Mid-term results of total hip arthroplasty with modified trochanteric osteotomy in Crowe type IV developmental dysplasia of the hip

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Abstract

Introduction: The objective of this study was to explore mid-term clinical results of cementless total hip arthroplasty (THA) with modified trochanteric osteotomy in Crowe type IV developmental dysplasia of the hip (DDH).

Patients and method: Thirteen patients (13 hips) with Crowe type IV DDH who underwent THA used modified trochanteric osteotomy between May 2013 and October 2019 were retrospectively analyzed. Mean follow-up was 5.2 ± 0.8 years (range, 4.9-6.1 years).

Results: Mean Harris Hip Score (HHS) significantly ($p < 0.05$) improved from 30.7 ± 5.8 (range, 22-38) to 87.5 ± 3.6 (range, 83-93). The mean leg length discrepancy (LLD) was 53.4 ± 9.1 mm (range, 42.1-68.5 mm) preoperatively. The final LLD was 5.6 ± 2.4 mm (range, 2.4-9.1 mm). The mean leg length after surgery was 47.4 ± 10 mm (range, 33.6-67.2 mm). The average duration of bone union for greater trochanter (GT) was 2.5 ± 0.6 months (range, 1.5-3.6 months). There was no infection, GT non-union, or loosening (septic or aseptic) of the stem or cup in any case.

Conclusions: THA with modified trochanteric osteotomy with cementless cup is an effective treatment for Crowe type IV developmental dysplasia of the hip. It can rebuild complex biomechanics and biology of hip dysplasia without increasing complications.

Tables

Table 1. Demographic Details and Preoperative Status of Patients.

Age	50 ± 9.4 (range,31-68)
BMI	22.6 ± 2.3 (range, 19.14-25.92)
Follow up duration (y)	5.2 ± 0.8 (range, 4.9-6.1)
Male	3
Female	10

BMI Body mass index

Table 2. Details of Perioperative Parameters.

Operation time (min)	111.5 ± 20.9 (range, 85-165)
Hemoglobin change after operation (mg/dl)	2.6 ± 0.8 (range, 1.3-3.9)
Intraoperative blood loss (mL)	738.5 ± 160.9 (range, 500-1000)
Total drainage (mL)	499.2 ± 112.9 (range, 340-700)
Transfusion (No. of units)	3.3 ± 0.8 (range, 2-5)

Table 3. Details of Components and Fixation of Greater Trochanter.

	No. of cases
Acetabular component	
Delta PF (Lima-Lto, udine, Italy)	13
Ceramic on ceramic bearing (Biolox, Osteo AG, Selzach, Switzerland)	13
Head size 28 mm	10
Head size 32 mm	3
Bulk bone autografts	7
Femoral component	
Wagner Conical stem (Zimmer, Winterthur, Switzerland)	13
Size 13	2
Size 14	3
Size 15	2
Size 16	3
Size 17	3
Average of stem size	15.2 (range, 13 to 17)
Greater trochanter fixation	13
Grip plate (Dall-Miles)	

Table 4. Details of clinical and radiological results.

Preoperative HHS	30.7 ± 5.8 (range, 22-38)
Postoperative HHS	87.5 ± 3.6 (range, 83-93)
Preoperative LLD (mm)	53.4 ± 9.1 (range, 42.1-68.5)
Postoperative LLD (mm)	5.6 ± 2.4 (range, 2.4-9.1)
Leg lengthening (mm)	47.4 ± 10 (range, 33.6-67.2)
Lateral open angle	37 ± 5 (range, 29-46)
Cup anteversion	17 ± 1 (range, 16-20)
Cup coverage (%)	83.8 ± 24.3 (range, 85-100)
Duration of osteotomy site union (m)	2.5 ± 0.6 (range, 1.5-3.6)

LLD leg length discrepancy, *HHS* Harris hip score

Table 5. Over view of Relevant Literature in the Treatment of Crowe IV Dysplasia Combined with Subtrochanteric Femoral Shortening Osteotomy.

