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Total Hip Arthroplasty With Subtrochanteric Osteotomy for Crowe IV Dysplasia Using an Extensile Direct Anterior Approach: A Surgical Technique

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ABSTRACT

The direct anterior approach (DAA) has been increasing in popularity for primary total hip arthroplasty (THA). Despite previously documented anatomic limitations to its direct distal extension, alternative exposure methods have been described to safely access the femoral diaphysis and facilitate increasingly complex primary and revision THA scenarios. The DAA has several purported advantages compared to alternative approaches (eg, posterior and lateral-based), including its muscle-sparing nature, use of an internervous plane, and preservation of posterior stabilizing structures. Proponents of the DAA cite decreased postoperative pain, quicker recovery times, potentially lower dislocation rates, ease of intraoperative fluoroscopy, and improved implant placement/restoration of leg lengths. The current literature, however, is sparse when considering the use of this approach in the setting of severely dysplastic hips necessitating a concurrent subtrochanteric shortening osteotomy. When utilizing a posterior approach in this population, previous work from Ollivier and colleagues demonstrated high rates of cementless implant osseointegration and significantly improved clinical outcomes at long-term follow-up. Although relatively few reports of addressing this pathology via the DAA currently exist, initial results are promising. This study seeks to provide a detailed description of a surgical technique for performing primary THA and ipsilateral subtrochanteric shortening osteotomy in this patient population utilizing an extensile DAA.

Introduction

The direct anterior approach (DAA) has been increasing in popularity for primary total hip arthroplasty (THA) with a reported 45%-55% of practicing arthroplasty surgeons utilizing this approach for primary THA. [1,2] Despite previously documented anatomic limitations to its direct distal extension, alternative exposure methods have been described to safely access the femoral diaphysis and facilitate increasingly complex primary and revision THA scenarios. [3–5] Although long-term studies have yet to demonstrate significant differences with regard to dislocation or functional outcomes, the DAA has several purported advantages compared to alternative approaches (eg, posterior and lateral-based), including its muscle-sparing nature, use of an internervous plane, and preservation of posterior stabilizing structures. [6] Proponents of the DAA cite decreased postoperative pain, quicker recovery times, potentially lower dislocation rates, ease of intraoperative fluoroscopy, and improved implant placement/restoration of leg lengths. [7–9] The current literature, however, is sparse when considering the use of this approach in the setting of severely dysplastic hips necessitating a concurrent subtrochanteric shortening osteotomy (SSO). When utilizing a posterior approach (PA) in this population, previous work from Ollivier and colleagues demonstrated high rates of cementless implant osseointegration and significantly improved clinical outcomes at long-term follow-up. [10] Although relatively few reports of addressing this pathology via the DAA currently exist, initial results are promising [11–14].

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Hip dysplasia occurs on a spectrum of diseases and may manifest as a result of several different etiologies [15]. Most commonly, it is a result of unrecognized or untreated developmental dysplasia of the hip (DDH) [15,16]. In adults with a history of DDH, Crowe's classification is used to describe the degree of dysplasia. Severity is based on the magnitude of subluxation of the medial femoral head-neck junction relative to the radiographic teardrop compared to the femoral head diameter and pelvic height. [17] Crowe IV dysplastic hips, the highest degree of disease severity, are defined as having >100% subluxation of the femoral head-neck junction relative to the undeformed femoral head diameter or proximal displacement of >20% of pelvic height. Typically presenting with early-onset advanced osteoarthritis, this cohort presents a technically challenging reconstruction for the arthroplasty surgeon, as concurrent rotational deformities of the proximal femur (increased anteversion), soft tissue contractures (commonly adduction and/or flexion), and/or a hypoplastic acetabulum are frequently encountered [18]. Efforts should be made to reestablish the native hip center, restore proper abductor tension, and correct abnormal femoral version to promote improved gait biomechanics and improve long-term survivorship. [19] In order to accomplish these goals, an SSO may be indicated. In Crowe III/IV dysplastic hips, increased native femoral length is common when compared to the unaffected side. [20] This length difference allows for the achievement of similar leg lengths following SSO without excessive shortening. Excess limb lengthening without a concurrent shortening procedure places the sciatic nerve at risk for a traction-related injury. While the magnitude of this maximal-allowable lengthening is controversial, most authors believe it to be in the 2-5-centimeter range, or 5%-10% of the femoral length. [21,22] DDH, complex primary/revision THA, posttraumatic arthritis, and preexisting hip contractures are all risk factors for its occurrence. [22,23] Previous studies have demonstrated the efficacy of the DAA in THA for Crowe IV dysplasia. [11–14] This study seeks to provide a detailed description of the surgical technique for performing primary THA and ipsilateral SSO in this patient population utilizing an extensile DAA.

