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Use of Computer Navigation for Optimal Acetabular Cup Placement in Revision Total Hip Arthroplasty: Case Reports and Surgical Techniques

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ABSTRACT

Background: The outcomes of revision total hip arthroplasty (rTHA) have become increasingly important as their volume increases. Computer navigation, a reliable method to improve component positioning during primary total hip arthroplasty (THA), is not well studied in the rTHA setting. Given that dislocation rates following rTHA are significantly higher than those of primary THA, component positioning becomes paramount in these cases.

Methods: Here, we present two case reports and surgical techniques, one of a 77-year-old man undergoing rTHA for recurrent hip instability following primary THA, and one of a 61-year-old woman undergoing rTHA for severe iliopsoas bursitis who was at increased risk for instability and dislocation given her history of large segment spinal fusion.

Results: Both patients achieved optimal acetabular component positioning after rTHA with imageless computer navigation.

Conclusions: The use of imageless computer navigation in rTHA provides accurate and reproducible component positioning during acetabular rTHA.

Introduction

With the number of revision total hip arthroplasty (rTHA) cases increasing year over year, and with an associated cost of over $50,000 per case, the outcomes of rTHA have become increasingly important [1,2]. Indications for rTHA are broad and commonly include instability, periprosthetic fracture, infection, mechanical failure, and metallosis [3]. Instability is a multifactorial concern following total hip arthroplasty (THA), caused by a combination of patient-related positional factors, innate soft-tissue laxities, implant design, bony impingement, and component positioning [4-7]. Computer navigation has emerged in the primary THA setting as a method to improve component placement and orientation [8-19]. By optimizing component positioning, one of the most easily correctable factors associated with postoperative instability, computer navigation may help mitigate a common mode of failure leading to rTHA [20-24].

Conventionally, computer navigation methods in primary THA have used computed tomography (CT) and intraoperative fluoroscopy to assist in acetabular component positioning. However, due to metal artifacts and changes in bony landmarks with the removal of well-fixed components during rTHA, CT-based computer navigation is not currently a viable option in rTHA. While less commonly adopted into practice, imageless computer navigation methods utilize mounted cameras and probes to identify the functional pelvic plane to assist in component positioning, thus avoiding the need to rely on potentially deformed anatomic landmarks [25].

Alternatively, in rTHA, there are fixed intraoperative landmarks, eg, the primary THA acetabular component, that can be referenced during surgery to make desired changes to acetabular orientation based on preoperative planning. Furthermore, changes in leg length and offset can also be reliably captured [26]. This technique is especially beneficial in cases of soft tissue or bony impingement or

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instability as indications for rTHA as correction of component position is a crucial goal in these cases.

There is a paucity of literature on the use of computer navigation in rTHA [25,27-31]. Given that rates of dislocation after rTHA can be as high as 28%, component positioning becomes paramount [32]. As it is well known that computer navigation helps mitigate hip instability, there is a need for further evaluation of its use in rTHA. Here, we present a case report and surgical technique for the use of the Intellijoint HIP (Intellijoint Surgical, Inc., Waterloo, ON, Canada) system for optimal acetabular component placement during rTHA for recurrent instability. We also present a case of rTHA for iliopsoas bursitis in a patient with an anteriorly proud acetabular cup and an increased risk of postoperative dislocation given their history of large segment spinal fusion, making them an ideal candidate for optimizing acetabular component placement.

Case histories

Case 1

The patient is a 77-year-old man with a history of left hip osteoarthritis status-post left THA via a posterolateral approach 12 months prior at an outside hospital. He presented to our tertiary care facility with increasing left hip pain and dysfunction for the last 10 months. He reported an initially uncomplicated THA recovery until he dislocated his left hip after bending down while gardening at 2 months postoperatively. This was treated with a closed reduction in his local emergency department. He dislocated again at 4 and 9 months postoperatively, both treated with a closed reduction. Since that time, he has been experiencing increasing hip and groin pain and has significantly modified his activities out of fear of dislocating again. The pain and decreased functional status were significantly affecting his quality of life.

On physical examination of the left hip, the skin was intact with a well-healed posterolateral incision with no tenderness over the greater trochanter. He had a range of motion including full extension to 90° of flexion, 10° of internal rotation, 30° of external rotation, 40° of abduction, and 10° of adduction. There was pain with passive and resisted flexion as well as a positive Stinchfield test. Radiographs of the left hip showed a cementless THA with a well-fixed femoral component. The acetabular component contained 2 screws but overall appeared to be retroverted with a near circumferential radiolucent line consistent with possible fibrous ingrowth of the cup (Fig. 1). There was also an offset acetabular liner in place. This was confirmed with axial CT demonstrating 7° of acetabular retroversion and 15° of femoral anteversion (Fig. 2). On functional EOS radiographs, he had spinal sagittal deformity with posterior tilt in the standing position (15°) but experienced 21° of pelvic rollback moving from the standing to sitting position (Fig. 3), important considerations for his preoperative planning as patients with spinal sagittal deformity (abnormal anterior or posterior tilt and stiffness) are at increased risk of impingement and prosthetic dislocation [33,34].

After a lengthy discussion of treatment options, including risks and benefits of continued nonoperative management and surgical management, he decided to proceed with revision surgery. Based on the above imaging, using previously published guidelines for hip-spine classification in which the patient is stiff, we planned for isolated acetabular component revision to increase the anteversion by ~25-30° to target a combined anteversion of 45-50° and increase the head length/offset as we would be removing the offset acetabular liner and place a dual mobility articulation [34].