	Patient (Hips)	DDH type	Osteotomy type	Follow up duration (y)	Pre LLD (mm)	Post LLD (mm)	Leg lengthening (mm)	Nerve injury	Osteotomy site union (m)	Non-union	Revision	Dislocation	Intraoperative fracture
V. Emre Ozden et al. [4]	35 patients 45 hips	Crowe IV	Step-cut	10 (range, 7-14)	33±25 (range, 0-75)	10±6 (range, 0-25)	37±14 (range, 21-47)	1	3.8 ± 0.7 (range 3-6)	3	4 stem 1 acetabular component	2 closed reduction 2 performed surgery	5
Kiliçoğlu Oİ et al. [5]	16 patients 20 hips	Crowe IV	Modified oblique femoral shortening	6.8 (range, 3.7-10.3)	45 ±10 (range, 30-65)	10 (range, 0-30)	35±17 (range, 0-58)	0	4 (range, 3-6)	1	1 stem 1 acetabular component	2 closed reduction 1 performed surgery	3
Xigong LI et al. [6]	18patients 22 hips	Crowe IV	Double chevron	6.5 (range, 5-10)	45 (range, 30-62	15 (range, 0-24)	38 (range, 25-60)	0	3 to 6 months	0	0	0	0
Junfeng Zhu et al. [7]	20 patients 21 hips	Crowe IV	Transverse	3.3 (range, 2-5)	47±11(range, 20-70)	12±4 (range, 0-20)	38±9 (range, 30-55)	2	5 (range, 3-9)	1	1 stem	1 closed reduction	0

J. A. F. Charity et al. [8]	15 patients 18 hips	Crowe IV	Shortening derotational	9.5 (range, 4.3-14)	No details	No details	30 (range, 10-40)	1	No details	1	3 acetabular component	0	0
Yalcin N et al. [23]	31 patients 44 hips	Crowe IV	Transverse	5.3 (range, 2-8	34 (range, 20-60)	22 (range, 10-32)	>20, 6 patients <20, 25 patients	27 (range, 19-45) 0	4 (range, 2.5-14)	5	1 acetabular component	2 closed reduction	0
Wang et al. [26]	49 patients 56 hips	Crowe Type-III or IV	Transverse	10 (range, 4.8-14.3)	42 (range, 21-65)	11 (range, 6-14)	27 (range, 19-45)	3	6 (range, 4-9)	1	1 acetabular component	2 closed reduction 1 performed surgery	4
Giuseppe Rollo et al. [28]	15 patients 17 hips	Crowe IV	Transversal and Z-shaped	7.3 (range, 5.3-11.1)	45 (range, 38-90)	12 (range, 9-16)	39 (range, 30-50)	2	2.9 (range, 2.3-3.5)	0	0	0	1
Ollivier et al. [29]	24 patients 28 hips	Crowe IV	Transverse and step-cut	10 (range, 0.8-14.5)	43 (range, 26-60	6 (range, 0-20)	40 (range, 20-80)	0	10 (range, 2-28)	0	3 stem 1 acetabular component	2 closed reduction 1 performed surgery	5

David J Yasgur et al. [30]	8 patients 9 hips	Crowe IV	Transverse	3.6 (range, 2-7)	50 (range, 30-70	15 (range, 5-30)	35 (range, 30-55)	0	5 (range, 3-9)	1	1 stem	1 closed reduction	0
Wang et al. [31]	62 patients 76 hips	Crowe IV	Transverse	10 (range, 6.6-13.2)	43 (range, 21-65)	10 (range, 6-17)	22 (range, 12-38)	2	6 (range, 4-8)	1	1 stem 1 acetabular component	3 closed reduction	4
Baz et al. [34]	15 patients 21 hips	Crowe IV	Transverse	4.9 (range, 3-8).	58.19 (47–72)	No details	31.95 (21–45)	1 permanent	No details	No details	3 stem 1 acetabular component	2 performed surgery	5
Present Series	13 patients 13 hips	Crowe IV	Modified trochanteric	5.2 (range, 4.9-6.1)	53.4 ± 9.1 (range, 42.1-68.5)	5.6 ± 2.4 (range, 2.4-9.1)	47.4 ± 10 (range, 33.6-67.2)	0	2.5 ±0.6 (range, 1.5-3.6)	0	1 stem	1 closed reduction	0

DDH developmental dysplasia of the hip, *LLD* leg length discrepancy

Introduction

Developmental dysplasia hip (DDH) is the most common cause of secondary osteoarthritis of the hip. If patients are not treated adequately, they will have severe leg length discrepancy (LLD) and other many problems when they become adults. In DDH patients, the acetabulum is deficient anteriorly and superiorly. Hypoplastic acetabulum usually makes it difficult to obtain enough bony coverage of the cup.

