 ± 0.23	0.589

SD = standard deviation.

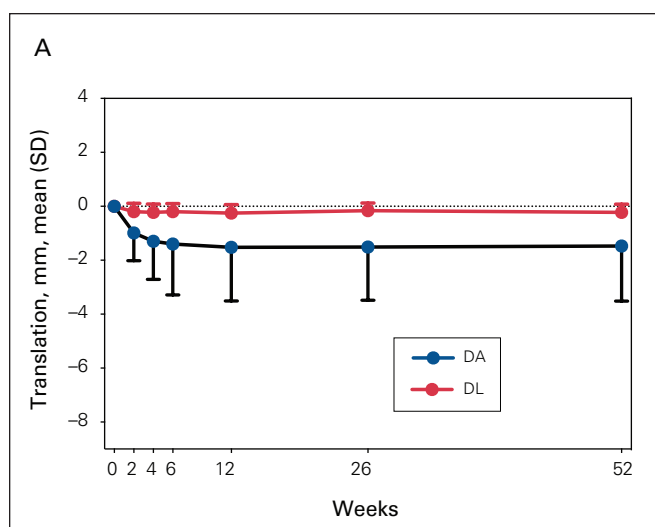


Fig. 4: Migration (y-axis translation) between direct anterior (DA) and direct lateral (DL) surgical groups for patients who received (A) collared stems ($p = 0.031$) or (B) collarless stems ($p = 0.002$), from day of surgery until 1 year after surgery. SD = standard deviation.

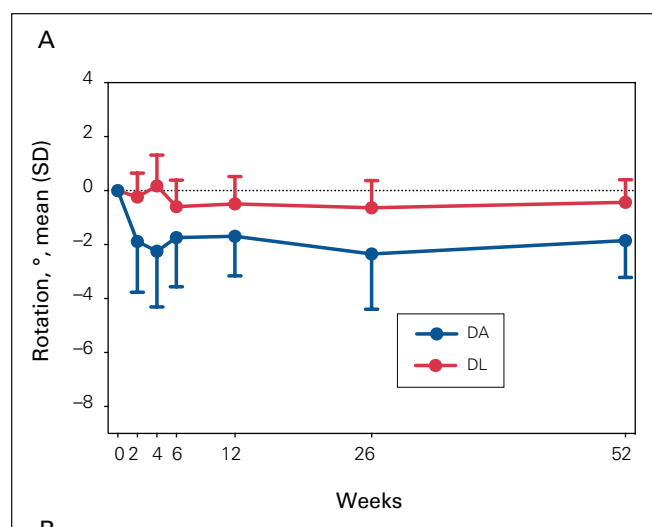


Fig. 5: Version (y-axis rotation) between direct anterior (DA) and direct lateral (DL) surgical groups for patients who received (A) collared stems ($p = 0.004$) (B) collarless stems ($p = 0.040$), from day of surgery until 1 year after surgery. SD = standard deviation.

Table 6: Correlation of femoral stem subsidence (y-axis translation) to patient function and patient activity by surgical approach at each time point*

Time, wk	Direct anterior, collared		Direct anterior, collarless		Direct lateral, collared		Direct lateral, collarless	
	Function	Activity	Function	Activity	Function	Activity	Function	Activity
2	$r^2 = 0.017$, $p = 0.567$	$r^2 = 0.003$, $p = 0.818$	$r^2 = 0.031$, $p = 0.442$	$r^2 = 0.024$, $p = 0.489$	$r^2 = 0.053$, $p = 0.520$	$r^2 = 0.006$, $p = 0.861$	$r^2 = 0.110$, $p = 0.349$	$r^2 = 0.021$, $p = 0.689$
4	$r^2 = 0.006$, $p = 0.757$	$r^2 = 0.028$, $p = 0.508$	$r^2 = 0.001$, $p = 0.900$	$r^2 = 0.012$, $p = 0.633$	$r^2 = 0.079$, $p = 0.432$	$r^2 = 0.010$, $p = 0.789$	$r^2 = 0.028$, $p = 0.621$	$r^2 = 0.033$, $p = 0.589$
6	$r^2 = 0.050$, $p = 0.344$	$r^2 = 0.003$, $p = 0.818$	$r^2 = 0.020$, $p = 0.529$	$r^2 = 0.048$, $p = 0.355$	$r^2 = 0.123$, $p = 0.292$	$r^2 = 0.000$, $p = 0.992$	$r^2 = 0.090$, $p = 0.343$	$r^2 = 0.008$, $p = 0.798$
12	$r^2 = 0.028$, $p = 0.467$	$r^2 = 0.159$, $p = 0.091$	$r^2 = 0.014$, $p = 0.602$	$r^2 = 0.099$, $p = 0.178$	$r^2 = 0.0001$, $p = 0.976$	$r^2 = 0.001$, $p = 0.945$	$r^2 = 0.002$, $p = 0.901$	$r^2 = 0.021$, $p = 0.669$
26	$r^2 = 0.023$, $p = 0.521$	$r^2 = 0.085$, $p = 0.292$	$r^2 = 0.002$, $p = 0.831$	$r^2 = 0.079$, $p = 0.259$	$r^2 = 0.122$, $p = 0.443$	$r^2 = 0.097$, $p = 0.610$	$r^2 = 0.038$, $p = 0.614$	$r^2 = 0.001$, $p = 0.950$
52	$r^2 = 0.104$, $p = 0.164$	$r^2 = 0.051$, $p = 0.419$	$r^2 = 0.004$, $p = 0.795$	$r^2 = 0.013$, $p = 0.638$	$r^2 = 0.075$, $p = 0.514$	$r^2 = 0.672$, $p = 0.180$	$r^2 = 0.011$, $p = 0.771$	$r^2 = 0.001$, $p = 0.921$

*No significant correlations.

activity levels soon after surgery did not have more implant migration than patients who took longer to recover, regardless of surgical approach.

Limitations

We were unable to reach target recruitment for the DL group; however, the interim analysis showed we had sufficient power to compare migration between surgical groups. There is also potential bias introduced since surgical approach was not randomized; however, the expertise-based trial design in orthopedics has been reported to reduce challenges related to differential expertise bias and clinical equipoise.^{19,20} Further, with the steep learning curve associated with the DA approach and substantial differences in surgical technique, the expertise-based design ensured the best technique was used in all cases.²¹ Another limitation is that the DA surgeon had access to intraoperative images, as these are commonly used for the DA technique; but despite this, the DA group had greater migration. In addition, baseline RSA exams were conducted before each patient left the hospital, but not necessarily before they were bearing weight, so some initial migration may have been missed. It is possible that asking patients to wear their activity tracker at least a week before each appointment may have influenced an increase in their activity, but despite this potential increase, we saw no impact on implant migration.

Conclusion

In this study, we investigated the impact of implant design and surgical approach on implant stability, including the potential effect of enhanced patient recovery. Early functional ability and higher activity levels did not influence the magnitude of migration. Migration did not differ between collared and collarless stem designs in the DL group, but the collared stem

design significantly reduced the migration in the DA group. Although the DA group had significantly more migration than the DL group for both stem designs in the first 2 weeks after surgery, both groups had continued stability thereafter, suggesting a low risk of aseptic loosening for both groups. Adequate stem fixation is achievable with either surgical approach, and the collared stem design can provide greater initial stability for patients undergoing THA using the DA approach.

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