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Case report

Computer-Assisted Navigation for Complex Revision of Unstable Total Hip Replacement in a Patient With Post-traumatic Arthritis

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ABSTRACT

Imageless computer-assisted navigation (CAN) excels in the post-traumatic arthritis and complex revision case setting when altered anatomy and landmarks are inaccurate references for cup positioning. We describe the case of an adult male patient who suffered an acetabular fracture which was treated nonoperatively. He subsequently developed post-traumatic arthritis and underwent an anterior approach total hip arthroplasty 25 years later. Postoperatively, he developed recurrent hip instability due to malpositioned components. We describe the use of imageless CAN during revision total hip arthroplasty to correct malpositioned components, with 3-year follow-up without dislocation. In these complex cases, CAN reduces the risk of component malpositioning and joint instability.

Introduction

Recurrent hip dislocations following primary total hip arthroplasty (THA) may require revision of component position to achieve stability [1–6]. Traditionally, surgeons have relied on anatomic markers and tactile and visual assessment for component placement [7]. In the last 2 decades, computer-assisted navigation (CAN) in THA has become more widely used. CAN involves the utilization of computer tracking software for the purposes of aiding in component alignment [8]. It has also been demonstrated to be a more accurate, repeatable method for achieving preoperative component positioning and alignment goals [7,9]. Particularly, imageless CAN has demonstrated utility in complex cases where anatomic landmarks may be distorted, such as patients with hip dysplasia, history of previous surgery, or fracture.

In this case report, we describe a 72-year-old male who underwent an anterior-approach THA to treat post-traumatic arthritis from a 25-year-old acetabular fracture. Owing to the challenging exposure and altered anatomy, the components were malpositioned, and the patient suffered from hip instability. We describe the use of imageless CAN during revision THA to correct the malpositioned components, with 3-year follow-up without dislocation.

We obtained written informed consent from the patient to publish the patient's clinical history, surgical procedure, diagnostic studies, and radiographs.

Case history

The patient is a 72-year-old African American male with a history of post-traumatic arthritis of his right hip (Fig. 1). This dates to an acetabular fracture at the age of 47 years, stemming from a motor vehicle accident in Liberia, which was treated nonoperatively with traction. Twenty-five years later, the patient underwent primary THA of his hip at an outside institution utilizing a direct anterior approach (Fig. 2). The surgeon noted a challenging exposure due to significant soft-tissue contracture and osteophytosis. A size 64-mm Stryker (Mahwah, New Jersey, USA) Tritanium shell, 36-mm Trident X3 zero-degree insert, size 4 Stryker Accolade 2 stem, and 36-mm, −5 Biolox Delta ceramic femoral head were implanted. On postoperative day (POD) 1, the patient was

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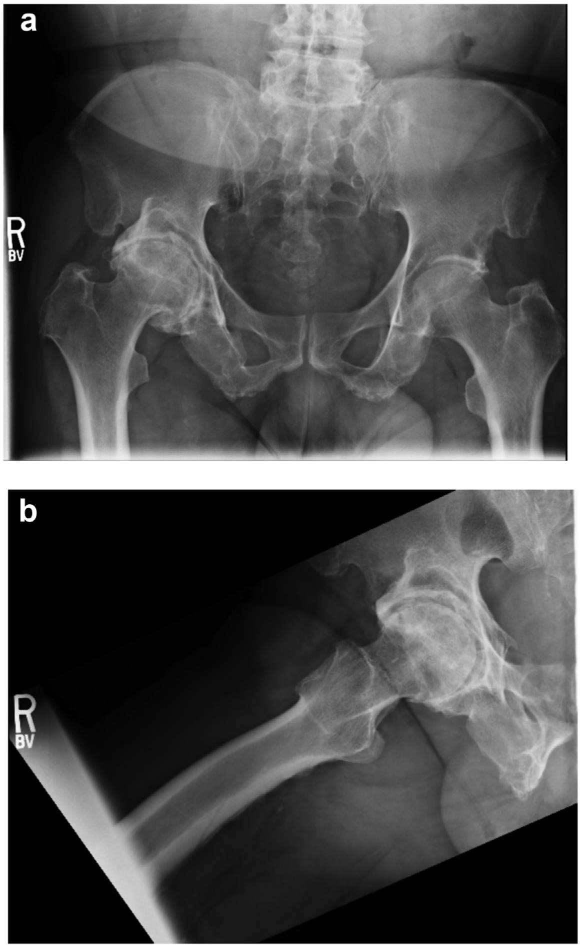

Figure 1. (a) Preoperative anteroposterior (AP) pelvis radiograph. (b) Preoperative right hip lateral radiograph.