In cases with a high false acetabulum, the cup is generally recommended to be placed in the true acetabular region to improve long-term survival of the implant [1, 2].

Difficulties for reconstruction of the femur include hypoplasia of the femur, excessive femoral anteversion, valgus neck-shaft angle, metaphyseal-diaphyseal mismatch, and posteriorly displaced greater trochanter [3]. Combining trochanteric osteotomy with proximal femur shortening can solve many of these problems. Many techniques such as step-cut osteotomy, modified oblique femoral shortening osteotomy, double chevron osteotomy, transverse osteotomy, and shortening derotational subtrochanteric osteotomy have been reported[4–8] .

In 1990, Paavilainen et al. [9] performed femoral shortening osteotomy to treat 52 severely dysplastic and 48 totally dislocated DDH patients. Our osteotomy method used in the present study was based on the method of Paavilainen et al. [9] with some modifications. It was first used by Park et al. [10] in 2012 to treat 18 patients with severely dysplastic septic hip sequelae (SSH), but never used in DDH Crowe type IV patients before.

In the present study, we used the same method to treat DDH Crowe type IV sequelae patients. We evaluated the outcome of LLD and bony deficiency for acetabular cup coverage, osteotomy site union, and surgical technique with bulk bone autografts to define the effectiveness and safety of this procedure in DDH patients.

Patients And Method

Between April 2013 and October 2019, 13 patients (13 hips) were treated with THA in combination with modified trochanteric osteotomy. All operations were performed by one surgeon (Yoon TR). There were three men and ten women. The average age of patients at the time of surgery was 50 ± 9.4 years (range, 31-68 years). Five patients received the procedure on the right side and eight patients had the procedure on the left side. No patients were lost to follow-up, with a mean follow-up period of 5.2 ± 0.8 years (range, 4.9-6.1 years) (Table 1). All subjects had Crowe group IV DDH according to the classification of Crowe et al. This study was cleared through the ethics committee of our hospital. Informed consent was obtained from each patient. No patient underwent any hip surgery before the procedure.

Metal cup (Lima-Lto, Udine, Italy) with ceramic on ceramic (Biolox, Osteo AG, Selzach, Switzerland) bearing (COC) was used for all prosthetic acetabulum. Wagner Conical stem (Zimmer, Winterthur, Switzerland) was used in all cases. Cable and screw (13 hips) with a grip plate system (13 hips) (Dall Miles®, Stryker Orthopedics Inc., Mahwah, NJ, USA) were used for fixation of the greater trochanter to prevent intraoperative proximal femoral site fracture.

All patients underwent the surgery in lateral decubitus position with a posterolateral approach. A provisional osteotomy was usually performed at the inferior half of the lesser trochanter. After adequate exposure, the true acetabulum was widened and deepened by the reamer. To avoid excessive reaming or acetabular wall fracture, the reaming was performed mainly in superior and posterior directions where the bone stock was usually thick enough. After preparing the true acetabulum, the final metal cup (Lima-L to, Udine, Italy) with ceramic on ceramic (Biolox, Osteo AG, Selzach, Switzerland) bearing was inserted. If the cup coverage was still not satisfied, bulk bone autografts with resected femoral head were utilized to provide adequate coverage of the acetabular cup.

In all hips, Wagner cone prosthesis (Zimmer, Winterthur, Switzerland) was used. If the proximal part of the femur considered to be weak after femoral reaming, prophylactic cerclage wiring was used to avoid proximal fragment fracture during the reaming of the medullary canal or insertion of the stem into the femur. The stem size was chosen during preoperative planning and intraoperatively considering soft tissue tension. Stems were inserted at 15 degrees of anteversion. After the final reduction, the greater trochanter was reattached to the proximal femur using +/- cortical screw, cables, and grip plate with the hip abducted position (Fig. 1).

Antibiotic prophylaxis was done before surgery and at one or two days after surgery. Exercise for range of motion was encouraged after two to three days of bed rest; non-weight bearing, postoperative the patient followed crutch ambulation. Complete weight-bearing was permitted only after obtaining radiographic confirmation of bone union. Active exercises were then strongly encouraged to stretch and strengthen abductor muscles.