Surgical technique

Preoperative optimization and planning

Prior to surgical intervention, a detailed history and physical examination must be obtained and accurately documented. In addition to understanding the characteristic nature of the patient's pain and functional limitations, the history should also investigate the presence of any additional medical comorbidities, including those that may underlie the patient's hip dysplasia. Bilateral hip rotational profiles, the presence of hip flexion and/or adduction contractures, clinical leg length discrepancy, and patient gait should be assessed on examination. The soft tissue envelope around the hip and abdomen should be inspected for previous incisions. Anteroposterior pelvis and orthogonal hip plain radiographs are recommended (Fig. 1). Standing radiographs are preferable, as they best capture the functional pelvic position. Bilateral hip-to-ankle radiographs, if attainable, allow the surgeon to more accurately quantify an actual vs apparent leg length discrepancy. Advanced imaging in the form of computed tomography of the bony pelvis with extension through the bilateral femurs can be utilized to calculate the patient's native femoral version preoperatively.

Accurate templating is imperative to establish intraoperative targets for component size/positioning, SSO location, and changes in limb length that minimize the risk of perioperative

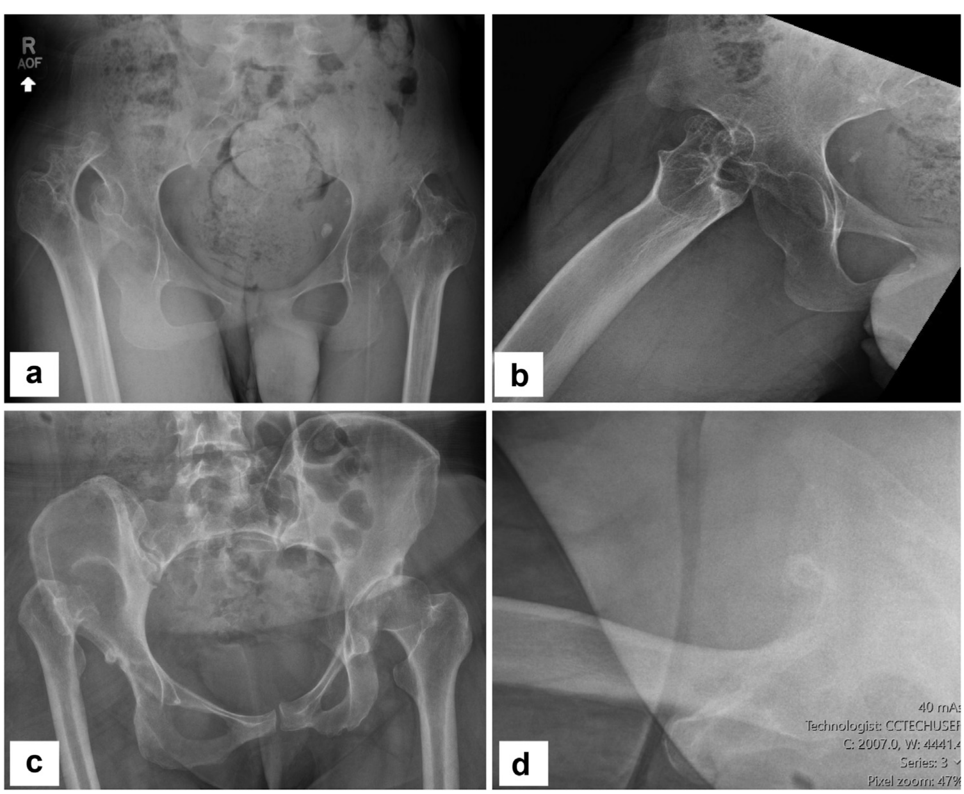

Figure 1. Preoperative (a) anteroposterior pelvis and (b) frog-leg lateral radiograph of the right hip from example patient #1. Preoperative (c) anteroposterior pelvis and (d) cross-table lateral radiograph of the right hip from example patient #2.

complications. Given the high incidence of excessive femoral anteversion in this patient population, the authors recommend the use of a femoral component, whose version can be easily changed and is modular. Additionally, the surgeon should consider the use of a multihole revision-style acetabular component that allows for adjunctive screw fixation in the ilium, ischium, and/or pubis, as indicated. The increased screw options of these implants can provide enhanced stability until long-term osseointegration is obtained. As with all elective arthroplasty procedures, the patient should be medically optimized, and a multidisciplinary approach can be helpful to reduce perioperative medical complications in this patient population.

