© 2020 The Authors. Orthopaedic Surgery published by Chinese Orthopaedic Association and John Wiley & Sons Australia, Ltd.

VIDEO OF ORTHOPAEDIC TECHNIQUE

Subtrochanteric Osteotomy in Direct Anterior Approach Total Hip Arthroplasty

Zai-yang Liu, MD[1†], Zi-qiang Li, MD[2†], Song-tao Wu, MD[3], Jie Li, MD[1], Jun Zhang, MD[1], Xia Zhang, MD[1], Yue Zhou, MD[1], Yuan Zhang, MD[1]

[1]*Department of Orthopaedics, Xinqiao Hospital, Army Medical University and* [3]*Department of Orthopaedics, People's Hospital of Yunyang, Chongqing and* [2]*Department of Orthopaedics, People's Hospital of Linshui, Linshui, China*

Subtrochanteric osteotomy of the femur (STO) is a valuable corrective procedure in hip surgeries. However, STO in traditional posterolateral approach usually encounters complications such as postoperative dislocation, bone non-union, and prosthesis failure. Some relevant pathologies and mechanisms have been identified, but there is sparse evidence for verification. The aim of this video in orthopaedic technique is to test our hypothesis of STO in direct anterior approach to total hip arthroplasty in a complicated hip surgery, and to further illustrate the rationality, reproducibility, and superiority of STO in this minimally invasive and enhanced-recovery approach by presenting a standardized and systemic protocol, as well as operational pearls and pitfalls.

Key words: Bone nonunion; Direct anterior approach; Hip arthroplasty; Minimally invasive; Subtronteric osteotomy

Introduction

Subtrochanteric osteotomy of the femur (STO) is a widely used corrective procedure in hip preservation and arthroplasty surgeries. Beneficial functions and advantages have been well-documented, especially subtrochanteric shortening and de-rotation osteotomy[1, 2]. A transverse subtrochanteric osteotomy facilitates intra-operative adjustment of both the degree of de-rotation and the amount of shortening of the proximal femur. This permits acetabular shell in the anatomical location, and allows proper femoral anteversion to be set to provide adequate hip stability and tension of abduction muscle[3]. Besides, this corrects leg length via diaphyseal shortening, thereby minimizing the risk of sciatic neuropraxia while maximizing proximal femoral bone stock[4]. However, a variety of reports suggest that the implementation of STO is mainly in posterolateral approach and very few STO are finished in other approaches[5].

Although series of studies have shown satisfactory middle- to long-term clinical results of STO by traditional posterolateral approach (PLA) total hip arthroplasty (THA)[6, 7]. Complications related to STO were widely reported, such as increased prevalence of dislocation, bone non-union, femoral stem break, and aseptic loosening, among others[8]. In our philosophy, these complications are closely related to the deficiencies of STO in traditional posterolateral approach. First, implementing a STO usually requires a large incision and extensive exposure, and complete disruption of the short external rotators, which causes great damage to the hip dynamic stabilizers. Second, interruption of the medial femoral circumflex branch of the femoral artery impairs osteointegration on osteotomy ends and the host bone-prothesis interface.

To overcome these deficiencies, we raised our hypothesis that STO under direct anterior approach (DAA) would be superior in preserving the soft tissue and blood supply,

Address for correspondence Yuan Zhang, MD, PhD, Department of Orthopaedics, Xinqiao Hospital, Army Medical University, 183 Xinqiao street, Shapingba District, Chongqing, China 400038 Tel: +86 23 68755618; Fax: +86 23 68755608; Email: joint_chueng@hotmail.com
†These authors contributed equally to this work.
Grant Sources: Clinical research program of Xinqiao Hospital, Army Medical University (2015YLC23); Technological Innovation and Application Demonstration Project of Chongqing (cstc2018jscx-msybX0051); Central Committee Guiding Local Technology Development Project.
Disclosure: All of the authors confirm that there is no conflict of interest. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article.
Received 12 February 2020; accepted 3 June 2020

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

which further decreases postoperative complications after THA. The purpose of this study is: (i) to test the feasibility and reproducibility of our hypothesis; (ii) to demonstrate the theoretical principle, the specific techniques, and standardized procedure of STO in direct anterior approach; and (iii) to exhibit the intraoperative variables and postoperative outcomes as persuasion to this study.

