

CROWE IV hip dysplasia treated by THA combined with transverse sub-trochanter osteotomy to balance functional leg length discrepancy: a prospective observational study

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Research article

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Abstract

Background There are various malformations in the pelvises and femurs of hip dysplasia patients, consequently leg length discrepancy (LLD) can often become one of the most common post-surgical complications in CROWE IV hip dysplasia patients. To our knowledge, there are few researched focus on relationship between acetabular prosthesis position and postoperative LLD while optimal leg length balance strategy for CROWE IV hip dysplasia patients remains unclear. In this paper, we measured the factors that affect functional leg length of CROWE IV DDH patients and reviewed our own methods to balance LLD of CROWE IV DDH patients.

Methods During June 2017 to June 2018, 14 consecutive CROWE IV patients (17 hips) and 18 consecutive CROWE I patients (20 hips) were included in this study. Prior to surgery, subluxation height of the femoral head on the affected side, functional LLD, bony length of lower limbs, and distance from teardrops to the lowest point line of the sacroiliac joint were recorded. All patients received THA, and several of them also received subtrochanter osteotomy. After surgery, cup sizes, functional LLD, and hip rotational centers were measured.

Results Functional LLD of the CROWE IV patients group was significantly improved from 4.00 (3.00-5.00) to 0 (0-0.08), $P=0.003$. Only three of 14 CROWE IV patients remained under 1 cm functional LLD.

Conclusion After elaborate pre-operative planning and leg length balancing during operation, THA combined with transverse sub-trochanter osteotomy is an effective method to achieve equal function in leg length.

Declarations

Ethics approval and consent to participate: All procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional Review Board (IRB) of First Hospital of Jilin University (2017-411) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Consent for publication: Not applicable.

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Authors' contributions:

Study conception and design: Jianguo Liu and Xiaotong Shi . Data collection: Xiaotong Shi, Chengming Cheng, Chunyang Feng and Jianguo Liu. Data analysis: Shuxuan Li, Chengming Cheng and Chaofeng Li. Result interpretation: Xiaotong Shi, Chengming Cheng and Shuxuan Li. Reporting & editing: Xiaotong Shi, Jianguo Liu . Final approval of the version to be submitted: all authors. All authors read and approved the final manuscript.

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Background

Hip dysplasia is a common reason for which patients undergo total hip arthroplasty (THA). There are various malformations in the pelvises and femurs of hip dysplasia patients, such as shallow acetabulars, small femoral medullarys, enlarged combined anteversions, and others. These malformational changes are particularly severe in CROWE \square hip dysplasia patients^[1,2]. THA is an effective method to treat CROWE \square hip dysplasia and has demonstrated excellent clinical results^[3,4]. However, leg length discrepancy can often become one of the most common post-surgical complications in CROWE \square hip dysplasia patients. Recently, we found that hip dysplasia patients who underwent THA placed growing attention on LLD post surgery and LLD, and these have become some of the primary sources of patient dissatisfaction with surgery. There is also research indicating that post surgery LLD affected hip function and psychological status of hip dysplasia patients^[5,6].

In past years, original acetabular position, pelvic tilt, and bony leg length have all been shown to affect LLD of CROWE \square hip dysplasia patients^[7-9]. However, few studies have taken all these factors into account, and little research has examined the position of acetabular cup after surgery relative to its original anatomical position. In this study, taking all these factors into consideration, we studied whether patients could achieve equal functional leg length and whether the relative position of the acetabular cup affected leg length with CROWE \square hip dysplasia patients.

Materials And Methods

Two groups of patients were included in this study; 14 consecutive CROWE type I hip dysplasia patients (17 hips) who underwent THA during July 2017 to June 2018 were defined as group A; whereas group B consisted of 18 consecutive CROWE type II hip dysplasia patients (20 hips) who underwent THA during the same time period. Exclusion criteria included a history of pelvic trauma, previous pelvic surgery, history of hip infection or tumor, absence of any necessary patient data, any patients who had unilateral or bilateral other CROWE types forms hip dysplasias, lumbar spine stiffness (lumbar spine lateral curve $<15^\circ$) or severe spinal deformity. Patients in group A were all women, and there was only a single male patient in group B.