Surgical exposure

Following induction of anesthesia and prior to patient positioning, the performance of an ipsilateral percutaneous adductor tenotomy in the setting of a significant adduction contracture is recommended to aid in eventual hip reduction. If adductor release is desired later in the case, traction is released, the peroneal post is temporarily removed, and the hip is placed in a flexed and externally rotated position to facilitate tenotomy. At our institution, a Hana table (Mizuho OSI, Union City, CA) with an associated perineal post is utilized. Given the relatively distorted underlying anatomy secondary to the longstanding cranial displacement of the femoral head in the setting of Crowe IV dysplasia, a radiopaque object in conjunction with fluoroscopy may be used to make slight adjustments as needed to the planned incision to ensure proper placement. A DAA to the hip joint with Hueter modification is then performed. Meticulous hemostasis is obtained during dissection. The femoral neck osteotomy is performed with or without fluoroscopic guidance in accordance with preoperative templating.

Femoral preparation

Unless the femur is relatively posterior to the acetabulum, allowing for easy acetabular access without femoral mobilization, the femur is prepared prior to the acetabulum. As previously described, extensile limbs of the DAA are performed extending from the iliac crest proximally to the mid-portion of the femoral diaphysis distally. [4,5] Sequential soft tissue releases are performed for proper proximal femoral mobilization and exposure. Following a liberal capsulectomy (with care to preserve posterior capsule), the tendinous origin of the tensor fascia latae (TFL) may be detached proximally from the iliac crest (and tendon tagged for later trans-osseous repair), if necessary. Alternatively, the TFL origin may be partially released off the crest (approximately 1 cm) with later side-to-side repair. [4,5] However, with appropriate Trendelenburg of the table and femoral extension, TFL release is often avoided. With simultaneous application of manual and lateral traction on the proximal femur, the short external rotators are released. Typically, this release incorporates both the piriformis and conjoint tendon and spares the obturator externus tendon; however, obturator externus release is occasionally necessary for adequate femoral mobilization. If mobilization and exposure of the proximal femur remain inappropriate for femoral preparation or instrumentation, or if difficulty exists with eventual trial reduction, the iliopsoas may be incrementally released (Fig. 2). For these cases, the authors prefer to use a modular femoral component with a metaphyseal ingrowth surface that allows for the correction of version abnormalities often seen in Crowe IV dysplasia. The modular metaphyseal sleeve is prepared according to the manufacturer's instructions, and sequential reaming is then undertaken for appropriate stem sizing. At this step, the surgeon should ream several centimeters beyond the intended endpoint of the stem, as a 2-3 cm bony 'napkin-ring' segment will eventually be removed with the SSO following acetabular preparation.

Acetabular preparation

The acetabulum is exposed in standard fashion, commonly revealing the presence of hypertrophic labrum and pulvinar. Liberal clearance of such soft tissues is key for adequate visualization of acetabular anatomic landmarks. The lateral extents of the anterior wall, posterior wall, and the superolateral acetabulum should be fully visualized prior to the initiation of reaming. In addition, the cotyloid fossa should be cleared to guide the appropriate medialization of the acetabular component. As the characteristic superolateral acetabular deficiency frequently seen in Crowe II and III hips is typically not present in Crowe IV dysplasia, a small hemispherical cementless acetabular component in the anatomic center of rotation (COR) can be utilized rather than intentional overmedialization of the hip joint [24] or placement of a high hip center in a false acetabulum. [25] The authors recommend initially medializing to the base of the cotyloid fossa with a reamer that is several sizes smaller than templated. The anterior wall is often very thin in Crowe IV hips, and if the surgeon begins reaming without posteriorizing the COR, the anterior wall will quickly become deficient. The surgeon can use a small burr to posteriorize the COR of the acetabulum, as the posterior cotyledon is relatively thicker