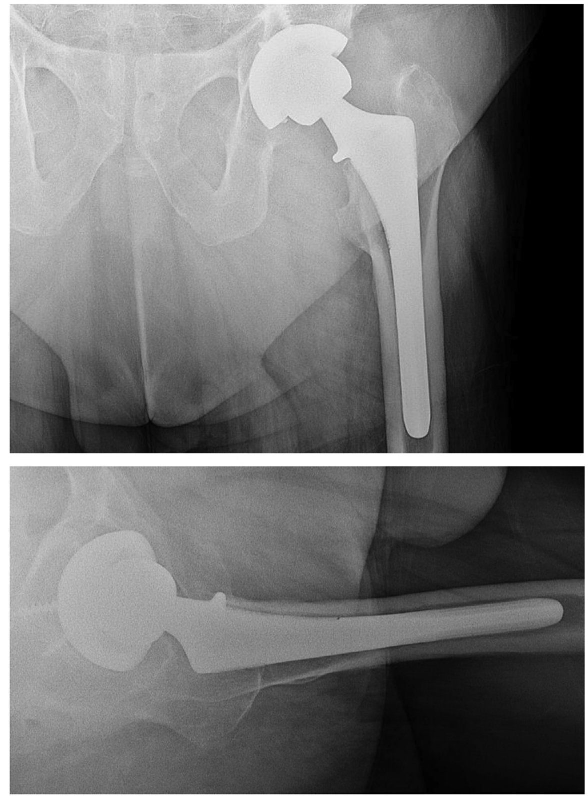

Figure 1. Case 1 preoperative radiographs. Initial presentation radiographs including anteroposterior (top) and cross table lateral (bottom), demonstrating a retroverted acetabular cup with a near circumferential radiolucent line consistent with possible fibrous ingrowth.

Approach

He was placed in a lateral decubitus position, prepped, and draped in the normal sterile fashion. Two pins were placed into the pelvic crest for computer navigation. The coronal and sagittal planes were registered to his body with the computer navigation system as described per the surgical technique [19,29]. The previous posterolateral skin incision was sharply incised, the dissection was carried down to the fascia which was split in line with its fibers, and the anterior and posterior fascia were mobilized. The posterior pseudocapsule had completely dehisced. Hip stability was then tested from full possible extension and external rotation to 30° and was stable, dislocating at 70° of flexion and 40° of internal rotation, and dislocating at 90° of flexion and 25° of internal rotation. The femoral component was inspected and appeared to be well fixed and in an appropriate position of ~10-15° of anteversion. The acetabulum was then circumferentially exposed; there was a 10-degree offset liner placed posteriorly but the acetabular component appeared to be retroverted (Fig. 4).

Establishing the acetabular reference plane

The existing acetabular cup was then registered using the probe, functioning as a known fixed landmark to establish the acetabular reference plane (Fig. 5) which read 55° of inclination and 1° of retroversion (Fig. 6). It is important to obtain a spread of 3 points on the actual acetabular component itself, not on the liner; this is especially important in this case with an offset lipped acetabular liner.

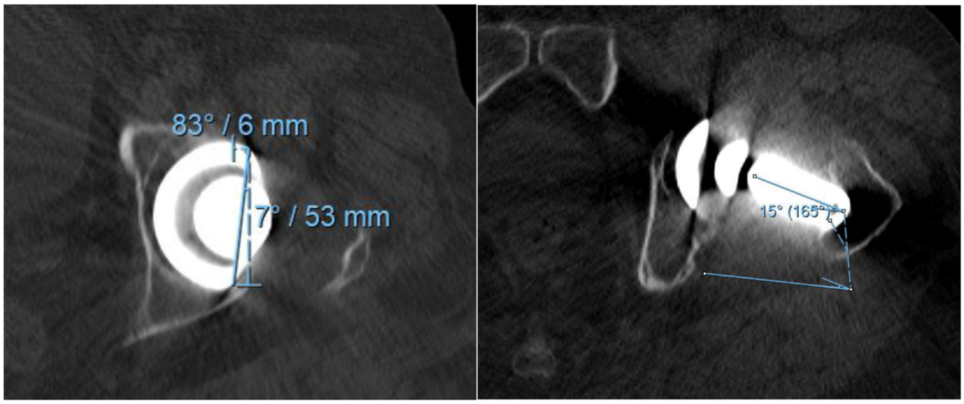

Figure 2. Case 1 preoperative computed tomography (CT). Axial CT scans at the level of the acetabular cup (left) and femoral stem (right) demonstrating 7° of acetabular retroversion and 15° of femoral anteversion.

Liner and acetabular cup removal

After circumferential exposure was achieved, the elevated acetabular liner was removed with a screw technique and the 2 acetabular screws were removed. The primary 58-mm acetabular cup was removed using the EZX System (Brasseler USA, Savannah, Georgia) with minimal bone loss.

Acetabular reaming and cup impaction

Using the magnetic tracker, we sequentially reamed for a good rim pinch to 63 mm, 1 mm under the planned revision shell (Figs. 6 and 7); we targeted ~50-55° of inclination and 25-30° of anteversion which is displayed on the navigation software in real-time. We opened a 64-mm Redapt revision acetabular component (Smith & Nephew, Andover, MA) which was impacted in place again using the magnetic tracker for guidance (Fig. 8), targeting similar numbers as listed previously, to ensure we were appropriately executing our planned change in acetabular component position. Our final numbers from the navigation system were inclination to 54° and anteversion to 28°, confirming substantial change compared to the primary acetabular component (Fig. 8). We then placed 5 screws in an array for augmentation, including 1 locking screw in the ischium.