Leg length balance strategy

Surgery for all patients aimed to reconstruct the rotation center at its anatomical position. During preoperative planning, leg length balance was considered as follows: after anatomical acetabular reconstruction, LLD caused by femoral head dislocation is diminished, bony LLD and inferior anatomical acetabular positions should be considered, subtrochanter osteotomy should be determined during THA process according to the degree of hip reduction difficulty or leg length discrepancy, and finally, leg length comparison should be completed, and any necessary further adjustment of leg length should be executed during the hip reduction process. For the first side of bilateral patients, osteotomy is determined only according to degree of hip reduction difficulty, and leg length comparison is unnecessary. For the second side of bilateral patients, we applied the same procedure as the first side, and leg length comparison during THA was necessary.

All patients in group B received no osteotomy, and some patients in group A received sub-trochanter osteotomy to help balance leg length or help hip reduction. Because true acetabula in group A patients were consistently shallow and small, and we consequently reamed them at a posterior and superior direction in order to enlarge the acetabular and gain enough cup bony coverage while reserving as much anterior acetabular bone as possible^[10]. On the femoral side, a cementless modular femoral component (Depuy S-ROM) was employed, and combined anteversion was set under 55° to prevent post surgery dislocation^[11]. Specific soft tissue release can vary widely and relate to the hip capsule, iliotibial tract, part of gluteus, the adductor, iliopsoas muscle, sartorius muscle, and rectus femoris^[12].

For patients who underwent subtrochanter osteotomy, after the first cut at the proximal femur, we physically pulled the affected limb until it was the same length as the other, then the overlapped part was removed. After hip reduction, leg lengths were compared while two legs were in an extended position and the operative leg was on top of the non-operative one. If the heels of two legs were at same position, leg lengths were considered to be equal. If the leg lengths were not equal, adjustment of femoral head size and additional osteotomy were used as final leg length adjusting measures.

Reduction was completed while the hip flexed at 60° with an adduction of 20° and the knee flexed with an internal rotation of 90° , as described by Yan F^[13]. During the reduction process, our attending surgeon

palpated soft tissue around the sciatic nerve to ensure its tension was acceptable according to his experience. Equal leg length should not be considered when the safety of sciatic nerve is in question.

Clinical evaluation

All patients underwent an initial clinical evaluation on the first day after hospitalization and last clinical evaluation during their final follow up. Clinical evaluation included Harris Hip Score (HHS) and SF-12 scale (American version) ^[14].

Measurement of radiology

Prior to surgery femoral head dislocation height was measured on the pelvic APs for all patients. For unilateral patients, femoral head subluxation height was calculated by subtracting the vertical distance from apex of lesser trochanter to the teardrop line on the healthy side from the affected side; for bilateral patients, this measurement was considered to be the distance between the head-neck junction to the teardrop line for each side. Because we never operated on the greater trochanter during the THA process, affected leg lengthening length was considered to be the distance that the greater trochanter migrated inferiorly from the pre-operation to post-operation positions ^[7]. After surgery, we measured the distance from the hip rotational center to the teardrop line for all affected hips ^[15]. **(Fig 1)** For unilateral patients, leg length was measured for both sides, including femur length, tibial length and bony leg length **(Fig 2)** ^[8]. For all unilateral patients, we also measured the distance from the teardrops to the lines that connected most inferior points of sacroiliac joints for healthy and affected sides, respectively. All measurements were taken with Traumacad 2.0 software (Orthocrat LTD. Ltd.2007).

Statistical analysis

SPSS19.0 software was used for statistical description and analysis of data. Measurement data were consistent with normal distributions described by mean \pm and standard deviation (\pm s). Paired sample t tests were used for intra-group comparison, and independent sample t tests were used for inter-group comparison. Measurement data with non-normal distributions were described by P50 (p25-p75), and comparison between groups was conducted by the mann-whitney test. $P < 0.05$ was considered statistically significant.

Results

32 patients (14 CROWE \boxtimes and 18 CROWE \boxtimes) were included in this study. Basic information for the two groups is shown in *table 1*.

