Case Report

Periacetabular Osteotomy Performed with Imageless Computer-Assisted Navigation: Case Report

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Abstract

Periacetabular osteotomy (PAO) is an effective surgical treatment for developmental hip dysplasia. The goal of PAO is to reorient the acetabulum to increase acetabular coverage of the femoral head, as well as to reduce contact pressures within the hip joint. The primary challenge of PAO is to accurately achieve the desired acetabular fragment orientation, while maximizing containment and congruency. As key parts of the procedure are performed out of direct field of view of the surgeon, combined with this challenge of precise spatial orientation, there is a potential role for technologies such as surgical navigation. Adjunctive technology may provide information on the orientation of repositioned acetabulum and may offer a useful assist in performing PAO. Here, we present a case of developmental dysplasia of the hip treated via PAO with the addition of an imageless computer navigation device. Surgery was successful, and, at 3 months after procedure, the patient was progressing well. To our best knowledge, this is the first case using imageless computer-assisted navigation in PAO surgery.

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Introduction

Hip dysplasia is a relatively common developmental condition, reported at an incidence of between 2.5 and 5% in young adults [1]. While nonsurgical treatments are attempted in the early stages of the disease [2], surgical treatment is often required to properly address the biomechanical deficits of the misshaped acetabulum. The most effective surgical approach for dysplasia has proven to be periacetabular osteotomy (PAO), the goal of which is to reorient the acetabulum to increase acetabular coverage of the femoral head. With improved orientation, there is a reduction in hip contact pressures and improved femoroacetabular load transmission [3]. These biomechanical improvements are important to long-term outcomes for patients with hip dysplasia, as if left untreated, the pathomechanisms of dysplasia eventually lead to the early development of osteoarthritis, functional limitations, and hip pain [4].

Due to the complex anatomical deformities of hip dysplasia, PAO is a challenging surgical procedure that requires tight tolerance to a desired correction goal. The procedure presents unique challenges, including osteotomy cuts that must be performed with the blades of the instruments out of view of the surgeon, and the risk of damage to the many neural and vascular structures within the pelvic region. The primary challenge of PAO is to accurately achieve the desired acetabular fragment orientation, while maximizing containment and congruency. The accurate repositioning of the acetabulum in a more biomechanically stable orientation relieves mechanical stress on the joint and decrease the propensity for instability [2]. The surgical technique has been written about extensively [5], as the complexity of this technique cannot be understated. There is also a substantial learning curve that surgeons must address when performing PAO procedures [6].

Computer-assisted navigation is an increasingly common adjunct to total hip arthroplasty and has demonstrated the ability to improve the accuracy and efficiency of cup positioning [7]. Navigation has also demonstrated additional benefits in demanding orthopedic surgeries for conditions such as Legg-Calve-Perthes disease and during cases requiring significant leg lengthening [8]. To our best knowledge, this is the first case report describing the use of imageless computer-assisted navigation for PAO in patients with hip dysplasia. Here, we report such a case of developmental hip dysplasia, corrected by PAO with the assistance of an imageless computer-assisted navigation system.

Case Report

A 16-year-old female presented with a chief complaint of significant, progressive right hip pain. The pertinent history included a diagnosis of developmental dysplasia of the hip. In addition to pain, the patient reported mechanical symptoms related to the hip, as well as feelings of instability with activities. She was a high-school student, who was active in dance team and other athletic activities. The pain and dysfunction had limited her ability to participate in these activities, as well as with certain activities of daily living. She had undergone a series of nonsurgical measures to address the hip pain, including oral anti-inflammatory medications, rest, activity modification, and formal physical therapy, with minimal symptom resolution.

On physical examination, the patient had a mildly antalgic gait with respect to the right hip. Leg lengths were equal. The range of motion of the right hip measured 10° of extension to 115° of flexion, 45° of internal rotation in flexion, 55° of external rotation in flexion, 40° of abduction, and 15° of adduction. There was a positive anterior impingement sign, with no

gross instability of the hip with stress maneuvers. Abductor strength was 5/5 bilaterally, and the remainder of the neurological examination was unremarkable.

Radiographs of the pelvis and hips revealed moderate right hip dysplasia evidenced by uncoverage of the femoral head (Fig. 1a), deficient acetabular volume, and abnormal Tönnis, lateral center edge, and anterior center edge angles. Magnetic resonance imaging of the right hip confirmed a large tear of the acetabular labrum, with preservation of the femoral and acetabular cartilage surfaces.