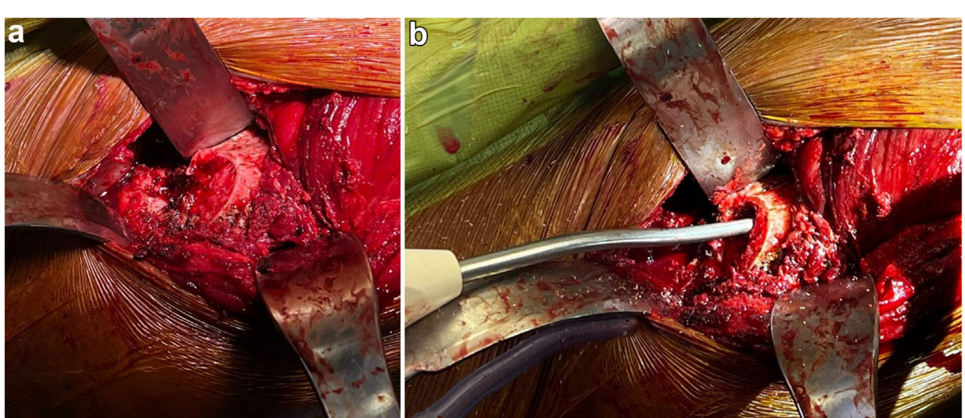

Figure 2. (a) Proximal femoral exposure and (b) cannulation of the intramedullary canal prior to instrumentation. Cranial is at the left of image, caudal is at the right of image, medial is at the top of the image, and lateral is at the bottom of the image.

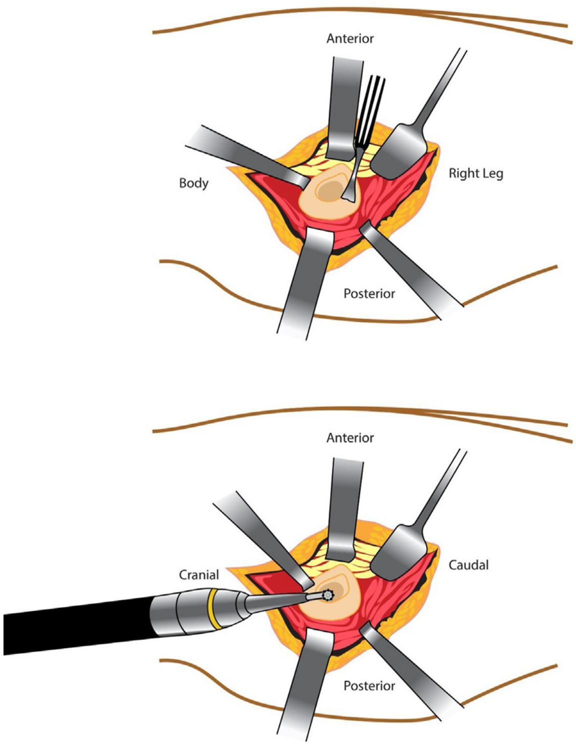

Figure 3. Demonstrates relative deficiency of the anterior wall and decreased density of the anterior cotyledon relative to the posterior cotyledon. In these cases, utilizing a burr to avoid overreaming anteriorly allows for adequate recreation of a hemispherical socket for acetabular component implantation.

than the anterior cotyledon in these cases (Fig. 3). Concurrent fluoroscopy use ensures appropriate medialization has been obtained and that the hip center has been restored to an appropriate position in a cranial-to-caudal direction (Fig. 4). A multihole, revision-style acetabular component is placed. A combination of the transverse acetabular ligament, anterior wall contour, posterior wall contour, cup overhang, and fluoroscopic recreation of the patient's standing AP pelvis are used to obtain and assess appropriate acetabular component anteversion as well as abduction. Care is taken to ensure the final cup is tucked beneath the anterior wall to avoid iliopsoas irritation. Adjunctive screw fixation for additional stability is placed in the ilium, ischium, and/or pubis, as indicated.