After surgery, HHS, SF-12 physical and mental score, and functional LLD were all significantly improved for both groups, and these results are shown in *table 2*.

The parameters of the two groups pre and post surgery are shown in *table 1*. Before surgery, functional LLD ($P < 0.01$) and femoral head subluxation height ($P < 0.01$) were significantly larger for group A compared to group B. After surgery, SF-12 mental score was significantly smaller ($P = 0.038$); functional LLD was significantly larger ($P < 0.001$); used cup size was significantly smaller ($P < 0.001$); hip center height was significantly lower ($P < 0.001$); and leg lengthening length was significantly longer ($P < 0.001$) for group A compared to group B. For patients in group A, only seven legs received femoral osteotomy, and the mean osteotomy value was 1.16cm overall. No osteotomy site nonunion occurred (*Fig 3*).

For the same patients in group A, the tibial lengths ($P = 0.009$) and lower limb lengths (0.037) of affected sides were significantly longer than those of healthy sides. The distance from the teardrop to the line connected to the most inferior points of the affected sacroiliac joint was also significantly larger than that of healthy side ($P = 0.019$). Bony length and teardrop position measurements are shown in *table 3*. Five patients in group A developed lower limb numbness immediately following surgery, and they all recovered within six months. No symptoms of motor nerve impairment occurred. No other complications occurred during THA and follow up period.

Discussion

CROWE \square DDH patients always displayed severe anatomical deformities on acetabular and femoral sides, including both bone and soft tissue deformities. Today, it is a generally held consensus that the hip rotational center should be reconstructed at its anatomical position for CROWE \square DDH patients. However, highly dislocated femoral head and severe periarticular soft tissue contracture render hip reduction a difficult process. Due to this, several osteotomy methods were recommended to aid in the hip reduction process [16–20]. With certain osteotomy techniques, hip reduction of CROWE \square DDH hips could be considered more trivial. However, with excessive osteotomy, achieving equal leg length post surgery for CROWE \square DDH remains difficult. Several non-osteotomy THA techniques were introduced, such as setting femoral osteotomy lines as low as possible, using powerful muscle relaxation medications [13], or using a Hohman retractor to help reduction [21]. Compared to THA combined with osteotomy, non-osteotomy techniques are widely considered to not sacrifice leg length. However, some research found that, except for highly dislocated femoral head, bony leg length discrepancy [9] and malformation of the pelvis [8] also affect post surgery leg length of CROWE \square DDH patients. In this study, for patients in group A, the tibial and full leg length of the affected side was significantly longer than that of healthy side. Furthermore, the distance from the teardrop to the line connected to most inferior points of the sacroiliac joint of the affected side is also significantly larger than that of healthy side. Compared to a healthy hip, after anatomical hip rotational center reconstruction, a more inferior anatomical acetabular position combined with a longer leg in bony length could easily lead to an obvious longer functional leg length of the operated side after THA. In this condition, osteotomy should be considered, not only to aid in hip reduction, but also to help balance functional leg length.

For CROWE \times DDH patients, there could be many LLD definitions, such as bony LLD, functional LLD and anatomical LLD^[7]. Therefore, choosing optimal LLD to balance is a careful process. Y Li et al^[7] described a lower limb balance strategy for CROWE \times DDH patients in detail. According to unilateral side or bilateral side DDH, they divided patients into type \times (unilateral) or type \times (bilateral), and patients are further subdivided into 3 subtypes according to pelvic oblique and fixed spinal curvature. If there were no bony LLD, this was noted for patients without pelvic oblique to balance functional LLD, for patients with compensatory pelvic oblique, they noted to balance anatomical LLD is optimal. In that previous research, there was an overall significant bony LLD of 3.5mm, however, they concluded that it had little clinical significance, besides they did not take pelvic malformation into consideration. At the onset of this study, we excluded patients with lumbar spine stiffness (lumbar spine lateral curve $<15^\circ$) or severe spinal deformity. After taking bony LLD and pelvic malformation into consideration, we reason that functional LLD is the most appropriate LLD to balance, and we agree that with bilateral CROWE \times DDH patients, the same femoral procedure is important. There are several reasons for choosing functional LLD to balance in our study. First, after functional LLD balance, patients could have a high degree of satisfaction of leg length after surgery at once, because functional LLD is the length they wanted to lengthen with the affected leg. Second, after taking bony LLD and pelvic malformation into consideration, and completed balance of functional LLD, the line connected to most inferior points of the sacroiliac joint would be horizontal, which generally lead to most appropriate positions of lumbar vertebra. And if there are no bony LLD and pelvic malformations or these factors have a little influence, the functional LLD is almost equal to femoral head dislocated height, and this opinion is verified by Y Li^[7]. Third, with bony LLD and pelvic malformation, choosing femoral head dislocation height or bony LLD to balance is not only inaccurate and could lead to functional LLD post surgery, it would also take a longer time for patients to adapt.