Following consultation with the patient and extensive discussions with the patient and her family regarding available treatment options, a recommendation was made for right PAO to correct the bony dysplasia. Imageless, computer-assisted navigation (Intellijoint HIP; Intellijoint Surgical Inc., Waterloo, ON, Canada) would be utilized during surgery to assist with three-dimensional mobile fragment positioning (Fig. 2). The patient's initial position is registered by touching a tracker probe to both anterior superior iliac spines and the pubic symphysis, which establishes the orientation of the anterior pelvic plane. The off-label use of this technology was discussed with the patient and family preoperatively. They understood that traditional measures of osteotomy fragment positioning (i.e., intraoperative fluoroscopy and plain radiographs), coupled with clinical judgment, would be used along with this novel application of the navigation technology.

Surgery was successful and, at 3 months after the procedure, the patient was progressing well. Her bony osteotomy sites were healed (Fig. 1b), and there was maintenance of excellent bony correction. She had experienced improving pain relief and increasing functional mobility in accordance with satisfactory recovery from PAO surgery. She was fully weight-bearing and pleased with her early surgical recovery.

Discussion

PAO as a corrective treatment for acetabular dysplasia has several advantages, including the posterior column remains mechanically intact, the blood supply of the acetabular fragment is preserved, and the birth canal volume remains unaffected. The PAO procedure itself is challenging, as the pelvis is not fully visible or accessible to the surgeon during parts of the surgery. Effectively, it requires guided osteotomy cuts around the acetabulum in order to free the mobile fragment from the stable hemipelvis, and to effectively reorient the unconstrained acetabulum into a more biomechanically stable orientation. The high degree of clinical complexity of this surgery results in a large learning curve and increased surgical risks. Here, we report the first use of an imageless navigation system to assist with acetabular reorientation during PAO.

The main challenge in PAO is the repositioning of the acetabulum into a stable and biomechanically sound orientation, to relieve mechanical stress on the joint and decrease the potential for instability. Achieving this ideal correction for the individual patient remains the most demanding and most critical aspect of the PAO procedure. Computer-assisted navigation can play an important role in this step, as the ability of this technology to provide real-time data on orientation and positioning may improve the accuracy with which the acetabular fragment is repositioned. Real-time data in three dimensions affords an excellent tool to improve the complex spatial orientation. In the current case, the ability to probe the acetabular rim as trial orientations were tested and calculate the real-time orientation of the acetabular fragment (inclination and anteversion) allowed the surgeon to more accurately confirm the optimal orientation of the acetabulum. The device described in this report has demonstrated

measurement accuracy of within 1° of computed tomography measurements when using the probe to measure total hip acetabular components [9]. As such, we were able to confidently measure the final acetabular orientation prior to fixation, which resulted in accurate execution of the preoperative plan.

Additional studies that investigated the relationship between PAO and image-guided 3-D computed tomography software have been published [10]; however, these studies have demonstrated limitations with the application of image-based navigation technology in PAO. While these programs allow for detailed preoperative planning, once the acetabular fragment has been osteotomized and mobilized from the pelvis, the program has no real-time tracking ability to guide reorientation. Further barriers, such as the sizable cost may make it difficult for computed tomography-based software to address the unique requirements of the PAO.

Conclusion

This report summarizes a case of developmental hip dysplasia treated with the assistance of an imageless computer-assisted navigation device. The device, along with clinical judgment and surgeon experience, provided intraoperative measurements of osteotomy fragment mobilization. Importantly, this device allowed confirmation of accurate fragment reorientation with real-time, three-dimensional feedback. Further research is needed with larger sample size RCTs to determine the efficacy, withdrawal effects, and adverse reactions of PAO and imageless navigation.

Statement of Ethics

The subject gave her written informed consent to publish this case (including publication of images).

Disclosure Statement

R.R.M. is an employee of Intellijoint Surgical Inc.

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Author Contributions

A.F.K. performed the surgery. R.R.M. wrote the first draft. All authors contributed to the final manuscript.

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Fig. 1. Preoperative hip radiograph (**a**) and postoperative hip radiograph (**b**) demonstrating satisfactory acetabular reorientation, including superolateral movement of preoperative rim fracture, which provided increased coverage at the anterior/superior aspect of joint (arrow).

Fig. 2. Imageless, mini-optical computer navigation tool in use during the case. The camera (A), enclosed in its sterile drape, is attached to the pelvic platform via two screws (out of view). The tracker (B) is magnetically attached to the femur platform (C), which is attached via a v-block to a pin placed into the mobile acetabular fragment. The Schanz pin (D) is seen in the mobile fragment of the acetabulum to reorient the acetabular segment. The camera captures the movements of the tracker when registering the native orientation and thereafter relays the information to a workstation for review by the surgeon. Real-time 3-dimensional data is converted to appropriate acetabular inclination and version targets.