Case Presentation

Patient

A 57-year-old female patient, complaining of chronic progression of left hip pain and limping over 15 years, was admitted into our hospital. Her BMI was 20.4 kg/m^2. Her medical history included a severe car accident in 2004, which resulted in severe cerebral contusion, hemopneumothorax, and "opening-book" injury of the pelvic (Tile classification C). The instant life-salvage surgery was performed, and the patient partially recovered 2 months later. Non-operative treatment of pelvic fracture was adopted thereafter. No abnormality was found in terms of vascular ultrasound and lab tests (cell count, ESR, CRP and D-dimer).

Physical Examination

Physical examination revealed severe limping, leg length discrepancy of 40 mm, and a positive Trendelenburg sign. The hip flexor and abductor muscles' strength scaled level IV and level III respectively. Negative findings in sensor and motor function in the lower limb extremity.

Imaging Study

Anteroposterior (AP) and oblique views of pelvis found apparent osteoarthritis of the hip, asymmetrical pelvis, and malunion in left sacroiliac joint and left acetabulum. The AP and bending views of lumbar vertebra suggested degenerative ankylosis. The diagnosis reached was: (i) traumatic arthritis of the left hip; (ii) malunion of pelvic fracture (type C); (iii) traumatic leg length discrepancy (LLD); and (iv) imbalance of lumbar-pelvis-hip complex (Fig. 1A).

Treatment

Decision Making

The patient asked for alleviation of the hip pain and limping, then we offered a comprehensive therapeutic program, including conservative treating, single left THA in PLA or DAA, two-stage surgery of supracondylar shortening osteotomy in stage 1 and left THA in stage 2, left THA and STO in PLA, left THA and STO in DAA. A final decision of left THA and STO in DAA was made for cost-effectiveness consideration and benefit–risk ratio of the plan (Table 1).

Surgical Procedure

Anesthesia and Position

The patient, under general anesthesia, was placed in a supine position on a standard operating table. The pubic symphysis was positioned directly at the flexion point of the table. Both lower extremities were sterilized and draped into the field to allow for direct comparison of limb lengths intraoperatively as well as for stability testing. The bilateral anterior superior iliac spine (ASIS) should be clearly identified to determine the position of the pelvis during the surgery.

Approach and Exposure

A standard incision, beginning 2 cm lateral to the ASIS and approximately 8–10 cm in length, is made upon the muscle belly of the tensor fasciae latae (TFL). The Hueter interval between the TFL and the rectus femoris was identified as the landmark for correct entry. All the ascending branches of the lateral femoral circumflex artery were coagulated to avoid bleeding. The anterior pericapsular fat and deep capsule were then resected to visualize the femoral neck. A horizontal bone cut at the femoral neck was located at 10 mm superior to the lesser trochanter by using the template design to ensure the proximal stability of the sleeve component.

Acetabular Reconstruction and Component Placement

When the femoral head was removed, a standard procedure composing of inferior capsule release, soft tissue retraction anteriorly and posteriorly, and annular labrum excision was performed to increase the acetabulum access. Because the pathology in the hip osteoarthritis was moderate, the reaming and cup implantation techniques are almost the same as those used in traditional THA. The cup was placed at 40° of inclination and 10° of anteversion, which was confirmed by intraoperative fluoroscopy. Technically, the inclination was estimated with the intersection angle of cup holder projection in coronal plane and the connecting line of bilateral ASIS, while the anteversion was determined with the angle constituted by cup holder projection in sagittal plane and the level of the surgical table.

Femoral Reconstruction and Component Placement

The operation table was adjusted into a "breaking" status to facilitate the femur exposure. The procedure was initiated from releasing the superomedial capsule attachment at the base of the greater trochanter using a reverse "L" manner until the internal side of the great trochanter was visualized. Additional exposure of the proximal femur was achieved with lateralizing and elevating manipulations when the hip is overextended, adducted and externally rotated, which was necessary for implanting a modular femoral stem. Then a standard proximal broaching and distal reaming process was performed according to the instructions of the modular design as in the posterolateral approach. A sleeve (size 16B) and a S-ROM component (size 11) were implanted in this patient. Particularly, the