Case completion

An OR30 Dual Mobility with OXINIUM DH Liner Technology (Smith & Nephew) was impacted into the locking mechanism. We trialed varying head sizes and found the +3.5 mm head best restored appropriate soft tissue tension and provided stability throughout the range of motion. A 28 mm + 3.5 mm head was assembled with a 50-mm dual-mobility polyethylene and impacted onto the trunnion. The hip was reduced, and we copiously irrigated the hip with dilute Betadine. Two grams of vancomycin powder were left in the hip. We were able to mobilize some posterior tissue to repair it to the greater trochanter with heavy non-absorbable sutures. The fascia was closed with interrupted 0 Vicryl followed by a running barbed suture. The subcutaneous tissue was closed with interrupted 3-0 Vicryl and interrupted 0 Vicryl. The skin was closed with staples and a silver occlusive dressing. The patient was made 30% flat foot weight bearing with posterior precautions. Immediate postoperative images demonstrated satisfactory alignment of the components without periprosthetic fracture (Fig. 9). He was discharged home on postoperative day 2 after an uneventful hospital course. At 6-week follow-up, anterior-posterior and cross-table lateral radiographs confirmed the substantial change in version without acute complications (Fig. 10).

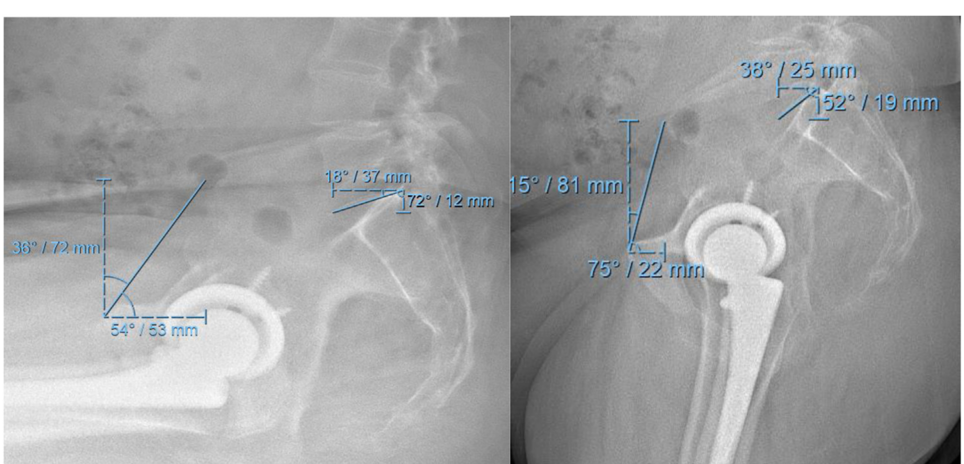

Figure 3. Case 1 preoperative EOS imaging. EOS films in the sitting direct lateral (left) and standing direct lateral (right) positions. The “delta” between sitting (18°) and standing (38°) sacral slope was 20°.

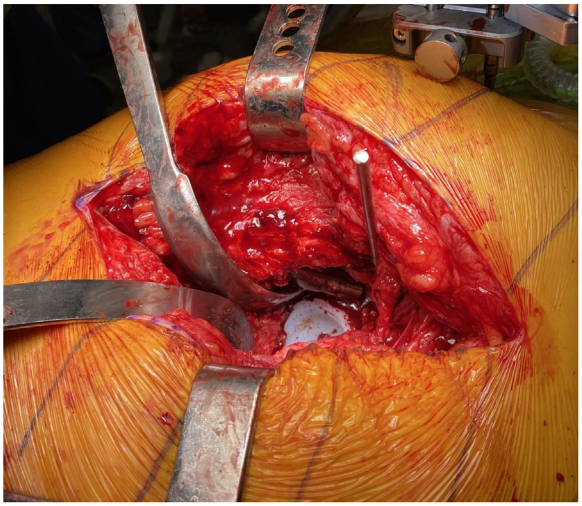

Figure 4. Case 1 intraoperative photograph. Standard posterolateral approach to the left hip with visible retroverted acetabular component.

Case 2

The patient is a 61-year-old woman with a history of large segment T3 to S1 spinal fusion 3 for thoracic and lumbar spondylosis secondary to adult scoliosis. She underwent right THA for osteoarthritis via an anterior approach 7 months prior at an outside

