Controlled Fracture of Medial Wall Versus Structural Autograft With Bulk Femoral Head to Increase Cup Coverage by Host Bone for Total Hip Arthroplasty in Osteoarthritis Secondary to Developmental Dysplasia of Hip: a Retrospective Cohort Study

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Research article

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Abstract

**Background:** Many methods have been proposed to increase cup coverage by host bone during primary total hip arthroplasty (THA) in hip osteoarthritis secondary to developmental dysplasia of hip (DDH). However, there was no study comparing results of controlled fracture of medial wall with structural autograft with bulk femoral head.

**Methods:** 67 hips classified as Crowe II/III were retrospectively included in this cohort study, which consisted of 33 controlled fracture (group A) and 34 structural autograft (group B). The Harris Hip Scores (HHS) was recorded. The radiological assessments were analyzed. Also, complications are assessed. The paired sample t test was used for data analysis before and after operation, while independent sample T test was used for the comparison between the two groups.

**Results:** All patients were reconstructed acetabulum at anatomical location. HHS increased greatly for both groups (P=0.18). No statistic difference was observed for two groups in postoperative leg-length discrepancy ((0.51±0.29) cm for group A and (0.46±0.39) cm for group B, P=0.64 ), postoperative height of hip center ((2.25±0.42) cm for group A and (2.09±0.31) cm for group B, P=0.13), inclination of cup ((39±4)° for group A and (38±3)° for group B, P=0.65 ). The rate of cup coverage for group B ((94±2)% ) was better than group A ((91±5)%), ( P=.009). Rate of cup protrusio was (48±4)% for group A. For both two groups, no complications were observed at the latest follow-up.

**Conclusion:** Controlled fracture of medial wall to increase cup coverage by host bone at anatomical location can act as an alternative technique for DDH Crowe II/III with advantage of shorter operation time and less technically demanding.

Introduction

Total hip arthroplasty (THA) in osteoarthritis secondary to developmental dysplasia of hip (DDH) is challenging [1]. And many studies [2–4] have reported unfavorable clinical outcomes and higher rate of complications of THA in osteoarthritis secondary to DDH compared with primary hip osteoarthritis. Because DDH presents a spectrum of anatomical disorders including the femur and the acetabulum. The abnormal femoral change of the oversize anteversion and narrow medullary cavity can be easily dealed with by modular hip stem, which can correct the overanteverted femoral neck and provide rotational stability if subtrochanteric shortening osteotomy was performed [5]. But for the distorted acetabulum especially DDH Crowe II/III, it always manifests with pathomorphologic changes including shallow true acetabulum, formation of a neoacetabulum and superolateral bony deficiency [1, 6–8], All of which make it more complicated and technically demanding to balance acetabular reconstruction at anatomical location and rate of cup coverage by host bone [9, 10].

There are three main techniques to increase cup coverage by host bone in primary THA: creation of a high hip center [11, 12], structural autograft with bulk femoral head [13, 14] and medial protrusio technique [10, 15]. Although creation of a high hip center can simplify the process of acetabulum management and has
been widely used for revision acetabular reconstruction, yet many scholars [10, 14, 16] agreed on inserting the acetabular implant into anatomical hip center due to superior biomechanics, better fixation and stability. Structural bulk bone grafting is another effective technique suggested by scholars to increase cup coverage by host bone[14, 17]. Bone grafting can restore bone mass and realize superior rate of cup coverage by superolateral fixation of the processed autologous femoral head. But the complexity of operation techniques and potential risks including resorption or collapse of the graft, aseptic loosening keep it away from us [18]. Medial protrusio technique consisting of medial wall penetration, medial wall osteotomy and controlled fracture of medial wall is a series of methods that deepen the acetabulum and insert the acetabular cup with medial aspect beyond the Kohler’ line to achieve higher rate of cup coverage. With the technique, bone grafting is not necessary to increase the rate of cup coverage. Zhang et al [10] and Hartofilakidis et al [15] have published excellent outcomes and safety of the technique. But currently, there are studies just reporting the clinical efficacy of bulk bone autograft or medial protrusio technique. And no cohort study was published. To our knowledge, this was the first study comparing the results of controlled fracture of medial wall with structural bone grafting to increase cup coverage by host bone for hip osteoarthritis secondary to DDH Crowe II/III.