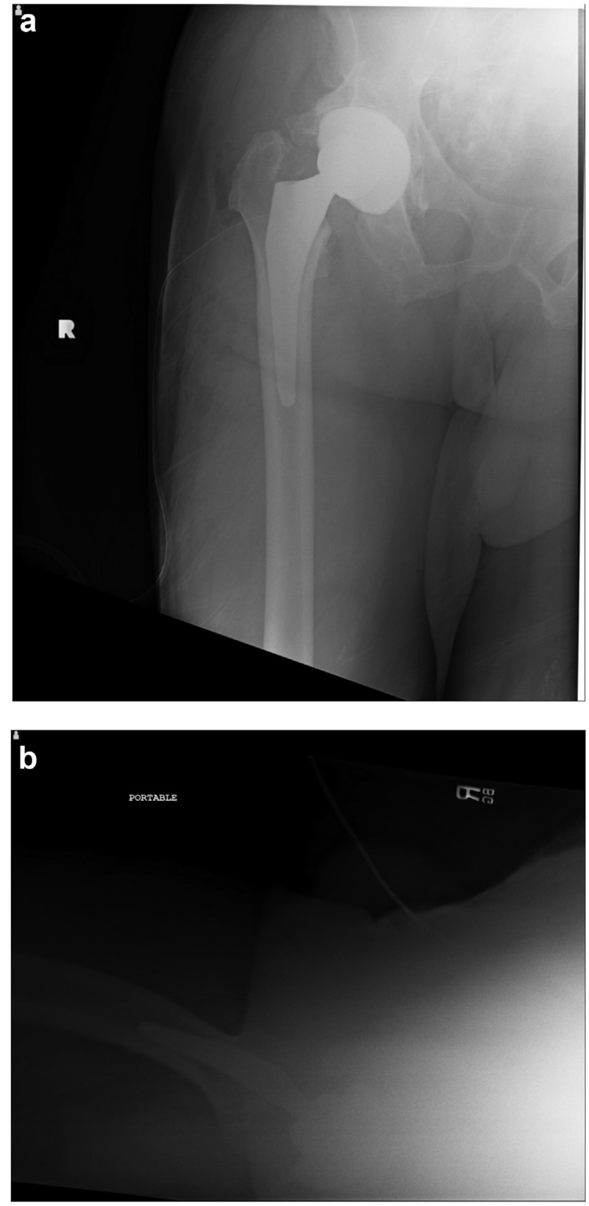

Figure 2. (a) Postoperative AP right hip radiograph following primary THA. (b) Lateral right hip radiograph following primary THA.

discharged home. He returned to the emergency department of this same outside institution on POD 17 with a superolateral hip dislocation that occurred while walking which was closed reduced with sedation in the emergency department. The following day, the patient suffered a second dislocation while working with physical therapy. The primary surgeon conducted a revision on POD 19, where he revised the acetabular component with a new zero-degree eccentric liner and revised the head to a 36-mm, −2.5 Biolox Delta ceramic femoral head (lengthening the neck). The cup position was not changed (Fig. 3). The patient was discharged with advice to maintain anterior hip precautions. On POD 22 from the initial surgery, the patient again returned to the outside institution with a recurrent dislocation. A closed reduction attempt in the emergency room was unsuccessful. He was admitted to the outside hospital and remained dislocated pending surgical planning. During this admission, the patient developed a right lower extremity deep vein thrombosis for which an inferior vena cava filter was placed, and he was started on coumadin. The patient was transferred to our institution on POD 30 for further management.