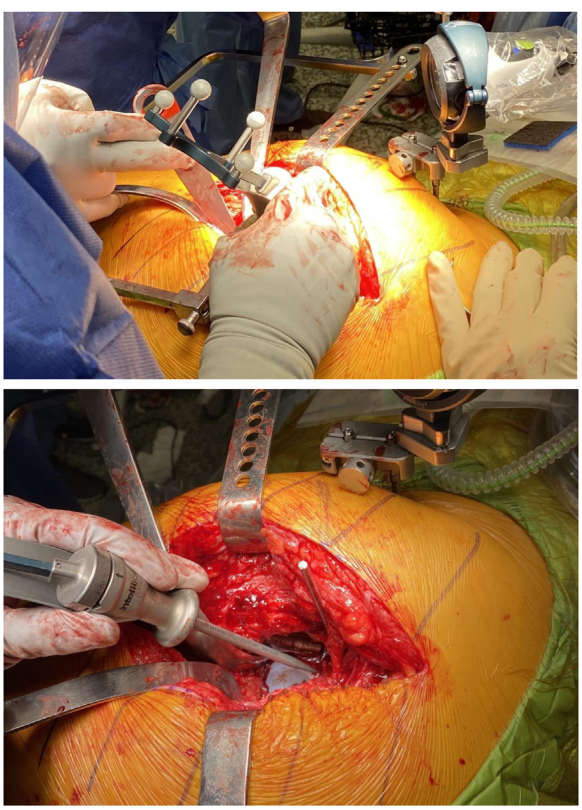

Figure 5. Case 1 intraoperative photographs. Top: tracker being used to establish the acetabular reference plane with the miniature camera in view which is magnetically mounted on the pelvic platform. Bottom: Establishing the acetabular reference plane with the probe – the acetabular reference plane required 3 reference points on the existing acetabular cup.

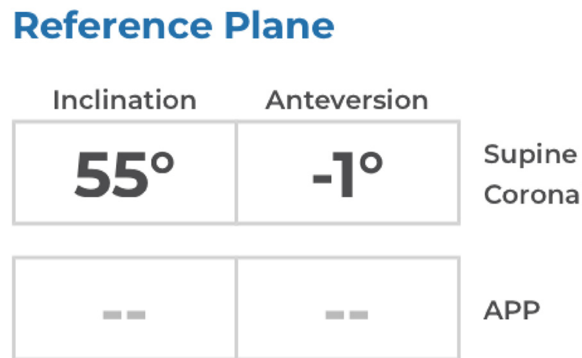

Figure 6. Case 1 computer navigation interface. Digital display of the index acetabular component position read as 55° of inclination and 1° degree of retroversion.

hospital. Shortly after, she developed severe and markedly limiting groin pain and it was found that her acetabular component was prominent anteriorly and that she was likely having significant iliopsoas tendinitis and groin pain secondary to this. She received a diagnostic lidocaine injection into the iliopsoas tendon sheath which provided moderate, short-term symptomatic relief. Therefore, she underwent an arthroscopic, partial, mid-substance

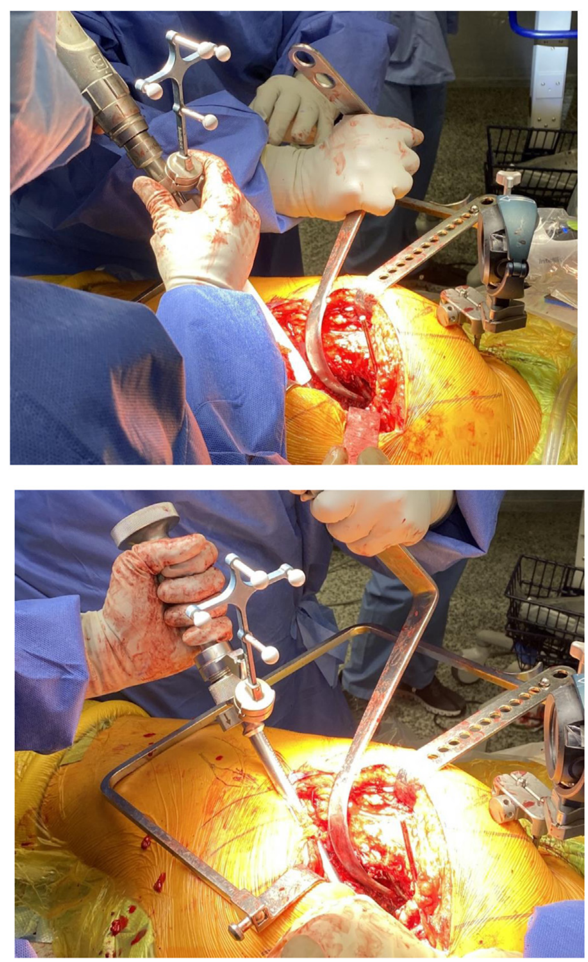

Figure 7. Case 1 intraoperative photographs. Tracker magnetically mounted to the acetabular reamer (top) and impactor (bottom) to ensure desired inclination and anteversion while reaming and impacting the acetabulum.

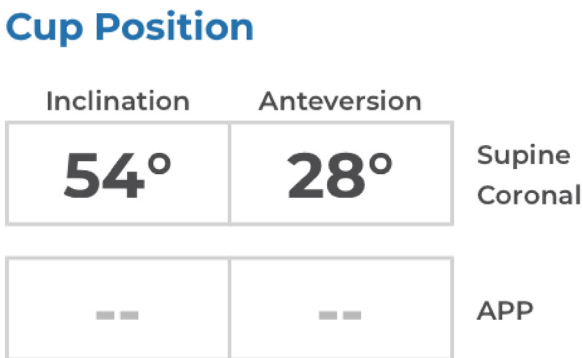

Figure 8. Case 1 computer navigation interface. Digital display of the final acetabular cup position in 54° of inclination and 28° of anteversion.

iliopsoas release 1 month after THA which provided minimal pain relief. She presented to our tertiary care facility 6 months later with continued pain with any type of flexion, necessitating significant modifications to her activities. She also complained about her right leg feeling shorter and that she had begun wearing a lift in the right shoe to compensate.

On physical examination of the right hip, the skin was intact with a well-healed anterior incision with no tenderness over the greater trochanter. She had a range of motion including full extension to 70° of flexion which was limited by pain, 10° of internal rotation, 30° of external rotation, 40° of abduction, and 10° of adduction. There was groin pain with any hip flexion, and she could not perform a straight leg raise.