We hypothesize that for hip osteoarthritis secondary to DDH Crowe II/III, controlled fracture of medial wall presents the similar results like structural autograft with bulk femoral head to increase cup coverage by host bone at anatomical location on clinical measurements and radiological evaluations.

Material And Methods

Study design

The study is a retrospective cohort study performed through the retrieval of information on hospital information system from January 2007 to December 2014. And the targeted patients were recalled to accomplish the follow up. Study approval was obtained from the Clinical Trials and Biomedical Ethics Committee of West China Hospital.

Patient selection criteria

Inclusion criteria: (1) patients diagnosed with end-stage hip osteoarthritis secondary to DDH and scheduled to undergo primary THAs during the target period; (2) the classification of DDH belonging to type II or III according to Crowe [2]; (3) the patients performed controlled fracture of medial wall or structural autograft with bulk femoral head to increase cup coverage by host bone by the same senior surgeon (the corresponding author). Exclusion criteria: (1) patients performed THAs due to other reasons; (2) other types of DDH according to Crowe; (3) increasing cup coverage by other methods. (4) THA performed by other senior surgeon. (5) the patients lost to follow up.

Ultimately, we selected and analyzed the data of the patients performed by controlled fracture of medial wall (group A) or structural autograft with bulk femoral head (group B). All analyzed participants were
identified as Crowe II/III. And we called up the patients to return to our hospital to complete the follow-up. So, we obtained the latest clinical and radiological data.

**Surgical Techniques**

All acetabular cups were implanted at the true acetabulum. After general anesthesia, all patients were located in lateral position and exposed the hips with posterolateral approach. Then sawing off the femoral heads and resecting the osteophytes and synovium around the joint as well as the soft tissue in cotyloid notch of the true acetabulum. Standard acetabulum reaming (approximately 45 degrees of abduction and 15 degrees of anteversion) was initiated until the optimal fit for the acetabulum implant was realized. The acetabulum trial component was then inserted into the acetabulum and placed at the appropriate abduction and anterversion to examine the rate of cup coverage. If the rate was not satisfactory or the initial stability of cup was not realized, we would perform controlled fracture of the medial wall or structural autograft with the processed bulk femoral head to increase the rate of cup coverage.

The detailed steps of controlled fracture of medial wall were described as follows: Firstly, the medial wall was spherically fractured by osteotome with the center in the top of the cotyloid notch and one third diameter of the anteroposterior dimension of the true acetabulum. Take care not to perforate the internal layer of the periosteum. Secondly, migrate the superior autogenous mud-like cancellous graft to the fractured area and disperse uniformly. Thirdly, the cementless acetabular component was placed with appropriate orientation and pressure. At last, before placing the liner, examine the initial stability of the component. If the stability was not satisfactory, supplemental screws would be used to reinforce the early cup stability.

The detailed steps of structural autograft with bulk femoral head were described like Kim et al [14].

For the management of the femur, after expanding medullary cavity routinely, place the trial component and femoral head. Then try to realize hip joint reduction and check out the stability on different direction and assess sciatic nerve tension by palpation. For the condition that it was difficult to realize hip joint reduction or excessive tension of sciatic nerve, we would perform transverse subtrochanteric shortening osteotomy. Then, after finishing the procedures, we would evaluate the range of motion (ROM) of the hip, the limb length and nerve tension. Once all of these were satisfactory, we finally placed the components. Ultimately, irrigated the articular cavity, placed a drainage if transverse subtrochanteric shortening osteotomy was performed and sutured the incision.

**Perioperative Regimen**

For all patients, positive motion exercises were initiated on bed after recovering from anesthesia. Prophylactic intravenous antibiotics were used within the first 24 hours postoperatively. Additionally, low-molecular-weight heparin (LMWH) and painkillers were systematically managed to prevent deep venous thrombosis (DVT) and relieve pain, respectively. The drainage tube was removed within 24 hours.

From the first postoperative day on, all of the patients were allowed to partial weight-bearing exercises with the help of walker aid and full weight-bearing exercises after 6 weeks. Once the patients can realize
independent walking, the walker aid can be removed. For the ones receiving transverse subtrochanteric shortening osteotomy, internal and external rotation of the hip were forbidden until bony union of the osteotomy.