Radiographs demonstrated a superior right hip dislocation (Fig. 4), and from the lateral cross-table lateral radiograph, we were unable to determine the direction of dislocation (anteriorly vs posteriorly). Postoperative imaging prior to dislocation had demonstrated that the leg lengths and femoral offset were equal. On physical exam, the patient was neurovascularly intact. A computed tomography (CT) scan was obtained, which measured the cup at 50 degrees of inclination and 35 degrees of anteversion. Stem anteversion was estimated to be 30-35 degrees. The hypothesis of the surgical team was that the recurrent dislocations were secondary to anterior instability caused by malposition of the acetabular component (too much inclination and anteversion), over anteversion of the stem, and possible impingement from osteophytosis. The goals of surgery were to revise the cup position (35 degrees abduction, 10 degrees anteversion), evaluate stem version, increase femoral offset to decrease impingement, and improve abductor tension.

The patient underwent revision THA on POD 31 with imageless CAN using the Intellijoint System (Intellijoint Surgical Inc., Waterloo, ON, Canada) (Fig. 5). The Intellijoint hip system establishes a fixed reference on the pelvis of the patient and registers the horizonal and coronal planes of the patient in relation to that fixed

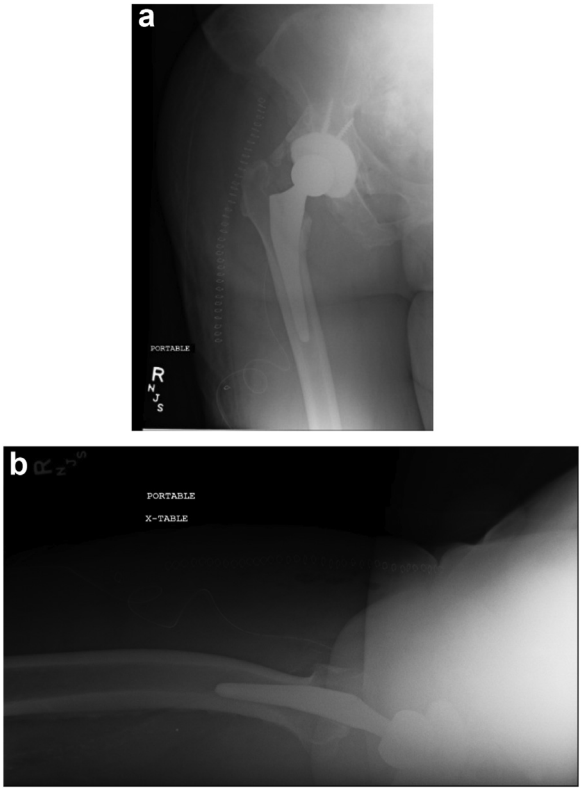

Figure 3. (a) Postoperative AP right hip radiograph following the first revision THA. (b) Postoperative lateral right hip radiograph following the first revision THA.

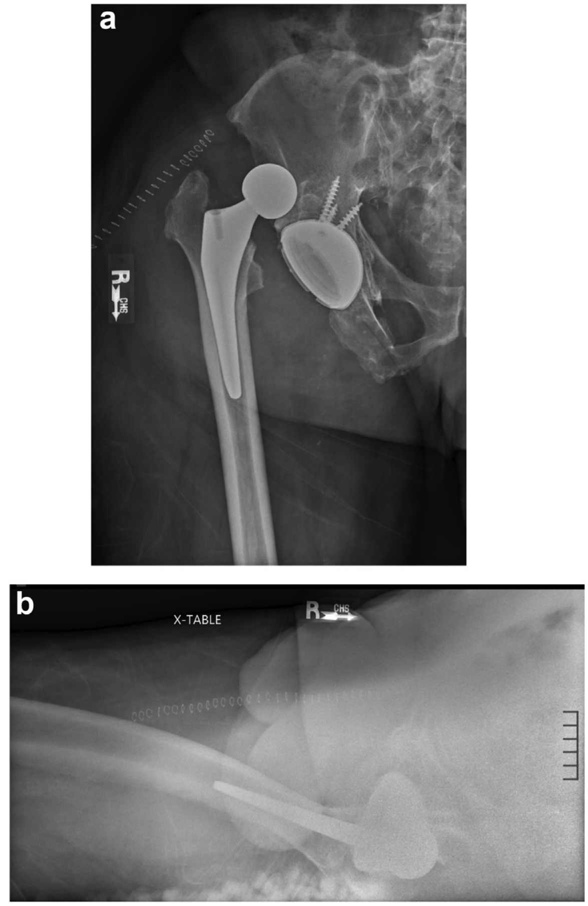

Figure 4. (a) AP right hip radiograph obtained in the emergency department, demonstrating right hip dislocation. (b) Lateral right hip radiograph obtained in the emergency department, demonstrating right hip dislocation.