Radiographs of the right hip showed a cementless THA with well-fixed components (Fig. 11). Preoperative CT scan demonstrated that the acetabular cup was 9 mm proud anteriorly (Fig. 12) with 43° of inclination relative to the interteardrop line and 12° of anteversion. Figure 11 includes a modified frog leg lateral view which is not the optimal radiographic view to assess for anterior acetabular cup overhang. The femoral neck was 6° retroverted. Standing and sitting EOS films showed a 2-mm leg length discrepancy with the right leg being shorter (Fig. 13). She did not have any spinal mobility from standing to sitting position. Magnetic resonance imaging of the right hip also showed well-fixed

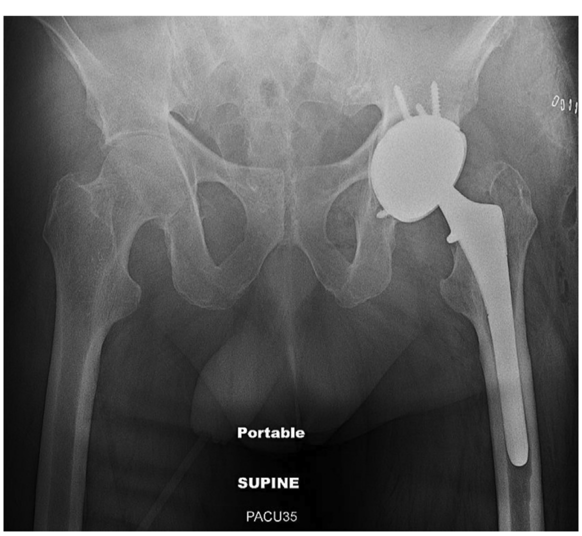

Figure 9. Case 1 immediate postoperative radiograph. Anteroposterior plain film pelvic radiograph demonstrating appropriate total hip arthroplasty positioning without periprosthetic fracture immediately postoperatively.

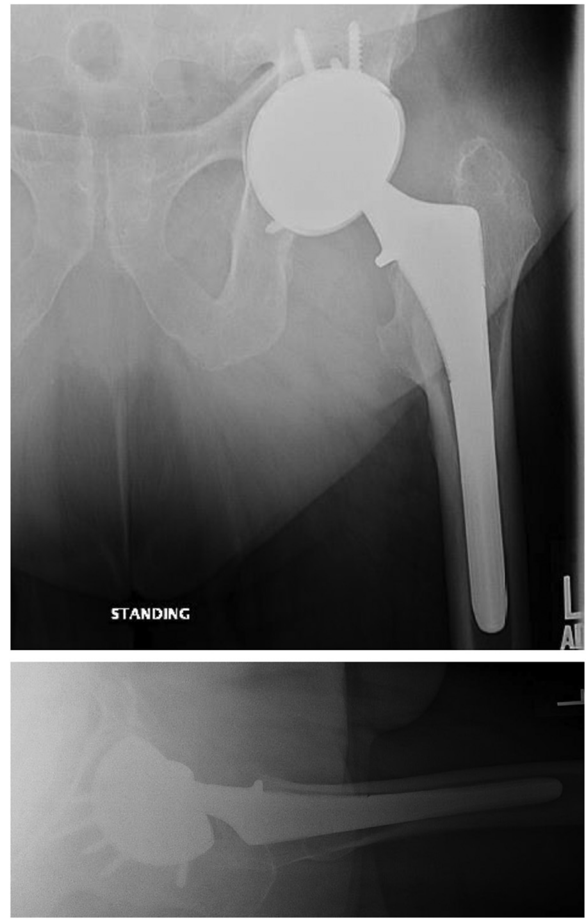

Figure 10. Case 1 6-week postoperative radiographs. Anteroposterior (top) and cross leg lateral (bottom) plain film radiographs demonstrating appropriate total hip arthroplasty positioning without periprosthetic fracture at 6 weeks postoperatively.

components and attenuation of the iliopsoas evidencing the prior release.

After a lengthy discussion of treatment options, including risks and benefits of continued nonoperative management and surgical management, she decided to proceed with revision surgery. Based on the previously mentioned imaging, we planned for isolated acetabular component revision to increase the anteversion by ~20-30° and tuck the revision acetabular component into the anterior wall.

Approach

Similar to case 1, she was positioned, prepped, draped, and navigation pins were placed and registered. While the primary THA was performed via an anterior approach, to ensure adequate exposure during rTHA, a posterolateral approach was used. Surgical approach discordance (changing from an anterior approach during primary THA to a posterior approach during rTHA has shown to have comparable dislocation and complication rates compared to approach concordant cases [35]. The posterior capsule was intact but was significantly scarred without any identifiable short external rotators. The posterior capsular structures were taken down full length. The hip was dislocated, the femoral component inspected, and found to be well-fixed and slightly retroverted — we elected to leave the stem in place. The anterior capsule was not in continuity and the iliopsoas muscle belly was prominent anteriorly. Given that the prior iliopsoas release was only a partial mid-