**Clinical Measurements**

Clinical details were recorded including ROM of the hip and Harris Hip Scores (HHS) [19]. ROM consisting of flexion, extension and abduction and Harris scores were examined by 2 authors. Postoperative HHS (the total score is 100) are defined as excellent (≥90), good (80–89), fair (70–79) and poor (<70).

**Radiological Assessments**

Standard AP radiograph were obtained before and after surgery. Preoperatively and postoperatively, radiographs were analyzed by 2 authors. The assessments included length discrepancy (LLD), the height of the hip center, inclination of cup, rate of cup coverage and rate of medial protrusion. LLD was assessed by standardized-trochanteric method to avoid the influence of pelvic and femoral inclination on the radiographs [20]. Standardized-trochanteric method requires the vertical distance from the interteardrop line to the center of rotation and the femoral vertical distance (center of rotation to the lesser trochanter) reference to femoral anatomical axis. So, the unilateral distance is defined as the difference of the two vertical distances. And LLD is equal to the difference of the two unilateral distance (Fig. 1). The height of hip center is defined as the perpendicular distance from the femoral head center to the inter-teardrop line [21]. Inclination of cup is defined as the angle between a horizontal line joining the ischial spines and a line parallel to the opening plane of the cup [22]. Rate of cup coverage and rate of medial protrusion are measured according to the methods introduced by Dorr et al [23] and Kim et al [24]. Rate of cup coverage is defined as the ratio of degree of cup covered by the host bone and 180°(Fig. 2). Rate of medial protrusion is defined as the ratio of degree of cup medialization beyond the Kolher's line and 180°(Fig. 2).

**Complications**

The complications are recorded including early-onset and late-onset complications during the period of perioperation and follow-up. The early-onset ones consist of infection, intraoperative fracture, DVT, pulmonary embolism and nerve palsy. Meanwhile, the late-onset ones consist of postoperative dislocation, nonunion of the femoral osteotomy, graft collapse, polyethylene wear, osteolysis and aseptic loosening [25–27].

**Statistical Analysis**

Statistical analysis was performed using SPSS software for Windows Version 22.0 (SPSS, Chicago, IL). The level of statistical significance was set at p<0.05. The results were expressed as the mean ± standard deviation. The paired sample t test was used for data analysis before and after operation, while independent sample T test was used for the comparison between the two groups.

**Results**
For group A, the mean age of all patients (male:female = 4:27) was 49.2 years (49–67) and mean body mass index (BMI) was 22.8 kg/m² (17.2–27.4). Besides, the patients (33 hips) were analyzed with 12 hips classified as type II and 21 hips classified as type III according to Crowe. For group B, the mean age of all patients (male:female = 6:24) was 50.9 years (33–63) and mean BMI was 22.9 kg/m² (17.3–29.7). Moreover, the patients (34 hips) were analyzed with 10 hips classified as type II and 24 hips classified as type III according to Crowe. These patients underwent 67 THAs performed by the same senior surgeon. 5 patients of group A and 6 patients of group B were performed transverse subtrochanteric shortening osteotomy. All patients were followed up using a standard clinical and radiographic protocol mentioned above. Also, we recorded the information about the components. And the related details were presented on Table 1. All implants of both groups used during the procedures were from DePuy, USA. The patients requiring THAs on both hips were performed separately.
### Table 1
Baseline of all recruited patients

|                          | DDH (no = 67 hips) | Group A (no = 33 hips) | Group B (no = 34 hips) |
|--------------------------|--------------------|------------------------|------------------------|
| **Mean age (yrs)**       | 49.2 ± 8.3 (range, 49–67) | 50.9 ± 9.1 (range, 63–33) |                      |
| **Male : female**        | 4:27               | 6:24                   |                        |
| **Mean height (cm)**     | 157.4 ± 6.2 (range, 149–175) | 155.0 ± 6.5 (range, 145–170) |                      |
| **Mean weight (kg)**     | 56.3 ± 6.7 (range, 43–70) | 54.8 ± 7.6 (range, 43–68) |                      |
| **Mean BMI (kg/m²)**     | 22.8 ± 2.6 (range, 17.2–27.4) | 22.9 ± 3.3 (range, 17.3–29.7) |                      |
| **Crowe classification** |                    |                        |                        |
| II                       | 12                 | 10                     |                        |
| III                      | 21                 | 24                     |                        |
| Follow-up(months)        | 85 ± 36            | 78 ± 35                |                        |
| **Cup type**             |                    |                        |                        |
| Pinnacle                 | 33                 | 34                     |                        |
| **Stem type**            |                    |                        |                        |
| Corail                   | 15                 | 10                     |                        |
| Tri-lock                 | 3                  | 3                      |                        |
| S-rom                    | 15                 | 21                     |                        |
| **Friction couples**     |                    |                        |                        |
| Ceramic-on ceramic       | 28                 | 30                     |                        |
| Ceramic-on-polyethylene  | 5                  | 4                      |                        |
| **Subtrochanteric osteotomy** |            |                        |                        |
| Yes/no                   | 5/28               | 6/28                   |                        |