reference. A tracker attached to the acetabular cup impactor allows intraoperative assessment of cup anteversion and inclination angles while a femur platform placed on the greater trochanter allows one to determine intraoperative leg length, offset, and change in the hip center of rotation. The Intellijoint hip system has been validated to measure cup position to less than 3 degrees, leg length to less than half a millimeter, and offset to within half a millimeter [10–12]. Intellijoint is compatible for either anterior or posterior approach.

The decision was made to utilize the posterior approach, as the original surgeon warned the surgical team of a very challenging anterior exposure (which the revising team believed was a major cause of the component malpositioning), and the revision team felt more comfortable addressing potential intraoperative complications from the posterior approach. The patient was positioned in the lateral decubitus position. The CAN was registered to the patient's pelvis (Table 1). A 25-cm incision was made overlying the posterior hip, utilizing the posterior approach. The proximal femur was exposed. After extensive dissection, the femoral neck was identified, and the hip was reduced under direct visualization. The femoral platform was attached, and the center of rotation of the femoral head was registered by the CAN. The hip was dislocated, and the femoral head was removed. Using the measurement stylus, the CAN measured the orientation of the existing acetabular component at 45 degrees of abduction and 35 degrees of anteversion, which suggested that excessive cup anteversion was a contributing factor to the patient's recurrent anterior dislocations. The acetabular component was explanted, and the acetabulum was reamed for a size-66 cup, and a Stryker Restoration Anatomic Acetabular Shell was used to restore the center of rotation given the extent of superior acetabular bone loss. Utilizing the CAN, the cup was positioned at 35 degrees of abduction with 10 degrees of anteversion. Using a trial liner and head, the hip was reduced. The Ranawat angle was approximately 50 degrees [13]. The hip was taken through a full range of motion. However, the hip remained unstable secondary to the anteversion present in the stem (intraoperatively thought to be >40 degrees based on visual assessment). The hip was unstable in extension and external rotation due to component impingement (not bony impingement). The hip was stable at maximum flexion; at 90 degrees of flexion, it was stable to 45 degrees of internal rotation; and at 45 degrees of hip flexion, it was stable an additional 15 degrees. The hip was stable in the position of sleep. The decision was made to proceed with implanting the acetabular cup and to address the further anterior instability by revising the femoral stem to correct the excessive femoral anteversion. The final acetabular component was secured with screws, and a multidirectional trial liner was inserted. The stem was revised to reduce the original stem's anteversion and increase offset. The femoral stem was removed with a stem extraction system, and the canal was prepared for a modular splined tapered stem. The femur was reamed to a size of 17, and the proximal body was implanted. Multiple instability trials were conducted with varying degrees of stem version. The most stable construct was noted in approximately 5 degrees of anteversion of the femoral neck. The hip was taken through a full range of motion. The hip soft tissues were examined in extension and external rotation, and the anterior capsule and iliotibial band were palpated. The hip was stable at maximum flexion; at 90 degrees of flexion, it was stable to 45 degrees of internal rotation; and at 45 degrees of hip flexion, it was