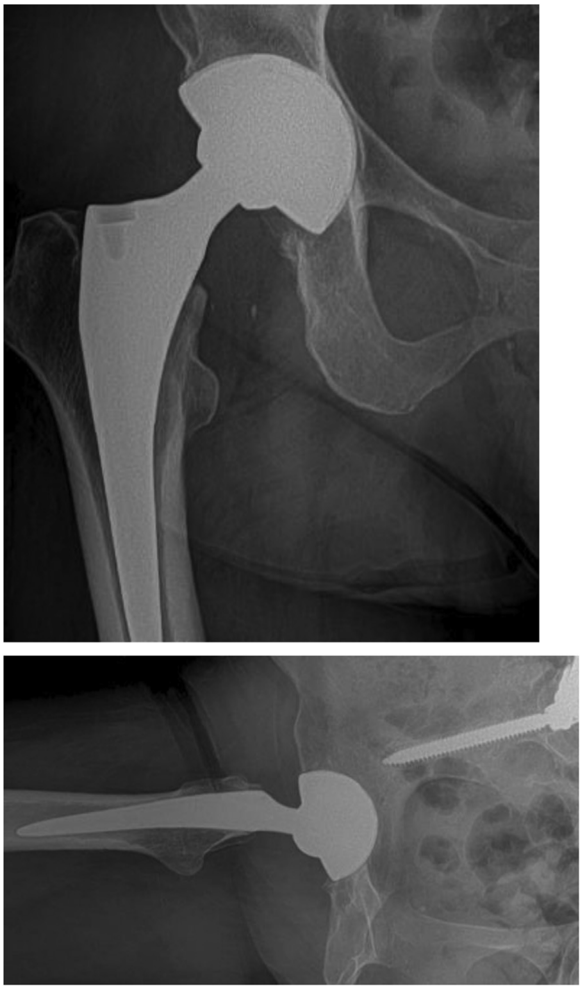

Figure 11. Case 2 preoperative radiographs. Initial presentation radiographs including anteroposterior (top) and modified frog leg lateral (bottom). A modified frog leg lateral view is not an optimal radiographic view to assess for anterior acetabular cup overhand which is more appropriately visualized on the axial computed tomography in Figure 12.

substance release, the entire iliopsoas tendon was still attached to the lesser trochanter and there were fibers in continuity. The acetabular component was significantly proud of the anterior wall on manual inspection.

Establishing the acetabular reference plane and leg lengths

The acetabular cup was registered using the same technique as case 1 to establish the acetabular reference plane and the computer interface read 44° of abduction and 12° of anteversion, consistent with the preoperative CT findings. Unlike the prior cases, we then registered the femur using the tracker to allow for correction of her 2-mm leg length discrepancy.

Liner and acetabular cup removal

The liner and 50-mm acetabular cup were removed similarly to case 1 with minimal bone loss.

Acetabular reaming and cup impaction

Using the magnetic tracker, we reamed to 51 mm with good rim pinch, 1 mm under the planned revision shell. Using the tracker, we

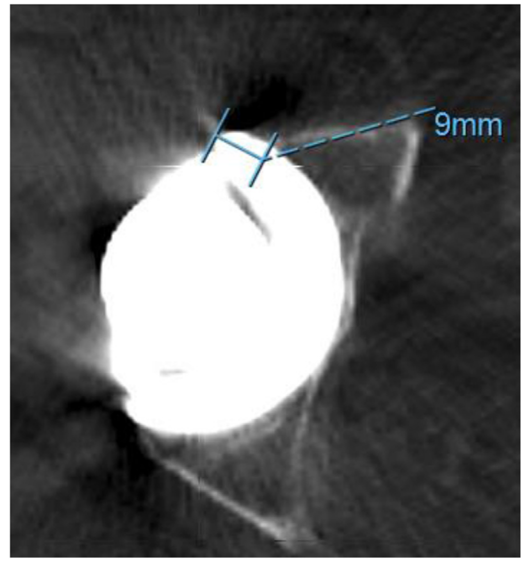

Figure 12. Case 2 preoperative computed tomography. Axial computed tomography scan at the level of the acetabular cup which is 9 mm proud anteriorly with 12° of anteversion.

placed a 52-mm G7 OsseoTi revision cup (Zimmer Biomet, Warsaw, IN) after reverse reaming crushed allograft chips in the acetabulum to establish an improved medial base and bone stock of the socket. The cup was tucked under the anterior wall as much as possible based on the anatomy and the final implant registered at 44° of abduction and 32° of anteversion. Four screws were placed

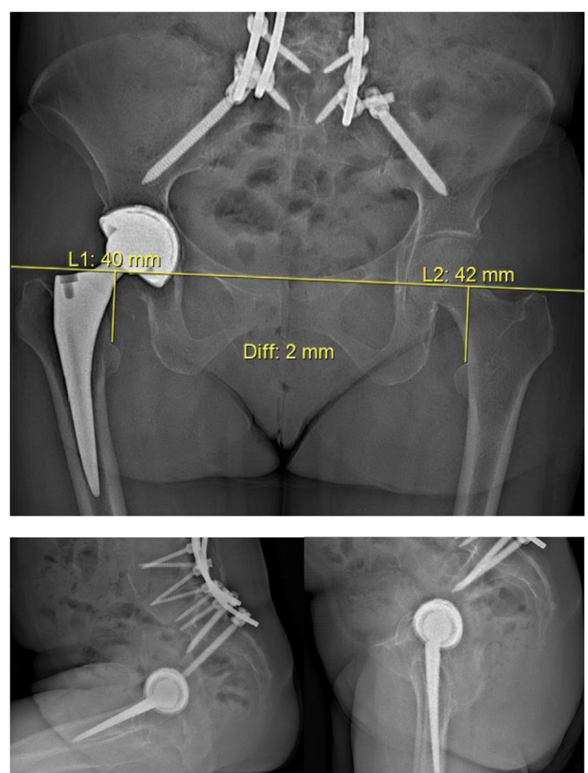

Figure 13. Case 2 preoperative EOS imaging. EOS films in the standing anteroposterior (top) sitting direct lateral (bottom left) and standing direct lateral (bottom right) positions used for preoperative planning with prior thoracolumosacral spinal fusion hardware visible.

superiorly in the dome with good purchase and 1 screw inferiorly in the ischium for additional fixation. A dual mobility liner was impacted into the locking mechanism given her dislocation risk with prior long-segment spinal fusion.