DDH: developmental dysplasia of hip
Table 2
Range of motion and Harris Hip Scores for all recruited patients preoperatively and postoperatively of both two groups

| DDH       | Group A (Pre) | Group B (Pre) | Group A (Post) | Group B (Post) | Intra | Inter |
|-----------|---------------|---------------|----------------|----------------|-------|-------|
|           | Flexion (°)   |                |                |                |       |       |
|           | Pre           | Post          | Pre            | Post           |       |       |
|           | 88 ± 25       | 113 ± 7       | 91 ± 16        | 116 ± 5        | t=−5.86, p<.001* | t=−9.97, p<.001* |
|           |               |               |                |                | T=−0.55, P=.59 | T=−1.37, P=.18 |
|           | Extension (°)  |                |                |                |       |       |
|           | Pre           | Post          | Pre            | Post           |       |       |
|           | −1 ± 3        | 0 ± 0         | −2 ± 3         | 0 ± 0          | t=−1.75, p = .095 | t=−2.30, p = .031* |
|           |               |               |                |                | T = 0.26, P = .54 | - |
|           | Abduction (°)  |                |                |                |       |       |
|           | Pre           | Post          | Pre            | Post           |       |       |
|           | 20 ± 11       | 38 ± 4        | 23 ± 6         | 36 ± 3         | t=−10.29, p<.001* | t=−12.88, p<.001* |
|           |               |               |                |                | T=−1.08, P=.29 | T=1.58, P=.12 |
|           | HHS           |                |                |                |       |       |
|           | Pre           | Post          | Pre            | Post           |       |       |
|           | 38 ± 6        | 87 ± 6        | 40 ± 4         | 89 ± 6         | t=−65.35, p<.001* | t=−77.36, p<.001* |
|           |               |               |                |                | T=−1.24, P=.22 | T=−1.36, P=.18 |

Pre: preoperatively; Post: postoperatively; HHS: Harris Hip Scores; Intra: Intra-group comparisons; Inter: Inter-group comparisons; DDH: developmental dysplasia of hip; P values with statistical significance are marked with *.

Table 3: Comparison of leg-length discrepancy and height of hip center by radiography preoperatively and postoperatively of all recruited patients

| DDH      | Group A (Pre) | Group B (Pre) | Group A (Post) | Group B (Post) | Intra | Inter |
|----------|---------------|---------------|----------------|----------------|-------|-------|
|          | LLD (cm)      |               |                |                |       |       |
|          | Pre           | Post          | Pre            | Post           |       |       |
|          | 2.31±1.65     | 0.51±0.29     | 2.46±1.37      | 0.46±0.39      | t=4.69, p<.001* | t=6.52, p<.001* |
|          |               |               |                |                | T=−0.32, P=.75 | T=0.48, P=.64 |
|          | HHC (cm)      |               |                |                |       |       |
|          | Pre           | Post          | Pre            | Post           |       |       |
|          | 4.34±1.03     | 2.25±0.42     | 4.59±0.59      | 2.09±0.31      | t=8.66, p<.001* | t=22.56, p<.001* |
|          |               |               |                |                | T=−1.02, P=.31 | T=1.54, P=.13 |

Pre: preoperatively; Post: postoperatively; Intra: Intra-group comparisons; Inter: Inter-group comparisons; LLD: leg-length discrepancy; HHC: height of hip center; DDH: developmental dysplasia of hip; P values with statistical significance are marked with *.
**Table 4**: Comparison of inclination of cup and rate of cup coverage by radiography postoperatively of all recruited patients

| DDH | Group A | Group B | Inter |
|-----|---------|---------|-------|
| IC  (°) | (39±4)° | (38±3)° | T=0.46, P=.65 |
| RCC (%) | (91±5)% | (94±2)% | T=-2.78, P=.009* |

IC: inclination of cup; RCC: rate of cup coverage; Inter: Inter-group comparisons;

DDH: developmental dysplasia of hip; P values with statistical significance are marked with *.