Subtrochanteric osteotomy

Distal extension of the DAA approach as described by Nogler and colleagues is performed, safely exposing the femoral metadiaphysis and diaphysis. [4] The vastus lateralis is elevated from posterior to anterior to allow for femoral diaphysis exposure. Dissection should not be carried directly anterior into the subtrochanteric region, or branches of the femoral nerve may be injured. The location of the proximal, transverse limb of the SSO is planned approximately 2 centimeters distal to the lesser trochanter. Prior to this, with the toes of the operative extremity pointed straight up, the authors recommend using a sagittal saw or burr to make a longitudinal cortical abrasion that will ultimately span both transverse limbs of the planned SSO. This mark ultimately provides the surgeon with information regarding the change in version of the distal femoral segment relative to the proximal segment once the intervening bone from the SSO is removed and derotation has occurred. The intervening segment will become a structural autograft, which is applied to the osteotomy site with circumferential fixation (described in the next section). The proximal limb of the SSO is performed, and then the trial femoral stem is placed through the modular metaphyseal sleeve in the proximal femoral segment. As described previously by Krych et al., a 'moderate' amount of longitudinal traction is placed on the limb to determine the magnitude of femoral shortening, which is determined by visualizing the amount of femoral bone needed to be removed to place the femoral component into a cup placed in the true acetabulum. [26] The location of the distal, transverse osteotomy limb is marked and executed at the location of proximal and distal segment bony overlap (Fig. 5).

Reduction and implant insertion

For the scenario of femoral anteversion that is typically present in this patient cohort, the proximal and distal segments are derotated relative to one another (internal rotation of the proximal or external rotation of the distal segment). The trial femoral stem is then reduced into the distal segment, and the hip is reduced. With the toes pointed straight upwards, the combined version is assessed through an evaluation of the relative head ball coverage/uncoverage anteriorly compared to that posteriorly. [27] Careful attention should be paid to the change in femoral version between segments as visualized by the relative positions of the now-independent cortical markings proximal and distal to the osteotomy site (Fig. 6).

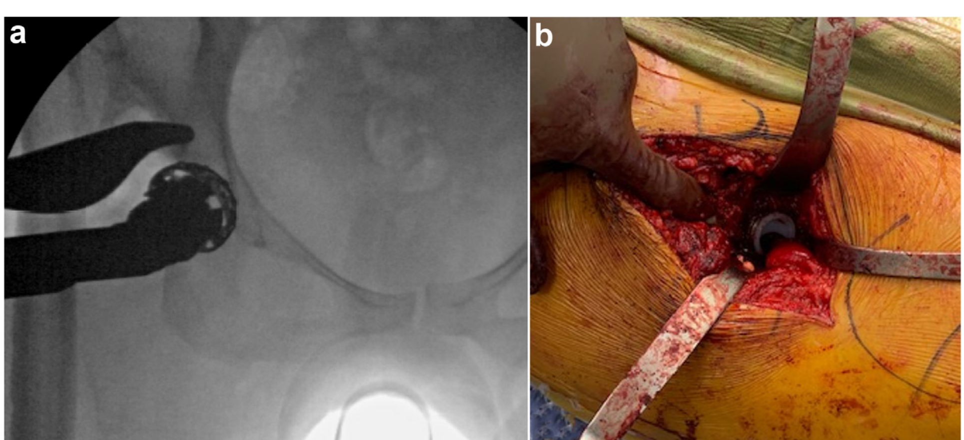

Figure 4. (a) Acetabular reaming under fluoroscopic assistance. (b) Clinical demonstration of acetabular exposure and component placement. Cranial is on the left of image, caudal is on the right of image, medial is on the top of image, and lateral on the bottom of image.