Preoperative data (such as hemoglobin level), blood loss, transfusion requirement, surgical time, post-operative complication, and radiological and clinical outcomes were assessed. Total blood loss was defined as intra-operative blood loss plus the volume of blood that was collected in the drain before removal. The drain was removed after 24 hours with drainage of less than 100 ml. Hemoglobin level was measured the day before surgery. Total number of transfusions including PRCs (packed red blood cells), fresh frozen plasma, and platelet concentrates used intra- and postoperatively was recorded. Surgical time was described from the time of incision to complete the wound completely. Details are summarized in Table 2

Medical history affecting the operation (as heart disease and deep vein thrombosis), physical examination (as Trendelenburg sign, limping gait), and radiographic evaluations (lumbosacral spine, lower limb, and pelvis) were obtained or performed for all patients preoperatively. True acetabulum parameters were obtained by 3D-CT. Templated measurements from anteroposterior and oblique hip radiographs were performed preoperatively to determine the location of the true acetabulum, the level of the femoral neck osteotomy, stem size, and cup size.

After the surgery, patients were followed up monthly until union at the osteotomy site and at 6 months, 1 year, and annually thereafter. At the postoperative visit, patients were evaluated with Harris Hip Score (HHS). Radiological evaluations were also performed. HHS was rated as excellent when it was greater than 90 points. It was considered as good when it was between 80 and 89 points. Excellent and good scores were considered to represent successful outcomes. When HHS was between 70 and 79 points, it was classified as fair. HHS of less than 70 was regarded as poor. Radiological evaluations were performed for reviewing acetabular component anteversion, acetabular lateral opening angle, radiological leg length measurement, the stability of the femoral stem and acetabular component, and the time of the osteotomy site union.

Leg length discrepancy was measured preoperatively and postoperatively with the method described by Sabharwal et al. [11]. To measure acetabular cup anteversion, we used the method described by Sah and Estok [12]. Stem subsidence was measured with the method of Callaghan et al. [13]. To measure acetabular and stem location of the extent of radiolucency, we used the method of De Lee and Charnley [14] and Gruen et al. [15]. To evaluate stem and cup loosening, we used methods of Harris et al. [16] and Hodgkinson et al. [17]. Leg lengthening was measured with the method described by Park et al. [10].

All statistical analyses were performed using the SPSS software package version 19.0 (SPSS Inc. Chicago, IL, USA). Two-sided, paired Student's t-test was used to analyze preoperative and postoperative continuous variables. Statistical significance was considered when p value was less than 0.05.

Results

Mean duration of surgery was 111.5 ± 20.9 minutes (range, 85-165 minutes). Postoperative hemoglobin levels, intraoperative blood loss, total drainage, and transfusion requirements are shown in Table 2. For seven patients, bulk bone autograft technique was used to have adequate coverage of the acetabular cup. The average stem size was 15.2 (range, 13 to 17). In all cases, a grip plate was used for greater trochanter fixation. Results are summarized in Table 3.

In our study, at the last follow-up, the mean HHS was 87.5 ± 3.6 (range, 83-93), which was significantly ($p < 0.05$) higher than the mean pre-operative score of 30.7 ± 5.8 (range, 22-38). Results were excellent in 5 (38.0%) hips and good in 8 (62.0%) hips.

Preoperatively, all patients had a limp. However, no patient used a cane due to limping at the last follow-up. No cases showed intra-operative fracture at the femur or acetabulum site. Intra-operatively, there was no gastrointestinal or cardiopulmonary complication. There was no postoperative nerve palsy in any patient.

The mean acetabular component angle of anteversion was 17 ± 1 degrees (range, 16-20 degrees). Bony coverage over the socket was 83.8 ± 24.3 % (range, 85-100%). Seven patients, bulk bone graft technique was used to increase cup coverage. The mean leg length discrepancy (LLD) was 53.4 ± 9.1 mm (range, 42.1-68.5 mm) preoperatively. It was 47.4 ± 10 mm (range, 33.6-67.2 mm) after surgery, showing a reduction of 5.6 ± 2.4 mm (range, 2.4-9.1 mm) postoperatively.

We reattached the proximal femur with (3 hips) (Fig. 2) or without (10 hips) (Fig. 3) cortical screw, cable, and grip plate for all patients. The mean time to greater trochanter union was 2.5 ± 0.6 months (range, 1.5-3.6 months) on average. There was no non-union of the osteotomy site in any patient. Details are shown in Table 4.