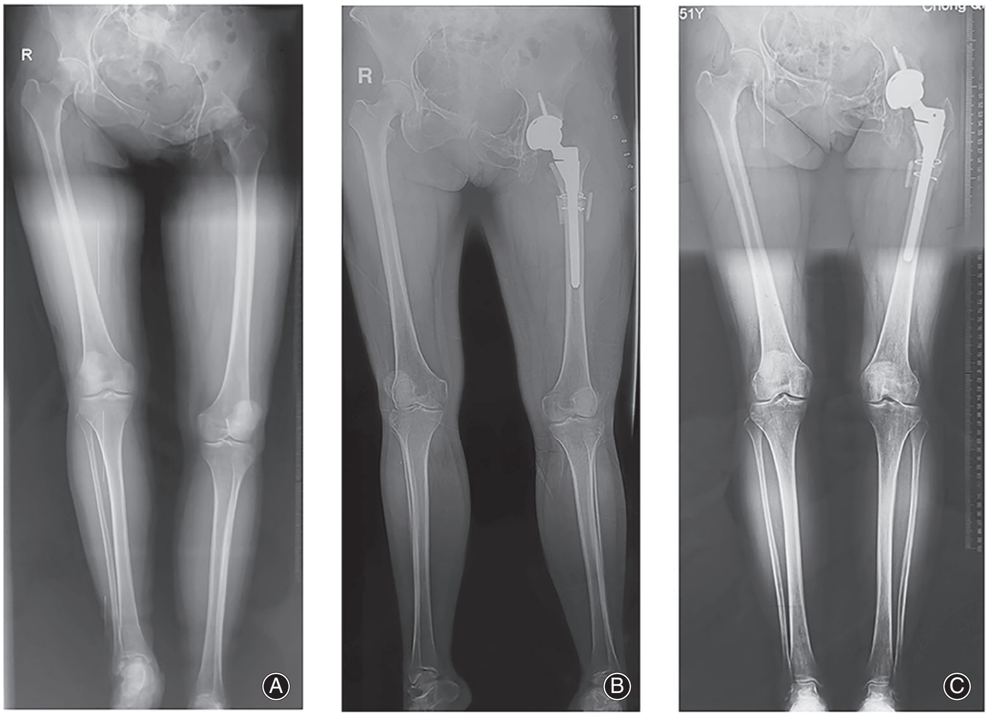

Fig. 1 Temporal change of pelvic tilt and leg length discrepancy after direct anterior approach total hip arthroplasty with STO. Standing full-length anteroposterior radiography of the lower extremity before surgery (A), 1 month after surgery (B), and 6 months after surgery (C).

TABLE 1 Decision-making of the treatment in this case

Plan	Treatment	Advantage	Disadvantage
A	Conservative therapy	Avoiding surgical trauma	Non-effective outcome
B	Single stage surgery: Posterolateral approach total hip arthroplasty (left)	Eliminating the hip pain	Unsolved LLD, Residual limping
C	Two-stage surgery: Stage 1: supracondylar osteotomy; Stage 2: total hip arthroplasty	High successful possibility of surgery and bone healing, low dislocation rate	Cost-effectiveness, Time duration, Surgical trauma
D	Single-stage surgery: Posterolateral approach total hip arthroplasty (left) & subtrochanteric osteotomy	Routine but dogmatic technique, high successful rate of surgery	Surgical trauma, higher rate of dislocation, infection, nonunion at the osteotomy site, and femoral stem failure
E	Single-stage surgery: Direct anterior approach total hip arthroplasty (left) & subtrochanteric osteotomy	Minimally invasive surgery, enhanced recovery, low dislocation rate	Specific learning curve and intraoperative complication: femoral crack or fracture, lateral cutaneous femoral nerve palsy

femoral anteversion was precisely determined by the intersection angle between the axis of proximal femoral component and trans-epicondylar line of the femoral condyle, which was set as 10° in value. And the entry depth of the femoral stem was determined by obtaining adequate locking mechanism in femoral stem with sleeve in the proximal part, and flutes with medullary cavity in the distal part.

Determination and Implementation of STO

The incision was extended 3 cm distally to expose the proximal femur along the interface between TFL and femoral rectus. Splitting of the femoral vastus lateralis was proceeded to directly achieve the anterior cortical bone of the femur. The use of the interval between vastus lateralis and medial vastus would increase the injury possibility of femoral nerve branch dominating the vastus lateralis, while damage to the nerve will cause paralysis of the muscle and dysfunction to the extension mechanism of the knee.