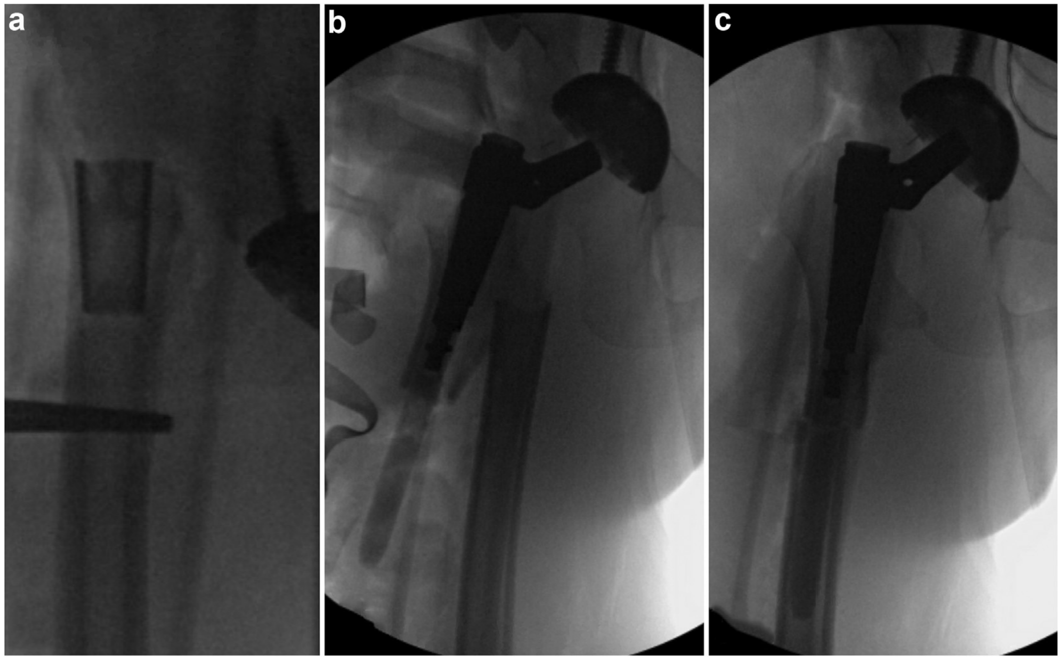

Figure 5. (a) Utilization of fluoroscopy to mark the site of proximal osteotomy limb. (b) Femoroacetabular reduction with trial femoral component in the proximal femoral segment only. (c) Trial reduction following completion of shortening osteotomy and derotation of the proximal femoral fragment.

As additional visualization confirms appropriate derotation, the greater trochanter should now be in a more lateral position. Once satisfied with the combined version and prior to dislocation, an extension of each cortical marking is made to span the SSO site. Now there is an appearance of an 'equal' sign, and this should be recreated during final femoral component implantation to ensure that the appropriate version is maintained (Fig. 7). The hip is dislocated, trial components are removed, and final implants are carefully placed. As previously described by Sanchez-Sotelo and colleagues, the removed osteotomized fragment is kept, and a portion is secured at the osteotomy site with circumferential cerclage cable(s)/wire(s) in a modified napkin-ring/clamshell technique [28].

Postoperative management

Following copious irrigation, a layered anatomical closure is performed. An incisional, negative-pressure wound therapy dressing is applied at the level of the skin. The authors recommend modified weight-bearing, typically in the form of touchdown weight-bearing, for a period of 6 weeks (Fig. 8). Thereafter, if

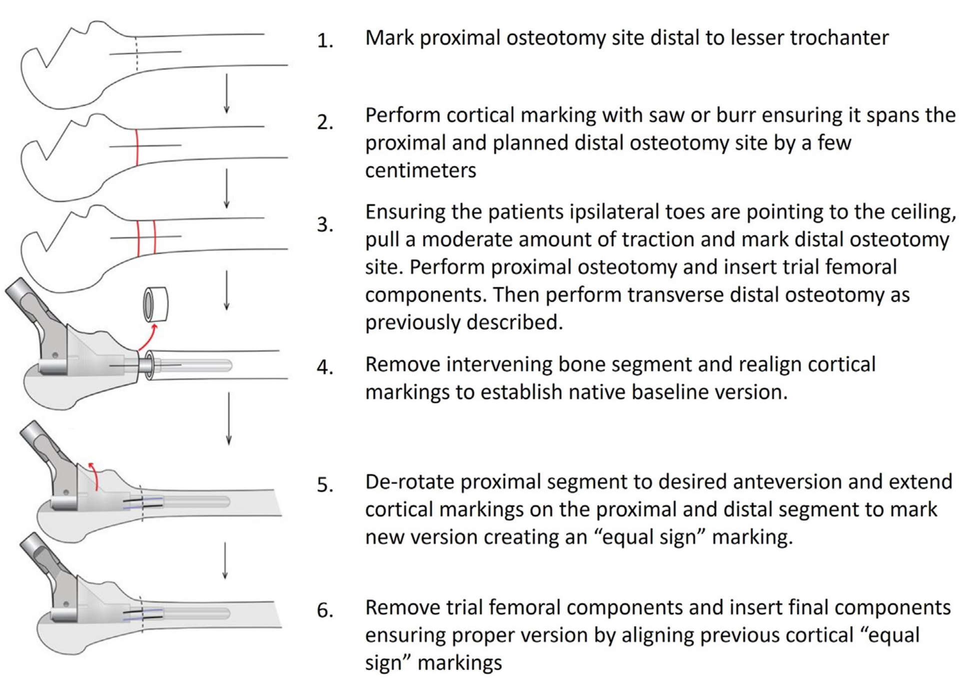

Figure 6. Steps to mark and verify version during femoral trial component positioning.