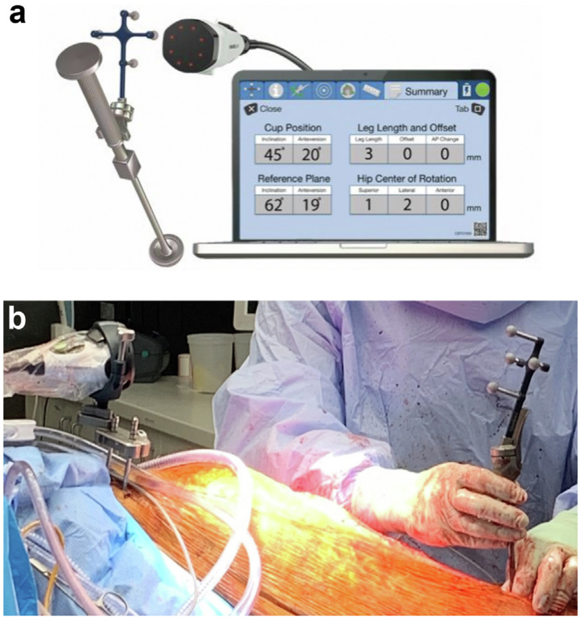

Figure 5. (a) Illustration of the Intellijoint Surgical computer navigation system. (b) Intraoperative image, with camera mounted to the pelvis platform, and array with stylus being used for intraoperative measurements.

Table 1
Steps for utilizing Intellijoint CAN.

1	Two pins are inserted in the pelvis iliac wing to mount an optical camera, and a pelvis platform is secured to the pins.
2	A camera is placed on the fixed pelvis platform, the field of view is focused on the surgical site, and the gyroscope and computer are registered to the orientation of the pelvis based on how that patient is positioned on the table and with an optical alignment rod.
3	Before dislocating the hip, a greater trochanteric platform is attached to the femur, an optical array is attached to the greater trochanter, and the center of rotation of the femoral head, leg length, and offset are measured by the computer.
4	During a revision case, the orientation of the original cup can be measured using an optical probe. This allows an intraoperative comparison to preoperative radiographic measurements.
5	The orientation of a reamer and a new acetabular component can be measured by placing an optical array on a reamer handle or an insertion handle.
6	Once the hip has been reduced, the new cup position, as well as leg length and offset, can be measured utilizing the greater trochanteric platform by re-registering the new hip center of rotation.
7	Prior to closing the incision, the greater trochanteric platform is removed. The 2 pins to secure the pelvis platform are removed as well.

stable an additional 15 degrees. It was stable in the sleeping position, in adduction of 15 degrees and external rotation and with an extension of 15 degrees and external rotation. After reduction of the hip, leg lengths appeared grossly similar. Leg length measurement on the CAN system noted the operative leg to be 3 mm longer, with 5 mm of additional offset. Even with the stability benefits from lengthening the limb, our surgical plan was to avoid lengthening greater than 1 cm due to patient dissatisfaction with over-lengthening. The plan was for additional offset to provide the benefits of stability without the disadvantage of overlengthening. Fluoroscopy was utilized to confirm the findings of the CAN system. A dual-mobility construct was used. The hip was reduced under direct visualization, taken through full range of motion, and noted to be stable. Postoperative imaging confirmed intraoperative component positioning (Fig. 6). Postoperatively, the patient remained hemodynamically stable and worked with physical therapy without special precautions or bracing. He was discharged to short-term rehabilitation on POD 5 from his third surgery. He remained there until POD 17 and demonstrated no evidence of recurrent instability or repeat dislocation.

The patient presented to the clinic for follow-up on POD 22, 50, and 298 and on 2-year and 3-year follow-up visists. He reported hip joint stiffness but had no repeat dislocations and reported minimal pain. On exam, he had full strength and sensation. Range of motion at the time of final follow-up was 110 degrees of hip flexion, full hip extension, 25 degrees of abduction, and 20 degrees of adduction. Radiographs demonstrated maintained anatomic position of the revision hip components. He also demonstrated significant heterotopic ossification around the femoral and acetabular components, which may have contributed to his stiffness and potentially decreased his risk of dislocation (Fig. 7).

Discussion

Dislocation is the most common complication following primary THA and is thought to be due to malpositioning of acetabular and femoral components [1]. The classic safe zone for acetabular cup placement has been cited as 40 ± 10 degrees of inclination and 15 ± 10 degrees of anteversion [4]. However, recent literature suggests that dislocations occur frequently despite component placement within these safe zones [14].