Once the osteotomy site was determined, the proximal and distal bone cut levels were labeled with a marker pen, and cerclages were performed to protect the two osteotomy fragments in case of intraoperative fracture. Technically, a cannulated wire introducer was used to guide weaved wires around the femur in an anticlockwise manner (Fig. 2). The proximal osteotomy level located 1–2 cm below the less trochanter, which ensured the sleeve component of the modular

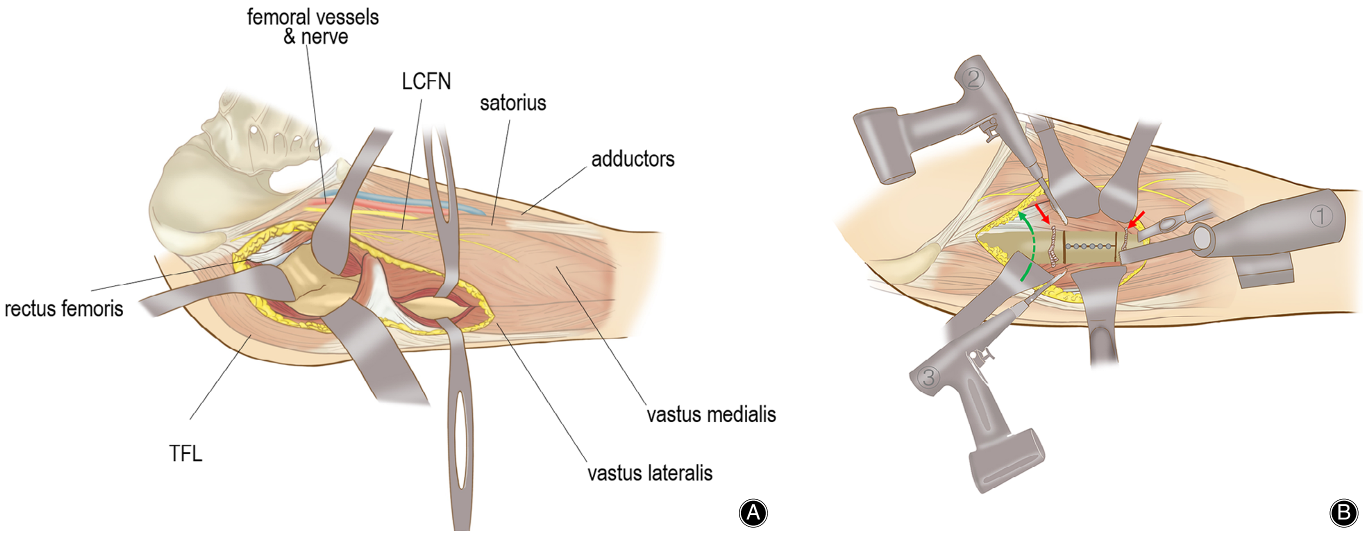

Fig. 2 Design and implementation of STO in DAA THA. (A) Anatomic illustration of STO: the soft tissue structures around STO were indicated. TFL, tensor fasicae latae; LCFN, lateral cutaneous femoral nerve. (B) Surgical technique of STO: the osteotomy ends were protected by cerclage using weaved wires (red arrows). The wires were introduced around the femoral shaft in an anticlockwise manner (green arrow), avoiding iatrogenic damage to the sciatic nerve. The osteotomies at medial and lateral sides were conducted with reciprocal saws, while the anterior side was cut using a suspension saw. The number labeled in the saw represented the order of the STO. The titanium flute of the stem should be carefully protected under close supervision. A sharp osteotome was then employed to open-up the osteotomy fragment by connecting the vertical holes in the middle line of anterior cortical bone.

stem was protected. The osteotomy length of 30 mm was determined by preoperative planning on full-length standing AP radiography and patient-reported correction of LLD by standing block method in our measuring system.

The key technique to finish the STO is the bone cuts at the anterior, lateral, medial and posterior aspects of the femur. Two types of powerful bone saws including suspension saw and reciprocal saw were needed. When the muscles around the femur were carefully protected using different retractors, the anterior cortex of the femur was cut using a suspension saw, the medial and lateral cortical bone were cut using a reciprocal saw, the invisible posterior cortical bone was penetrated using a 2.0 mm drill and a thin osteotome (Fig. 2). The bone cuts were made under direct supervision to avoid damaging the titanium flute of the stem. During bone cut, repeated rinsing of bone gap and saw blade with saline solution using an injection syringe is necessary to prevent bone necrosis caused by high temperature.