However, in this study, not all of the patients could gain equal leg length at the final time of leg length comparison after reduction due to excessive tension of soft tissue. At the last follow up, functional LLDs for the 3 patients were 0.3cm, 0.5cm, and 1.0cm. For the patients with 0.3cm and 0.5cm functional LLD, no other treatment measures were needed; for the patient with a 1.0cm functional LLD, shoe lift was recommended to improve limb function.

Other than femoral head dislocation height, soft tissue contracture, bony LLD and pelvic malformation, the hip rotational center can also affect leg length. In cases with small and shallow acetabular, it is difficult to predict cup size and position of CROWE \times DDH patients during preoperative planning process^[22]. After surgery, we measured vertical distance from cup center to teardrop line for every hip in two groups, and found that the height of hip rotational center of group A was significantly smaller than that of group B. This result indicates that a more inferior hip rotational center could lead to a longer functional leg length. In our opinion, a more inferior hip rotational center is related to a severely small and shallow acetabular of CROWE \times DDH patients, and due to insufficient bone stock of anterior acetabular column, the acetabular cannot be fully reamed in order to reserve the bone of the anterior acetabular column as much as possible.

Although some research notes that osteotomies should be chosen when leg lengthening is more than 3.0–4.0mm^[25], we opted to choose osteotomy according to operational conditions. The primary reason for choosing osteotomies is to protect against excessive stretching of the sciatic nerve. Although we agree that excessive stretching can be a primary factor in sciatic complications, the threshold of excessive stretching for high sciatic nerve complications remains unknown. On the other hand, in some studies lacking osteotomy, no permanent sciatic complication occurred^[13,21]. In this study, only 7 of 17 CROWE DDH received subtrochanter osteotomy, and the overall mean osteotomy value was 1.16 (range 0–3.7cm).

There are several limitations to the scope of this study. First, the sample size is relatively small (17 hips for group A and 20 hips for group B). However, CROWE DDH patients combined with other CROWE type DDH hips were excluded, and the overall time we recruited patients was one full year. Second, we did not test intraobserver and the interobserver agreement during radiological measurements. However, these measurement methods are nonetheless in line with previous studies, and they have been verified as having strong reproducibility. Third, we did not gain full leg length radiographs post surgery, therefore we could not study any effect of stem position to leg length further.

In a sense, after elaborate preoperative planning and leg length comparison during the operation process repeatedly, combined with femoral shortening osteotomy if necessary, THA could balance functional LLD of CROWE DDH patients.

Conclusion

After elaborate pre-operative planning and leg length balancing during operation, THA combined with transverse sub-trochanter osteotomy is an effective method to achieve equal function in leg length.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (include name of committee + reference number) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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Tables

Table 1. Basic information of the two groups.

Parameters	Group A	Group B	P
Age(y)	44.29±11.55	55.89±14.03	0.018
Height(cm)	162.71±5.32	161.72±3.80	0.340
Weight(kg)	64.36±7.30	62.89±8.25	0.953
BMI	24.30±2.45	24.10±3.48	0.985
Follow-up period(y)	14.00(12.75-18.25)	14.00(12.75-14.25)	0.585
Surgery time(m)	149.53±51.46	103.40±25.71	0.010
Osteotomy amount(cm)	0(0-3.0)	0(0-0)	0.002

Table 2. Comparison of parameters between pre and post surgery.