Given this patient's history of previous acetabular fracture and joint contracture, the anterior approach chosen for the primary surgery may have increased the risk of acetabular cup and femoral stem malposition. The contracted femur would not fall posteriorly, and this may have forced the surgeon's acetabular inserter anteriorly, leading to excessive anteversion and inclination. In addition, a contracted femur would have limited external rotation of the femur during preparation of the proximal femoral component and placement of the femoral component, resulting in increased anteversion of the femoral stem. In addition, the original postoperative radiographs demonstrate that the stem was quite low and the greater trochanter is prominent. We suspect that restoration of leg lengths was challenging given how contracted the hip was, so the stem was undersized, and a −5 head was used. Regarding why the revision surgical team chose the posterior approach, the original surgeon had struggled with the anterior approach due to significant scar and stiffness. In addition, the revision surgeon felt more comfortable addressing potential intraoperative complications from the posterior approach. The authors acknowledge that utilizing the posterior approach increased the risk of a multidirectional instability.

CAN has been shown to improve accuracy of positioning of the acetabular component and to reduce the rate of hip dislocations in the immediate postoperative period [9,15–18]. Several authors reported on the increased accuracy of CAN with cup anteversion [18–21], and this has been bolstered by a recent meta-analysis, which demonstrated that CAN in hip arthroplasty improves accuracy of the acetabular component position [9]. Evidence from a nationwide database demonstrated that CAN lowered 90-day complication rates and readmission rates compared with traditional THA, after controlling for confounding variables [22].

Importantly, this case provides evidence of how CAN is useful when normal anatomy is altered. In this case, the patient suffered a previous acetabular fracture, which distorted traditional anatomic landmarks typically used for intraoperative acetabular component positioning. The CAN used in this case relies on registration with the functional pelvic plane, which can be reliably identified on most patients with complex hips who are positioned accurately on the operating room table prior to the registration of the pelvis.

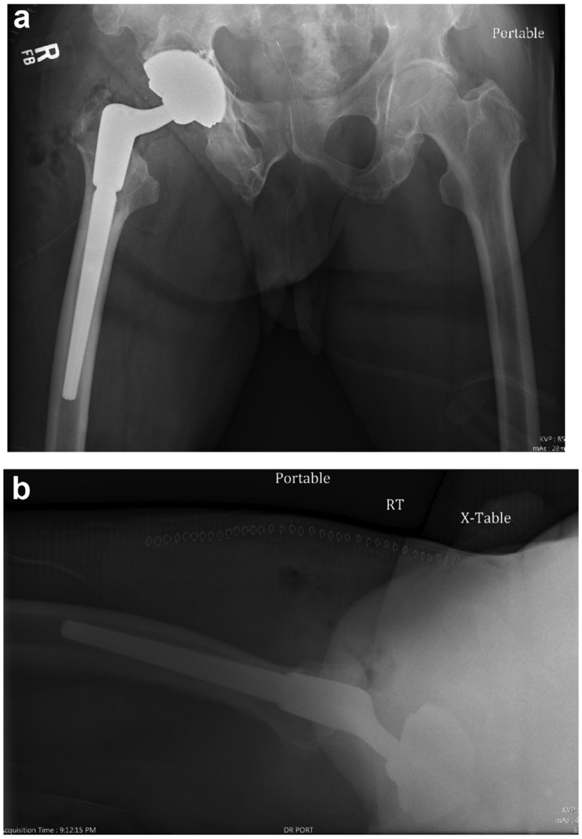

Figure 6. (a) Postoperative AP right hip radiograph following the second revision THA using CAN. (b) Postoperative lateral right hip radiograph following the second revision THA using CAN.