A vertical row of holes in the middle line of the anterior cortical bone was made by a 2.0 mm drill, followed by splitting the osteotomy bone fragment with a narrow suspension saw between these holes under extreme caution. When the osteotomy fragments were opened-up, relaxed and removed, part of the fluted stem was visualized and the osteotomy gap was closed by final impaction at the shoulder of the femoral stem. The residual gap should be minimized less than 1 mm to ensure bone healing on time. The final gap was filled with morselized bone derived from acetabular reaming. The cortical strut grafts from STO were not necessary for bone healing. When the STO was completed, a regular procedure of hip reduction, stability evaluation, and wound closure was performed.

Postoperative Management

A standard program of enhanced recovery conducted by multi-disciplinary team, was launched immediately after surgery. Intermittent pneumatic compression and cryotherapy were started when the patient was sent back to the ward. Antibiotics (cefazolin, 500 mg, Lukang, Shandong, China) were given by intravenous injection during the first 24 h. Oral administration of NSAIDs (celecoxib, 60 mg, b.i.d., Pfizer, USA) was taken for 2 weeks for analgesia. Oral administration of inhibitor of clotting factor X (rivaroxaban, 15 mg, q.d., Bayer, Germany) was taken for 35 days to prevent deep venous thrombosis (DVT). The drainage tube was removed when the drainage volume was less than 20 mL/day. No weight-bearing training was recommended for the first week, then toe-touch weight bearing for next 3 weeks, and half weight-bearing with crutches for another 3 weeks.

Methods of Follow-Up

The patient was examined clinically and radiologically at 1, 3, 6, and 12 months after surgery and then at yearly intervals. Fluoroscopy and blood tests including blood cell count, ESR, CRP, D-dimer were examined. Functional recovery was evaluated by patient-reported questionnaires and hip scales, including modified Harris Hip Score (mHHS), Western Ontario, McMaster Universities Osteoarthritis Index (WOMAC) and Short Form 12 health survey (SF-12). In addition, muscle strength of hip flexors and abductors, and correction of the pelvic tilt and LLD, were also investigated by a rehabilitation physician in the clinic.

Results

Operative Variables

A high-porous and cementless acetabular shell (Gription Pinnacle, size 52 mm, Depuy, Indiana, USA), was used to achieve high initial stability, two acetabular screws were needed for extra fixation. A modular femoral design of S-rom (Depuy, Indiana, USA) was used to correct the proximal femoral deformity. A triangle sleeve (size 16B) and a corresponding modular stem (size 11) were used to achieve proximal-distal dual-fixation. The width of the osteotomy gap was less than 1 mm (Fig. 1B). The operative duration was 116 min from incision to closure. The estimated intraoperative blood loss was 550 mL. Three hundred milliliters of erythrocyte concentrate and 200 mL of fresh plasma were transfused before closing the wound. The total volume of drainage was 180 mL, and drainage tube was removed at the second day after surgery.

Clinical Outcome

The follow-up programs were finished at 1, 3, 6, and 12 months after the surgery. From the sixth month postoperatively, significant changes in terms of the HHS (50 points of increment), WOMAC (48 points of decrement), and SF-12 score (four points of increment) were found according to the patient-reported questionnaires. These improvements reached their peak at the last follow-up of 12 months (Table 2). The hip abductor and flexor strength reached scale IV at the third month and scale V at the sixth month after surgery. The gross leg length discrepancy was found to be neglectable since the sixth month postoperatively. No complication was found throughout the follow-up period, including dislocation, infection, wound issue, hematoma, fracture, nerve palsy, DVT, and moderate to severe limp.

TABLE 2 Patient-reported hip outcome

Hip scales	Preoperative score	Postoperative score (12 months)
mHHS	34	84
WOMAC total	66	18
WOMAC pain	12	2
WOMAC stiffness	5	1
WOMAC function	49	15
SF-12 total	27	31
SF-12 physical	10	14
SF-12 mental	17	17

Radiographic Analysis

Sufficient press-fit of the component to host bone was observed by pelvic anteroposterior X-ray at the second day after surgery. The functional inclination angle of the acetabular shell was 47° and the anteversion was 11°, which was in the Lewinnek safe zone. The deviation of hip rotation center was +5 mm. Alignment angle of the femoral sleeve and stem was 180° as referenced to the anatomic axis of the femoral shaft (Fig. 1B). Sequential pelvic radiographs revealed satisfied bone growth onto the surfaces of acetabular shell and femoral sleeve, which can be classified as bone ingrown according to the method by Engh *et al.*[10] None of radiolucent line, migration, subsidence and loss of initial position were found. The pelvic tilt was gradually corrected after surgery, and the anatomic leg length discrepancy was 5 mm according to the radiographic measurement at 12 months postoperatively (Fig. 1B and C). New bone formation at osteotomy gap was observed at the third month, while the gap disappeared at the sixth month after surgery, which suggested bone healing of STO (Fig. 3). The residual cortical strut autografts, neither the lateral or the medial, were healed with the osteotomy fragments at the last follow-up.