In the evaluation of stem subsidence, no patient showed subsidence more than 1 mm until the last follow up. During postoperative follow-up, the radiolucent line between the stem and the femur was less than 1 mm in all cases, one patient had stem revision due to the patient slipped down postoperatively and had a periprosthetic fracture at the femur site. The region of osteolysis was limited in Zones 1 and 7. There was no aseptic or septic loosening in the acetabular component. Postoperatively, no patient had surgery-associated infection. One patient had postoperative dislocation, and the patient treated with closed reduction.

Discussion

Many surgeons have described that THA in DDH patient presents many surgical challenges owing to deficient bone stock of the acetabulum. The most troublesome issue is acetabular reconstruction. This was divided in two criterions and both of them could direct impact on cup survivorship. One is to re-establish the normal center of hip rotation because non-anatomical placement of a component is an important predictor of acetabular loosening [18, 19] . In our series, all acetabular reconstructed in a true acetabulum and controlled fracture of the medial wall was performed to place the prosthetic acetabular component within available iliac bone.   Another one is cup coverage. It is challenge for surgeons obtain enough cup coverage in DDH Crowe type IV patients. A common option for reconstructing the acetabular roof in cases with DDH is to use a bulk structural autograft with a cemented or cementless acetabular component [20]. Spangehl et al. [21] have reported a survival rate of 91% at 10 years using a cementless acetabular component in DDH patients with bulk bone graft. Kim and Kadowaki. [22] have performed cementless THA in 70 (83 dysplastic hips) acetabular defects reconstructed by bulk bone graft and found that cup coverage is increased 44%. In our study with combined bulk bone graft technique, we obtained 83.8% (range, 85-100) of cup coverage. There were no patients occurred cup aseptic loosening postoperatively, the survivorship of cup was satisfactory.

A common complication in femoral shortening osteotomy was osteotomy site non-union. Previous studies have reported non-union rates ranging from 2.8% to 11.4% at the osteotomy site in DDH Crowe IV hips [4, 7, 23]. Hak et al. [24] considered that osteotomy site non-union rate was related to the rigidity of osteotomy site fixation. Step-cut, oblique or chevron shaped osteotomies [4-6] , though these osteotomies have inherent stability due to their three-dimensional geometry and they increase the surface for bone healing. However, these osteotomies are technically complex and need surgical experience and prompt preoperative planning, especially when correcting femoral anteversion. On the contrary, transverse osteotomy was easier to perform but it is insufficient of rotational stability at the osteotomy site [25]. Moreover, Wang et al. [26] considered the nonunion rate was related to damage of the periosteum circumferentially. Keep the osteoblastic activity of periosteum could increase bone union rate. In our series the osteotomy site was just at the inferior half of the lesser trochanter and it was more closed to the proximal femur. All procedures were performed around proximal femur. This may lead less damage of the periosteum circumferentially during operation. After final reduction we used grip plate and cables with +/- cortical screw fixed at the osteotomy site. In our study, duration of osteotomy site union was 2.5 months (range, 1.5-3.6 months). There was no patient showed osteotomy site non-union. We believed our technique could provide better bone union at osteotomy sites. Moreover, it could lead to early weight-bearing for patients.

The incidence of sciatic nerve injury reaches up to 5.2% in THA performed for developmental dysplasia of the hip (DDH) [27]. There is no report on the maximum safe amount of LL for preventing significant sciatic nerve injury. Most of previous studies have reported that the range of leg lengthening is 3-4 cm [4-8, 23, 26, 28-30]. They considered leg lengthening more than 4 cm was suggested to be an indication for femoral shortening osteotomy to prevent nerve palsy. Rollo et al. [28] have combined two kinds of osteotomy in 15 patients with 17 hips, the mean leg lengthening was 27 mm (range, 19-45 mm). There were two cases of nerve palsy. Wang et al. [31] have performed transverse osteotomy to treat 62 patients with 76 hips and the mean leg lengthening was 39 mm (range, 30-55 mm). Postoperatively, there were three cases of nerve injury associated with the osteotomy. In our study, if the leg lengthening was not satisfactory, we only needed to adjust the degree of great trochanter overlapping no needed another osteotomy at the osteotomy site for leg lengthening, it was performed by surrounding soft tissue tension. The leg lengthening in our study was 47.7 ± 8.6 mm (34.5-67.3 mm). No patient showed sciatic nerve palsy symptom postoperatively.