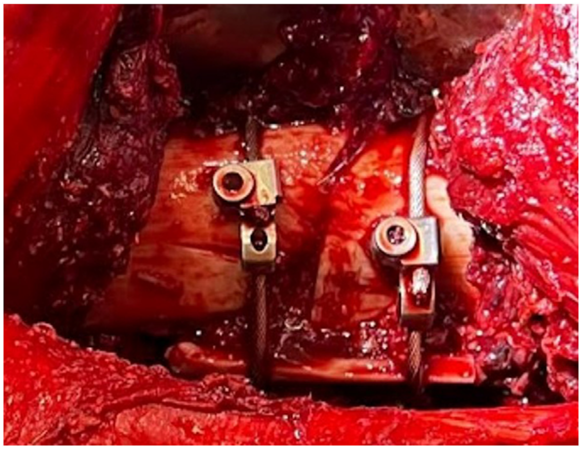

Figure 7. Clinical photograph of the osteotomy site with femoral autograft secured via cables.

follow-up radiographs remain appropriate and union is visualized at the osteotomy site, the patient is then transitioned to a partial progressive weight-bearing protocol over the next 6 weeks (Fig. 9).

Discussion

Several studies have reported on outcomes following THA via a DAA in Crowe IV hip dysplasia. Oinuma and colleagues were among the first to describe the use of the DAA for Crowe IV dysplasia in 2013. [11] Their series examined 12 hips with ipsilateral SSO at a mean follow-up of 3.7 years. The authors concluded that this approach was both safe and reproducible for this patient cohort. Noted benefits included early advancement in rehabilitation due to abductor muscle sparing, a shorter period of modified postoperative weight bearing, and the elimination of postoperative limp seen with other traditional approaches.

Viamont-Guerra et al. further expanded and confirmed these findings. [12] In their cohort of 9 Crowe IV hips with concurrent SSO, satisfactory medium- to long-term clinical and radiographic outcomes were observed in 5 of these 9 cases. Patient-reported outcomes were favorable among Crowe III and IV hips performed via the DAA. Harris hip scores improved from 32 ± 9 preoperatively to 94 ± 7 postoperatively, while the Western Ontario and McMaster Universities Osteoarthritis Index increased from 46 ± 18 preoperatively to 90 ± 7 postoperatively. In this series, 90% of patients were very satisfied, and 10% were satisfied with their surgical outcome. Overall, the reported limb length discrepancy was 2.5 ± 9.0 millimeters. The authors concluded that these results were comparable to similar techniques performed through other surgical approaches in this same patient population. As such, they believe it offers experienced DAA surgeons an additional option to consider for a surgical approach for this complex patient population.

Midterm follow-up with these patients has also been reported. Wang and colleagues reviewed 76 hips that underwent cementless THA via the DAA with an associated SSO. [13] At mean 10-year clinical follow-up, Harris hip scores improved from 38.8 points to 86.1 points, while mean limb length discrepancy was reduced from 4.3 centimeters (cm) preoperatively to 1.0 cm postoperatively. In all, complications included 3 cases of postoperative dislocation, 2 transient nerve palsies, one nonunion, and 4 intraoperative fractures. Two patients necessitated revision procedures for the isolated aseptic loosening of one acetabular component and one femoral stem.

Lan et al. directly compared outcomes following THA between the DAA and PA for Crowe III-IV dysplastic hips with SSO. [14] 20 patients in the DAA group and 22 in the PA group were retrospectively reviewed. No difference was observed between groups across multiple outcome measures: surgical time, intraoperative blood loss, change in creatine kinase levels, or radiographic parameters. The DAA group had a shorter hospital length of stay (6.9 vs 9.1 days) as well as more consistent horizontal differences in the radiographic hip COR. Outcome measures and complication rates between groups were similar at the final 2-year follow-up. The authors concluded that, with proper training and surgeon experience, the DAA approach can be successfully utilized for complex primary THA in this patient cohort.