Discussion

Because of the minimally invasive pathway and enhanced recovery of DAA, the majority of soft tissue sleeve and medial femoral circumflex branches of femoral artery could be preserved during surgery, this further ensures the accelerated recovery of the hip function and osteointegration between bone and prosthesis. Thereby, STO in this approach may constitute a superior adjunctive technique for complicated THA, such as high dislocated DDH and infection sequela.

However, the choice for STO should be carefully made. In our practice, the STO is indicated only for necessary functional equalization of the lower limb, or the prevention of sciatic nerve injury when the limb is overlengthened (typically more than 5 cm). Besides, the length of STO should be precisely determined. Many surgeons like to determine the length by observing the overlap distance between the femoral head center and acetabular center[9], this is usually correct for most scenarios. However, we prefer to conduct a patient-specific osteotomy by determining the length according to comprehensive preoperative measuring and planning.

A study by Oinuma firstly reported the early outcomes of nine patients diagnosed with Crowe type IV DDH by DAA, combined with STO in Japan from 2006 to 2015[11]. Despite their impressive technique, the limitation of his study is the lack of technical description and undesirable intraoperative variables and clinical outcomes compared to those of the posterolateral approach, which might attribute to their aggressive manipulation in exposing the proximal femur, and extensive damage of the short external muscles.

Our advancement in STO in DAA, as compared to Oinuma, is an evolutionary surgical technique and exposing procedure, which includes individualized preoperative

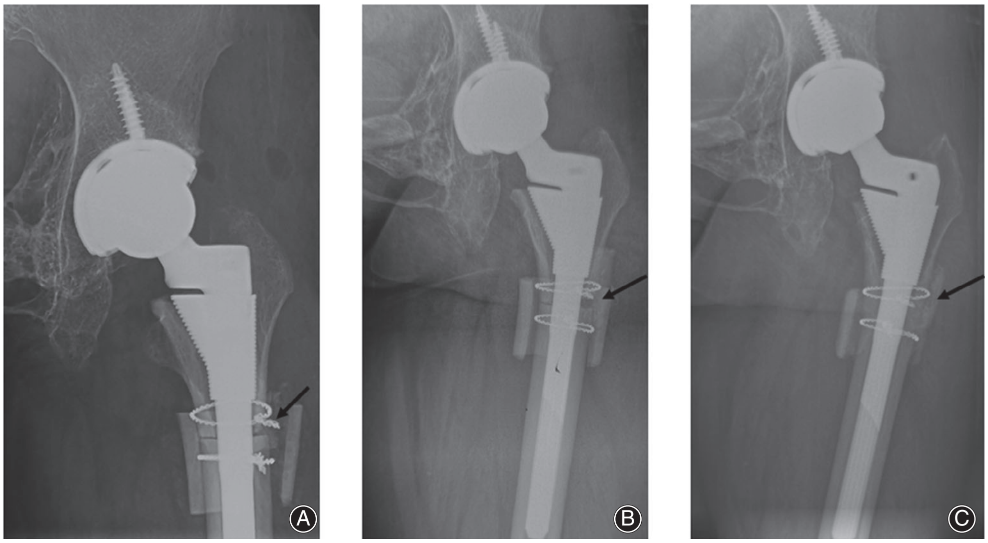

Fig. 3 The radiographic changes of osteotomy gap after direct anterior approach total hip arthroplasty with STO. Anteroposterior radiography of left hip at 1st day (A), the 1st month (B) and 6th month (C) after surgery. The gap was indicated by black arrow.

planning (such as algorithm of limb length equalization), specific soft tissue release techniques (such as peeling-off of tensor fasciae latae, pie-crusting of the iliotibial band, sleeve-like whole capsulectomy), as well as an innovative subtrochanteric shortening, de-rotation or oblique osteotomy via direct anterior approach.