Case completion

In the setting of iliopsoas impingement, even though previous work has shown that pre-rTHA anterior component prominence ≥8 mm results in pain resolution in over 90% of cases, given her persistent, severe groin pain and prior release, we elected to release the remaining iliopsoas that was in continuity [36]. We then trialed femoral heads and found a +0 head to provide excellent soft-tissue tension and full extension and external rotation without impingement in flexion and internal rotation. The final implant was assembled into the dual-mobility liner, placed onto the trunnion, and the hip was reduced. The case was closed similarly to case one. She was made toe-touch weight-bearing for 6 weeks on a walker with posterior hip precautions. Immediate postoperative images demonstrated satisfactory alignment of the components without periprosthetic fracture. She was discharged home on postoperative day 3 after an uneventful hospital course.

At 6-week follow-up, anterior-posterior and cross-table lateral radiographs confirmed the substantial change in version without acute complications (Fig. 14). At the most recent follow-up, 18 months after rTHA, she had much improved pain without any major complication, including instability or dislocation. She was still somewhat limited by pain during sitting and hip flexion, but the acetabular component appeared well fixed and was not proud

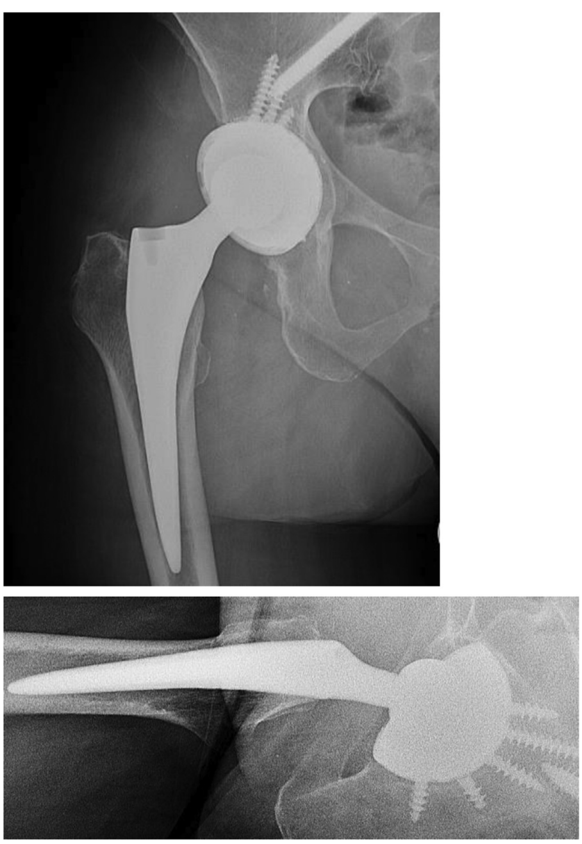

Figure 14. Case 2 6-week postoperative radiographs. Anteroposterior (top) and cross leg lateral (bottom) plain film radiographs demonstrating appropriate total hip arthroplasty positioning with areas of bony ingrowth and without periprosthetic fracture at 6 weeks postoperatively.

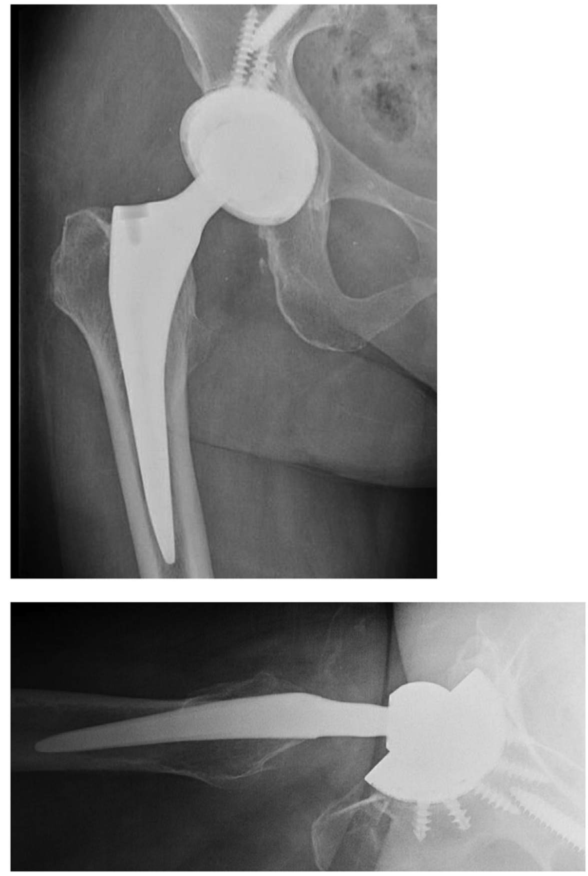

Figure 15. Case 2 18-month postoperative radiographs. Anteroposterior (top) and cross leg lateral (bottom) plain film radiographs demonstrating appropriate total hip arthroplasty positioning.

anteriorly (Fig. 15). We had discussed, both before rTHA and at each follow-up visit, that she may never be fully pain free, especially considering that she did have a significant soft-tissue manipulation with 3 different surgeries within 12 months via 2 different surgical approaches.