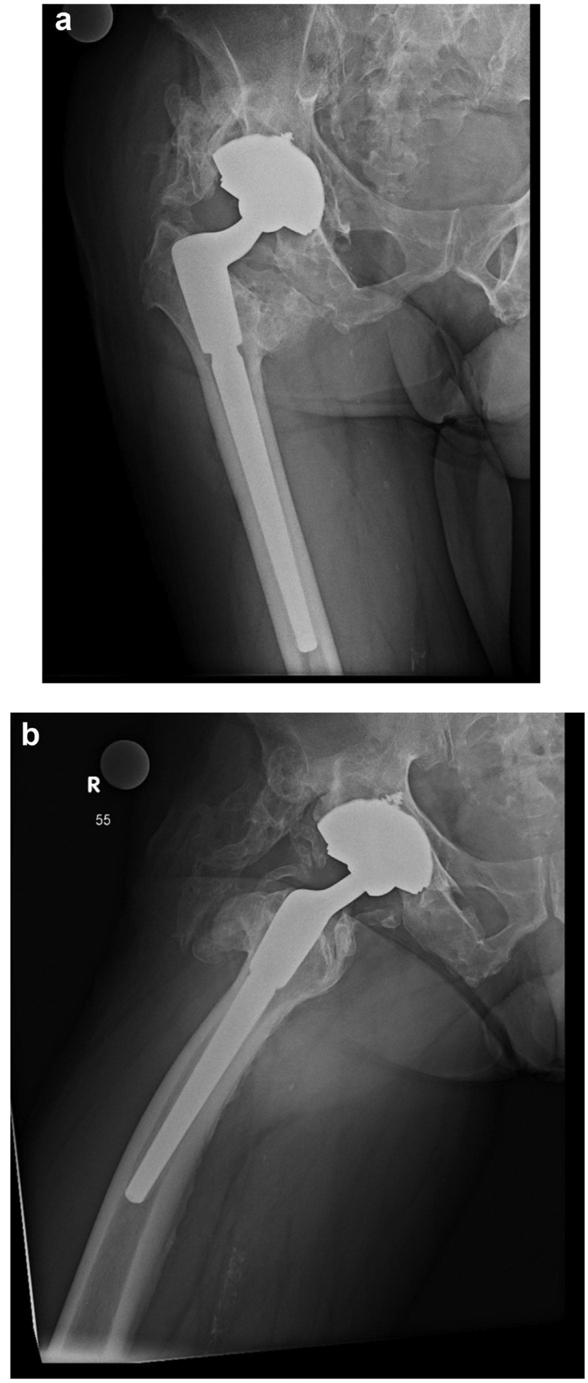

Figure 7. (a) The final postoperative AP right hip radiograph following the second revision THA using CAN demonstrating interval formation of heterotopic ossification. (b) The final postoperative lateral right hip radiograph following the second revision THA using CAN demonstrating interval formation of heterotopic ossification.

CAN has demonstrated its usefulness in many complex cases. For example, it has been used to determine acetabular position and orientation in a patient with severe acetabular dysplasia and those with leg length discrepancies secondary to previous hip fracture or Perthes disease [23–25]. In another example, CAN was used to identify the acetabulum and femoral neck cut level after a patient was converted from a hip arthrodesis to a THA [26]. CAN may also be used as a diagnostic tool to help identify malpositioning of previously placed components [27]. In cases of osteopetrosis where the femoral canal may be absent, CAN may be useful with femoral canal preparation and implant placement [28].

Judging acetabular component orientation on anteroposterior and lateral radiographs with the hip dislocated is not ideal given that the pelvis position will be tilted. Pulos et al. describe how to calculate version with a lateral radiograph [29]. We chose to utilize the CT scan to arrive at a numerical value. There was a discrepancy between the cup orientation measured on the CT scan (50 degrees of inclination and 35 degrees of anteversion) and that on the CAN (45 degrees of abduction and 35 degrees of anteversion). This is thought to be due to measurement inaccuracies, such as how the pelvis was positioned when lying in the CT scanner and how the patient's pelvis was positioned on the bed at the start of the case. In addition, the CAN relies on the surgeon to properly register the pelvis. The level of correlation between the CT scan and the CAN reinforced the accuracy of the intraoperative data and surgical decision-making.

Postoperatively, the patient suffered from significant heterotopic ossification. Given the patient's history of acetabular fracture and multiple surgeries, he may have benefited from heterotopic ossification prophylaxis at the time of revision surgery.

Summary

This case provides an example of how CAN provides reference data when the standard anatomy is altered. In this case, without CAN, the acetabular component was placed outside recommended parameters, likely due to altered anatomic landmarks. CAN allowed the revision surgeons to calculate the malpositioning of the acetabular component and correct with a more appropriate anatomic orientation. The CAN system was also able to calculate the leg length and increased femoral offset. This case demonstrates the utility of CAN to assist surgeons with intraoperative information, particularly those patients with altered anatomy. Further research is needed to determine which cases are best suited for CAN to reduce complication rates and control costs.

Conflicts of interest

D. H. Wiznia is a paid consultant for Intellijoint and Materialise.

Informed patient consent

The referenced patient consented to their information being included in this study.

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