In this study, we consider dislocation as an important complication, which may compromise the press-fit between femoral component and femoral fragment and result in disengagement and early loosening of stem [7]. The dislocation rate was reported to be 0.92%–2.93% [32, 33]. However, it is noteworthy that the postoperative dislocation rate in Crowe type IV hips was reported to be as high as 9.5%– 15.0% in some follow-up studies, with the sample size ranging from only 9 to 28 hips[5, 29, 30, 34]. Total dislocation rates were 7.6% in our series that compared favorably with dislocation rates in these studies.

This study has some limitations. First, the number of patients was small, and the follow-up duration was short. Second, this study was based on two-dimensional plain radiographs. In some patients, the lower extremities rotated slightly when radiographs were taken, although could be measured accurately. Third, no control group was enrolled.

Conclusion

In conclusion, we believe that our method is easier and provides earlier bone union at osteotomy sites but achieves similar leg length. Thus, total hip arthroplasty with modified trochanteric osteotomy in Crowe type IV Developmental Dysplasia of the hip is a safe and more effective treatment procedure.

Abbreviations

THA: Total hip arthroplasty; DDH: developmental dysplasia of the hip; COC: ceramic on ceramic; HHS: Harris Hip Score; LLD: Limb-length discrepancy

Declarations

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

JYJ Analysis of data and writing manuscript. TRY Make concepts and design of study. SYJ Data collection and analysis. QSL Data collection and analysis. YJL Analysis of data and writing manuscript. KSP Make concepts and design of study. Review and correction of draft manuscript. All authors have read and approved the manuscript and agreed it for submission to publish in this journal.

Ethics approval and consent to participate

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Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Fig 1. a A provisional osteotomy was performed at the inferior half of the lesser trochanter. Fig 1. b The greater trochanter was re-attached to the proximal femur with cables and screw. Fig 1. C The greater trochanter was re-attached to the proximal femur with cables and grip plate system.

Figure 2

Fig 2. A Preoperative radiograph of a 36-year-old woman, Crowe type IV dysplastic hip left side. Fig 2. B Postoperative 3 months, bone union was detected in osteotomy site, no occurred stem subsidence. Fig 2. C Postoperative 1 year. Fig 2. D Postoperative 4 years.

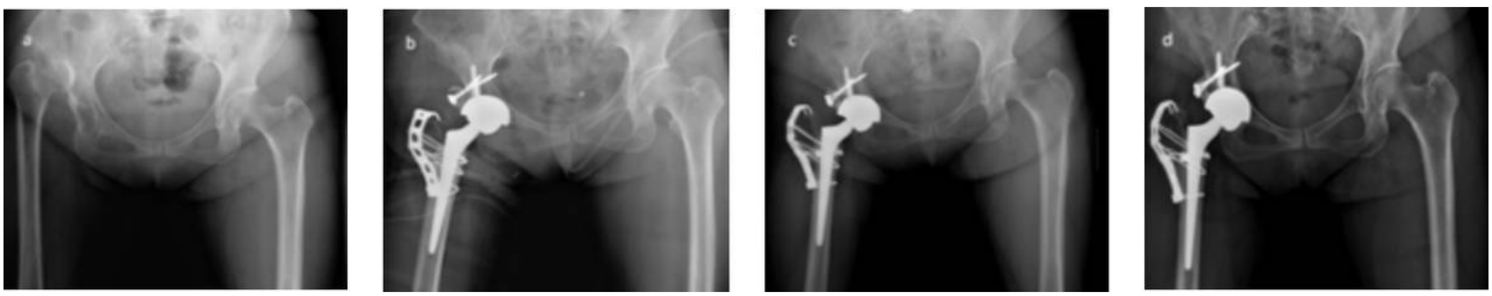

Figure 3

Fig 3. A Preoperative radiograph of a 36-year-old woman was Crowe type IV dysplastic hip right side. Fig 3. B Postoperative 3 months, bone union was detected in osteotomy site, no occurred stem subsidence. Fig 3. C Postoperative 1 year. Fig 3. d Postoperative 4 years.