Parameters	Pre-surgery	Post-surgery	P
Group A			
Harris score	57.53±11.59	89.82±3.03	<0.01
SF-12 physical	22.42±15.58	36.81±15.17	0.039
SF-12 mental	20.68±13.48	37.96±12.89	0.007
Functional LLD(cm)	4.00(3.00-5.00)	0(0-0.08)	0.003
Group B			
Harris score	60.42±12.66	90.40±3.30	<0.001
SF-12 physical	21.85±10.24	40.00±10.03	<0.001
SF-12 mental	15.38±7.22	46.15±4.37	<0.001
Functional LLD(cm)	0.90(0.13-1.75)	0(0-0)	0.003

Table 3. Comparison of parameters between the two groups

Parameters	Group A	Group B	P
Pre-surgery			
Harris score	57.53±11.59	60.42±12.66	0.477
SF-12 physical	22.42±15.58	15.38±7.22	0.099
SF-12 mental	20.68±13.48	21.85±10.24	0.783
Functional LLD(cm)	4.00(3.00-5.00)	0.90(0.13-1.75)	<0.001
Dislocated height(cm)	4.50(2.75-6.05)	0.88(0.53-1.10)	<0.001
Post-surgery			
Harris score	89.82±3.03	90.40±3.30	0.586
SF-12 Physical	36.81±15.17	40.00±10.03	0.480
SF-12 Mental	37.96±12.89	46.15±4.37	0.038
Functional LLD(cm)	0(0-0.08)	0(0-0)	<0.01
CUP size(mm)	44.82±3.32	50.90±2.71	<0.01
Hip center height(mm)	14.20±5.02	20.92±4.66	<0.01
Leg lengthening(cm)	2.70(2.50-4.10)	0.6(0.40-0.80)	<0.01

Table 4. Measurement of bony length and teardrop position of the two groups

Parameters	Affected side	Healthy side	P
Group A			
Femur length(cm)	39.51±2.52	39.33±2.85	0.485
Tibia length(cm)	33.92±2.09	33.37±1.91	0.009
Leg length(cm)	74.56±4.00	73.71±4.31	0.037
Teardrop position(mm)	80.46±10.24	76.71±9.18	0.019
Group B			
Femur length(cm)	41.89±2.14	41.31±2.23	0.214
Tibia length(cm)	34.43±1.95	33.96±1.92	0.185
Leg length (cm)	77.24±3.81	76.62±3.76	0.145
Teardrop length(mm)	71.48±7.28	70.41±7.39	0.289