Discussion

As the number of rTHA cases continues to increase year over year, methods to improve patient outcomes become paramount. Instability is a common indication for rTHA that stands to benefit considerably from the use of computer navigation as a way to mitigate failure modes related to inaccurate acetabular cup placement [3,20-24]. Imageless computer navigation has emerged as one method for establishing accurate and reproducible acetabular cup positioning to help prevent instability and dislocation [19,27,29]. This is important because previous studies have shown a large degree of variability in cup positioning when using manual, mechanical alignment guides with the Lewinnek safe zone as a reference during both primary and revision THA [22,37-39]. Additionally, when considering that average differences as small as 8° of version and 6° of inclination can mean the difference between stable and unstable acetabular components following acetabular component rTHA, control of component placement becomes essential [40].

Using benchtop and simulated clinic use testing, Paprosky and Muir [19] found this particular computer navigation system able to measure leg length and offset to within <1 mm and acetabular cup positioning to within <1° of anteversion and inclination. Mei et al [29] assessed the accuracy of this navigation system in measuring anteversion and inclination during 53 consecutive rTHA cases, comparing intraoperative measurements to preoperative CT scans, finding excellent agreement for both anteversion (r = 0.93, 95% confidence interval 0.88-0.96) and inclination (r = 0.89, 95% confidence interval 0.81-0.93). Sharma et al [27] retrospectively analyzed a cohort of 72 patients who underwent rTHA using this system and found a 0% dislocation rate at 3 months, 1 year, and 2 years postoperatively. However, they did not use the existing acetabular cup as a fixed reference point as we have here.

The reason that the use of computer navigation provides such accurate component placement and encouraging clinical outcomes in the rTHA setting is because a known fixed landmark (the existing acetabular cup) is used to establish the acetabular reference plane (Fig. 5). This contrasts with the use of computer navigation in the primary THA setting, where external landmarks are used which can become inaccurate based on patient positioning and anatomy. Thus, after establishing the acetabular reference plane, a “delta” can be calculated to determine how many degrees the revision acetabular cup must be changed in both anteversion and inclination. Furthermore, using computer navigation during rTHA provides the ability to optimize the operative plan using precalculated component position goals which are derived from preoperative hip-spine parameters and other preoperative imaging, as we described above (Figs. 2 and 3). Finally, the use of a computer navigation system eliminates the challenges of obtaining perfect radiograph or fluoroscopy images intraoperatively, especially with the patient in a lateral position. The computer navigation system has an easy and efficient workflow to double-check manual instrumentation without the need to bring in a radiograph or C-arm.

Computer navigation in THA and rTHA is not without potential limitations. One aspect of its use that is criticized is cost. Given that computer navigation in THA can increase median hospital charges by approximately 20%, this is an important consideration as we are faced with increased numbers of THA and rTHA being performed each year, potentially contributing to increasing healthcare costs [41-43]. In a similar vein, surgical duration is an important consideration. A recent study of over 2300 propensity-matched pairs determined that technology-assisted THA has significantly longer mean operative times compared to manual THA (101.0 vs 91.9 minutes, $P < .001$) [44]. As case volume continues to rise, operating room efficiency will become even more paramount. Finally, while rare, the use of computer navigation presents its own unique complications. Because computer navigation requires the placement of pins into the iliac crest and greater trochanter, there are potential complications related to this including pin site pain, infection, and periprosthetic fracture [45-47].

Importantly, rTHA is an on-label use for the computer navigation system described in this article. At our institution, the use of computer navigation in rTHA is expanding but is largely surgeon dependent. Of the surgeons at our institution who do more than 20 rTHA per year, more than half of them have adopted routine use of computer-navigated rTHA. As an important limitation of this study, the authors would like to highlight that one of the co-authors is a paid consultant and has stock options in the company that produces the computer navigation device used in these 2 cases.

Summary

As the number of primary and rTHA cases continues to increase in the United States, surgeons need effective and reliable methods for optimizing patient outcomes. Imageless computer navigation allows for accurate and reproducible component positioning that may help prevent instability, bony and soft-tissue impingement, and dislocation in the rTHA setting without compromising patient safety or operative efficiency. Further study is warranted with larger numbers to determine if this technology has the same benefits in rTHA as it has been shown in primary THA.

Conflicts of interest

P.K. Sculco is a paid consultant for, and has stock options of Intellijoint; all other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101347.

Informed patient consent

The author(s) confirm that written informed consent has been obtained from the involved patient(s) or if appropriate from the parent, guardian, power of attorney of the involved patient(s); and, they have given approval for this information to be published in this case report (series).

CRediT authorship contribution statement

Colin C. Neitzke: Writing – review & editing, Writing – original draft, Conceptualization. **Sonia K. Chandi:** Writing – review & editing, Writing – original draft. **Elizabeth B. Gausden:** Writing – review & editing, Supervision, Conceptualization. **Eytan M. Debbi:** Writing – review & editing, Supervision, Conceptualization. **Peter K. Sculco:** Writing – review & editing, Conceptualization. **Brian P. Chalmers:** Writing – review & editing, Supervision, Conceptualization.

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