As we exhibited in this case, the improvements in mHHS, WOMAC, and SF-12 scales, the fast recovery of hip flexor and abductor strength, the optimized position of the prosthesis, the desirable correction of pelvic tilt and lower leg length discrepancy, and the minimized intra- and post-operative complication suggest satisfied clinical outcome from our therapeutic plan of one-stage THA and STO in direct anterior approach. Our technique could maximally maintain the integrity of dynamic stabilizer around hip (especially the short external rotators), significantly reduce the surgical trauma, and further promote the postoperative recovery. Additionally, advanced technology and equipment, such as intraoperative CT, computer navigation, and nerve monitoring, have been introduced for some specific cases to guarantee the intraoperative accuracy and safety. As to our best knowledge, this is the first report in describing the principle, planning, and implementation of STO in direct anterior approach to total hip arthroplasty. We believe this work will be notably imperative to overcome the current difficulties in treating complicated hip surgeries by STO in DAA.

The limitation of this technique is the increased intraoperative risks such as fracture and nerve palsy derived from the learning-curve of direct anterior approach. However, this could be properly addressed by topic learning and cadaveric training.

Conclusion

Despite the learning curve, subtrochanteric osteotomy can be a valuable option to correct femoral deformity in a direct anterior approach to total hip arthroplasty. Comparative even superior clinical outcomes could be anticipated by this modified surgical technique.

Acknowledgment

This study was supported by Innovative Technology in Military and Clinical Medicine (2018JSLC0035), Clinical Research Program of Xinqiao Hospital, Army Medical University (2015YLC23), Technological Innovation and Application Demonstration Project of Chongqing (cstc2018jscx-msyb0541), Continuing Medical Education Program of Chongqing (2020-04-07-067), and Central Committee Guiding Local Technology Development Project (0028).

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Video S1 Subtrochanteric Osteotomy in Direct Anterior Approach Total Hip Arthroplasty.

Reference

1. Downing H, Morris R. A subtrochanteric osteotomy. JAMA, 1936, 12: 860.
2. Shi XT, Li CF, Han Y, Song Y, Li SX, Liu JG. Total hip arthroplasty for Crowe type IV hip dysplasia: surgical techniques and postoperative complications. Orthop Surg, 2019, 11: 966–973.
3. Yasgur DJ, Stuchin SA, Adler EM, DiCesare PE. Subtrochanteric femoral shortening osteotomy in total hip arthroplasty for high-riding developmental dislocation of the hip. J Arthroplasty, 1997, 12: 880–888.
4. Hua WB, Yang SH, Xu WH, *et al*. Total hip arthroplasty with subtrochanteric femoral shortening osteotomy for high hip dislocation. Orthop Surg, 2015, 7: 112–118.
5. Kamath AF, Ganz R, Zhang H, Grappiolo G, Leunig M. Subtrochanteric osteotomy for femoral mal-torsion through a surgical dislocation approach. J Hip Preserv Surg, 2015, 2: 65–79.
6. Takao M, Ohzono K, Nishii T, Miki H, Nakamura N, Sugano N. Cementless modular total hip arthroplasty with subtrochanteric shortening osteotomy for

hips with developmental dysplasia. J Bone Joint Surg Am, 2011, 93: 548–555.
7. Wang D, Li LL, Wang HY, Pei FX, Zhou ZK. Long-term results of cementless total hip arthroplasty with subtrochanteric shortening osteotomy in Crowe type IV developmental dysplasia. J Arthroplasty, 2017, 32: 1211–1219.
8. Yang S, Cui Q. Total hip arthroplasty in developmental dysplasia of the hip: review of anatomy, techniques and outcomes. World J Orthop, 2012, 3: 42–48.
9. Krych AJ, Howard JL, Trousdale RT, Cabanela ME, Berry DJ. Total hip arthroplasty with shortening subtrochanteric osteotomy in Crowe type-IV developmental dysplasia: surgical technique. J Bone Joint Surg Am, 2010, 92: 176–187.
10. Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. J Bone Joint Surg Br, 1987, 69: 45–55.
11. Oinuma K, Tamaki T, Miura Y, Kaneyama R, Shiratsuchi H. Total hip arthroplasty with subtrochanteric shortening osteotomy for Crowe grade 4 dysplasia using the direct anterior approach. J Arthroplasty, 2014, 29: 626–629.