Figures

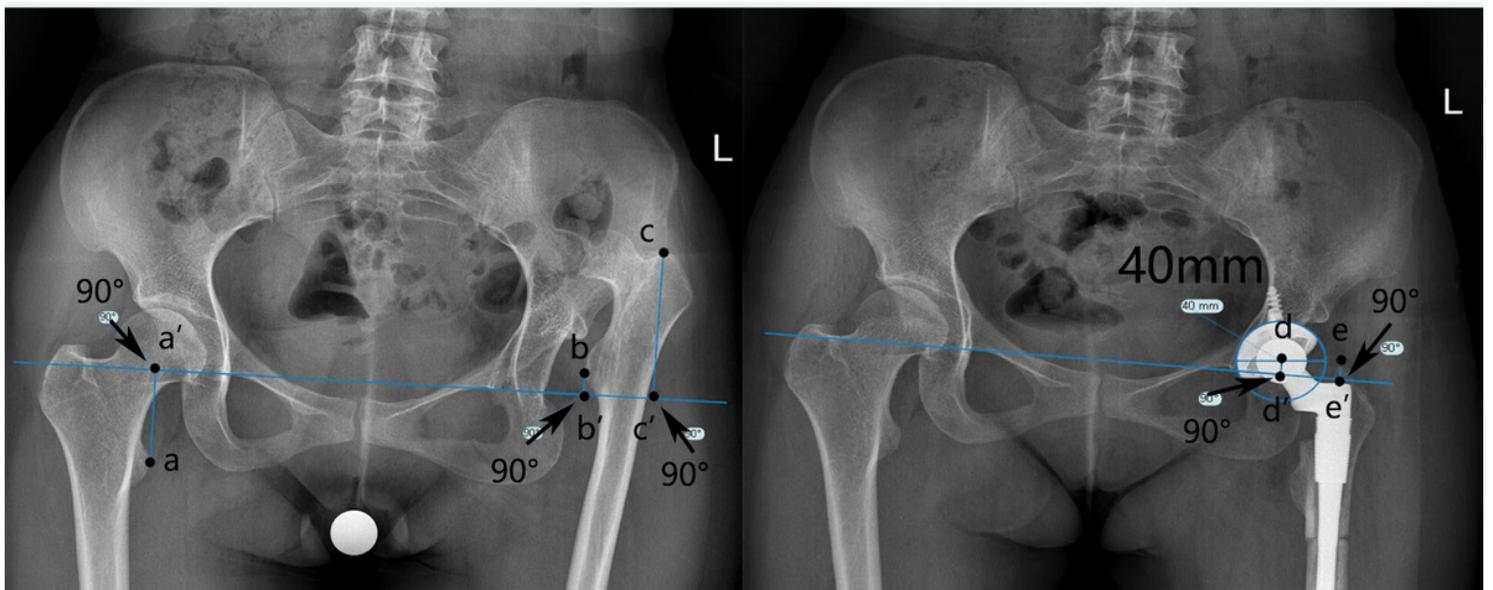


Figure 1

Anteroposterior pelvic radiograph of one CROWE ⌘ patient before and after surgery. The transverse lines are teardrop lines. Before surgery, femoral head dislocated height = $aa'+bb'$. After surgery, leg length lengthening = $ee'-cc'$. Used cup size was 40mm, hip rotational center height = dd' .

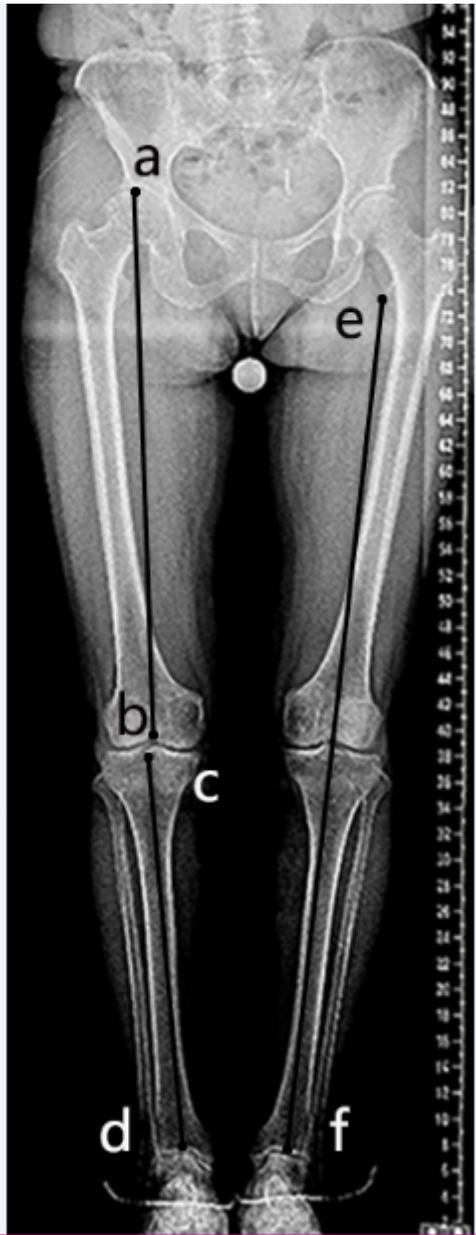


Figure 2

Full leg length radiograph of one CROWE ⌘ patient before surgery. ab is representative of femur length; cd is representative of tibial length; ef is representative for bony leg length.