**Clinical Outcomes**

Ultimately, 61 patients (33 hips of group A and 34 hips of group B) were followed-up for (85±36) months of group A and (78±35) months of group B. All patients were satisfied with the results that the pain had decreased and gait had improved markedly compared with preoperative status. For group A, the average HHS improved from (38±6) points preoperatively to (87±6) points at the latest follow-up. According to the postoperative HHS, 15 hips (45.5%) are defined as excellent, 13 hips (39.4%) good, 5 hips (15.2%) fair. The average flexion, extension and abduction of hip increased from (88±25)*, (−1±3)*, (20±11)* preoperatively to (113±7)*, (0±0)*, (38±4)* at the final follow-up. For group B, comparably, the average HHS improved from (40±4) preoperatively to (89±6) at the latest follow-up. According to the postoperative HHS, 17 hips (50%) are defined as excellent, 12 hips (35.3%) good, 5 hips (14.7%) fair. The average flexion, extension and abduction of hip increased from (91±16)*, (−2±3)*, (23±6)* preoperatively to (116±5)*, (0±0)*, (36±3)* at the latest follow-up (Table. 2).

**Radiological Outcomes**

For group A, at the latest follow-up, LLD restored from (2.31±1.65) cm preoperatively to (0.51±0.29) cm. The height of hip center restored from (4.34±1.03) cm to (2.25±0.42) cm. The inclination of cup was (39±4)*. The rate of cup coverage was (91±5)%. And the rate of cup protrusio was (48±4)% (Table. 3 and Table. 4) (Fig. 3). Additionally, for group B, at the final follow-up, LLD restored from (2.46±1.37) cm to (0.46±0.39) cm. The height of hip center restored from (4.59±0.59) cm to (2.09±0.31) cm. the inclination of cup was (38±3)*. The rate of cup coverage was (94±2)% (Table. 3 and Table. 4) (Fig. 4). For the patients performed transverse subtrochanteric shortening osteotomy of both two groups, most of them (10 of 11) realized bony union at 6 months after surgery and the remaining one realized at 9 months postoperatively. From the X-ray films of the latest follow-up, we did not find radiolucent lines, visible implant loosening and periprosthetic osteolysis for both groups. Moreover, we observed no patient encountering graft collapse or progressive migration of the implant from the radiographs.

**Complications**
None of the patients suffered from early-onset complications. But 2 hips of group A and 2 hips of group B encountered intraoperative fracture of proximal femur, which were addressed well by wires. For the late-onset complications such as dislocation, osteolysis and radiolucent lines were not observed. However, 1 patient (1 of group B) performed transverse subtrochanteric shortening osteotomy suffered from delay union and finally achieved bony union at 9 months postoperatively.

Discussion

The most important finding of this study was that the clinical measurements and radiological assessments of both two groups almost restore to normal and no one showed complications at the latest follow-up. Besides, for the patients, the pain has relieved and the gait has improved as well as no complaining about self-perceived LLD. So, both two approaches are effective to increase cup coverage by host bone and reconstruct acetabulum. According to the current literature [7], because of abnormal anatomy, secondary osteoarthritis of DDH occurs at a relatively young age (an average of 42 years old) and for the younger population, the long-term survival of implant was reported to lower than that of general ones due to more activity [28, 29]. Besides, for DDH Crowe II/III, the biggest challenge lies in cup coverage and acetabular reconstruction. Also, the study [30] has demonstrated that the rate of failure of the acetabular component showed a positive correlation with the severity of DDH. So, the surgeons are more concerned about how to obtain adequate initial stability of the cup in order to realize long-term survival of the acetabular component and postpone potential revision surgery.