There are several benefits to utilizing the DAA in conjunction with an ipsilateral SSO such as the ease of patient positioning and use of intraoperative fluoroscopy; the ability to apply sustained, controlled traction for reduction; and the preservation of some posterior-stabilizing soft tissue structures. [29] Despite these proposed benefits, utilization of the DAA for complex reconstruction should only be undertaken by an experienced DAA surgeon. [30]

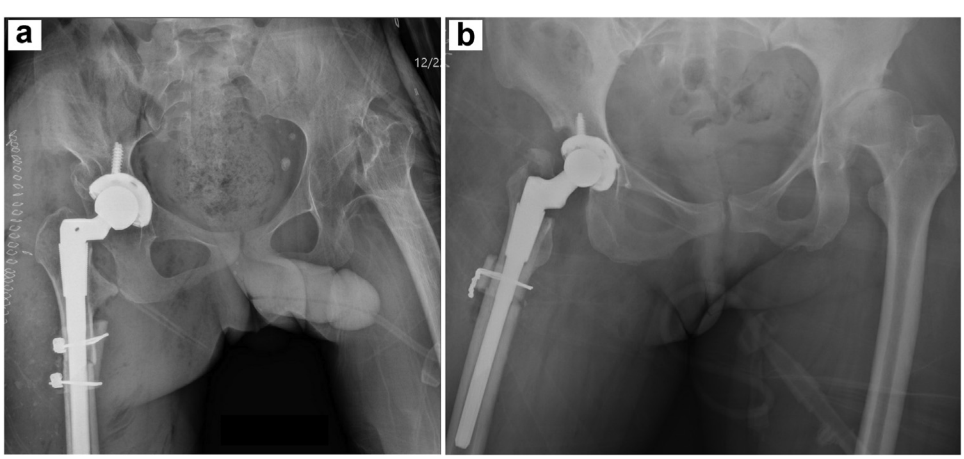

Figure 8. Immediate postoperative anteroposterior pelvis radiograph from (a) example patient #1 and (b) example patient #2.

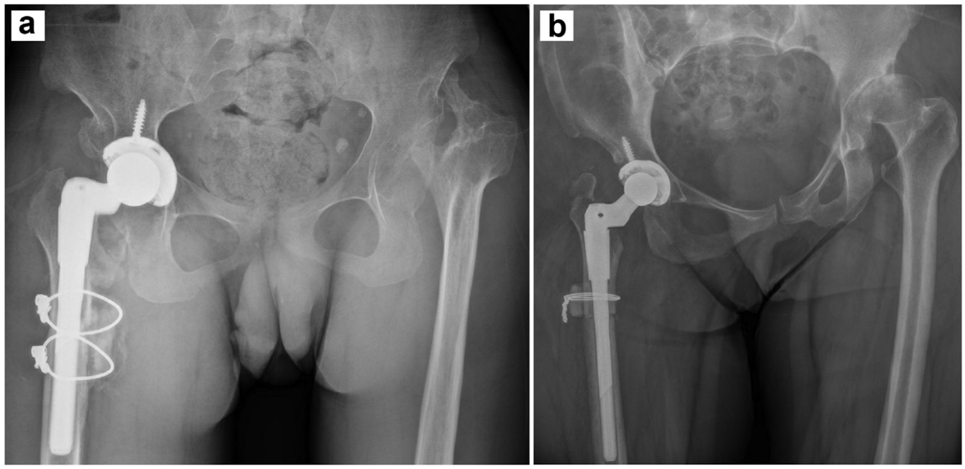

Figure 9. 3-month postoperative anteroposterior pelvis radiograph from (a) example patient #1 and (b) example patient #2.

Similar to the described learning curve to optimize outcomes in primary THA with the DAA, a learning curve also exists for complex primary and revision arthroplasty [31].

Conclusions

In the setting of Crowe IV hip dysplasia, THA with an associated SSO can be successfully performed via an extensile DAA. We hope this described surgical technique serves to both inform future treatment options for this cohort and optimize long-term patient outcomes.

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Conflicts of interest

G. Guild is a paid consultant at Smith & Nephew. B. Hartline receives research support from Smith & Nephew. B. Muffly receives research support from Smith & Nephew. K. Singh is a paid consultant and receives research support from Smith & Nephew. All other authors declare no potential conflicts of interest.

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CRediT authorship contribution statement

Brian T. Muffly: Conceptualization, Data curation, Writing – original draft. **Erik M. Hegeman:** Conceptualization, Project administration, Writing – original draft, Writing – review & editing. **Braden E. Hartline:** Conceptualization, Data curation. **Keerat Singh:** Conceptualization, Data curation, Writing – review & editing. **Ajay Premkumar:** Conceptualization, Writing – review & editing. **George N. Guild:** Conceptualization, Writing – review & editing.

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