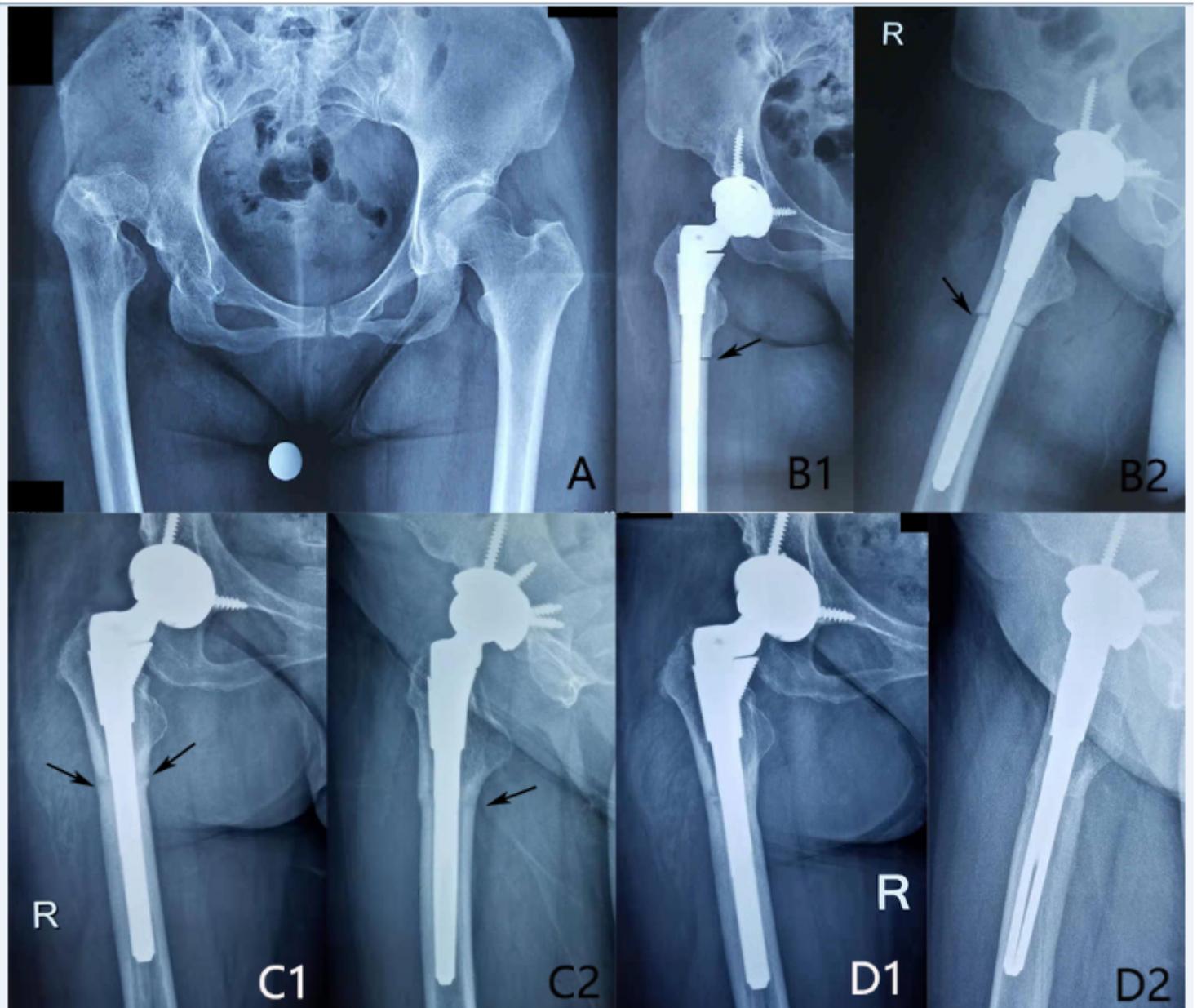


Figure 3

A series of plain X-ray photographs of one CROWE patient received subtrochanter osteotomy. Picture A is an anteroposterior pelvic radiograph before surgery. Pictures B, C and D are of the positive and lateral radiographs of the hip joint at 3 days after surgery, 6 months after surgery and 1 year after surgery. Arrows represent that the osteotomy site is visible, and at 1 year after surgery, the osteotomy site is a bony union.