There is no consensus on the position of acetabular component. And placement of the acetabular implant can be located in true acetabulum or high hip centre. High hip centre is defined as the perpendicular distance from the femoral head center to the inter-teardrop line more than 35 mm [21]. Some scholars [8, 10, 14, 16, 31] agreed on the inserting the cup into true acetabulum due to superior biomechanics, better fixation and more bone mass. Placing the implant at anatomical centre of the hip enables optimal abductor muscle function and the bone mass for fixation of the component is larger than at more proximal level [9]. However, we must address problems such as limb lengthening [32], nerve palsy [32], less coverage of the cup [16]. Gratifyingly, subtrochanteric osteotomy [7], structural autograft [14] and medial protrusio technique [8] have provided novel and valid methods. Additionally, creation of high hip center was also proposed for primary acetabular reconstruction and was reported good long-term outcomes and showed no difference in polyethylene wear [33, 34]. Nevertheless, there are many other problems to face. Firstly, high acetabular reconstruction often results in high, lateral and oversized cup placement leading to the problems like fixation, primary stability and restoration of normal hip biomechanics [7]. Secondly, at this high level, the bone stock is insufficient and shearing forces on the acetabular component may lead to early loosening. Meanwhile, longer lever arm for body weight can result in excessive load to the hip joint [16, 35]. Thirdly, longer prosthetic neck length used to balance leg lengths possibly leads to neck-liner impingement [10]. At last, the patients performed primary THA owing to DDH usually are younger than hip osteoarthritis and most of them likely need revision surgery, which may be more difficult owing to limited bone stock [14]. Bicanic et al [36] reported that every millimetre of lateral displacement of the acetabular cup compared with ideal rotation center resulted in an increase of 0.7% in hip load and every millimetre of
proximal displacement an increase of 0.1% in hip load. This accounts for high rate of failure if place the
cup component in high hip centre. Additionally, Chen et al [11] and Stans et al [37] have demonstrated that
using a high hip centre during acetabular reconstruction in DDH patients had higher failure rate. So, based
on these reasons, we have chose anatomic placement of the acetabular cup. And the results of this study
was that LLD was approximately 5 mm and no one complained about self-perceived LLD, if we
reconstructed acetabulum at true location. Also, aseptic loosening was not found at the latest follow-up.
These results demonstrated anatomic reconstruction of acetabulum was a superior choice once again.

- Currently, literatures [15, 38] have proved medial protrusio technique was an effective method to
increase the rate of cup coverage without bulk femoral head autograft. Medial protrusio technique
includes controlled medial wall fracture, medial wall osteotomy and medial wall penetration [8]. And
the reasons why we chose controlled medial wall fracture as cotyloplasty are the simplification and
safety compared with other two techniques. Besides, the current literatures [15, 38] have demonstrated
that the long-term survival of THA performing controlled fracture of medial wall showed no difference
compared with that of general THA at 10 years. For medial wall osteotomy, it's a more technically
demanding process and the thickness of medial wall should be not less than 10 mm according to
Zhang et al [10]. For medial wall penetration, the loss of bone stock is more than medial wall fracture.
And it's easy to ream excessively leading to the damage of the acetabular rim. Most of all, to our
knowledge, there is no report more than 10 years about the medial wall osteotomy and medial wall
penetration demonstrating the comparable outcomes with controlled medial wall fracture. So, based
on these factors, we thought controlled medial wall fracture is a better one for increasing cup
coverage in THA with DDH.

- Sufficient initial stability of cementless cup is imperative for successful osseointegration and good
long-term survival, but medial protrusion may decrease this stability. So, what rate of medial
protrusion of the cup is the best? Dorr et al [23] recommended this rate should be less than 45% and
Kim et al [24] suggested it should be within 50%-60%. Besides, according to Zha et al [8], a prospective
6- to 9-year follow-up of 43 consecutive patients using medial protrusio technique in cementless THA
for DDH demonstrated that the rate of medial protrusion more than 60% had a high aseptic loosening
rate in midterm. Also, excessive rate of medial protrusion may possibly result in cup component
migration into the pelvis. And the rate of medial protrusion of our study was (48 ± 4)% and no
complications were observed at the final follow-up. So, we suggested it was safe to realize enough
cup coverage with the least rate of medial protrusion and the rate should be less than 60%. If needed,
additional screws can be used for initial cup stability.

- The technique, controlled fracture of medial wall, has several advantages to deal with unsatisfying
cup coverage compared with structural autograft with bulk femoral head. Firstly, it can simplify the
operation and does not ask for special surgical instruments. Meanwhile, this technique does not
prolong the operation time and cause obviously additional damage to the patients. Secondly, the area
of operated medial wall belong to bony union because of the application of autogenous mud-like
cancellous graft and protection of the internal layer of the periosteum. And the integrity of acetabular
rim does not be damaged. So, there is little influence on the primary stability and bone ingrowth of the
cup component. Thirdly, medialization of the cup component can increase the rate of cup coverage and decrease wear due to the increase of the abductor lever arm and decreased loading of the hip joint. However, the primary concern of this technique is possibly excessive medial protrusio resulting in unsatisfied primary stability of the cup component or disastrous migration of the cup into pelvis when postoperative weight-bearing exercises. Besides, the range of medial fracture is not easy to control. For the mentioned concerns, we suggest that firstly don’t chase for excessive rate of medial protrusio if the cup component can realize enough rate of cup coverage and initial stability. Secondly, the application of autogenous mud-like cancellous graft and protection of the internal layer of the periosteum play a vital role in bony union of medial wall. Also, autogenous mud-like cancellous graft can improve bone ingrowth of cup component in the area of medial aspect of acetabular cup. At last, postoperative function exercise should be rational and not too be ambitious.

The limitations of the current study were the retrospective research with small population and relatively short period of follow-up and we couldn’t acknowledge the long-term outcomes. Additionally, when we conducted radiological assessments, we just used 2-dimensional images to accomplish evaluations, which might compromise the robustness of the final results. But, It was the first study to compare the effectiveness of controlled fracture of medial wall with that of structural bone grafting to increase cup coverage and reconstruct acetabulum. And the study demonstrated that controlled fracture of medial wall could increase the rate of cup coverage without technically demanding, which can act as a selectable method to increase cup coverage and reconstruct acetabulum.

Conclusion

Controlled fracture of medial wall is an effective and safe technique to increase the rate of cup coverage for THA in osteoarthritis secondary to DDH Crowe II/III. With the advantage of less technical demand, we recommended it as an alternative technique to increase cup coverage by host bone for THA in hip osteoarthritis secondary to DDH Crowe II/III.

Abbreviations

THA: total hip arthroplasty DDH: developmental dysplasia of hip ROM: range of motion LMWH: low-molecular-weight heparin DVT: deep venous thrombosis HHS: Harris Hip Scores LLD: leg-length discrepancy

Declarations

Ethics approval and consent to participate
This study has been approved by the Clinical Trials and Biomedical Ethics Committee of West China Hospital, Sichuan University. Each author certifies that all investigations were conducted in accordance with ethical principles. All participants involved in the study gave their informed consent.

Consent for publication
All data collected in this study have consent for publication.

**Competing interests**

The authors announce that they do not have any competing interests.

**Availability of data and materials**

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

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**Authors’ contributions**

PM and KL designed this study. KL and HLC were responsible for gathering, analyzing and interpreting data. MP wrote the manuscript. JY made contributions to revising the manuscript for crucial intellectual content. JY have contributed in the revision of the manuscript and interpretation of data. The final version of the text has been reviewed and approved by all authors. PM and KL contributed equally to this work and should be considered as equal first authors.

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Figures
Figure 1

Diagram showing standardized-trochanteric method to assess Leg-length discrepancy. R1 and R2 are the vertical distance from the bilateral center of rotation to interteardrop line. Line AB and line CD are the anatomical axis of the femurs. Point A and point C are the perpendicular intersections from the center of rotation to the femoral anatomical axis. Point B and point D are the perpendicular intersections from the tip of the lesser trochanter to the femoral anatomical axis. H1 and H2 are equal to AB and CD, respectively. Leg-length discrepancy= (H1·R1)/(H2·R2)
Figure 2

Schematic showing the measurement of medial protrusion and cup coverage. Point O is the center of the cup component. AB is the diameter of the cup component. Point C is the intersection between the edge of the cup implant and the ilium. Point D and point E are the intersections between the medial edge of acetabular component and Kolher's line. The rate of cup coverage = \((180^\circ - \angle AOC)/180^\circ\)×100%. The rate of medial protrusion = \(\angle DOE/180^\circ\)×100%.
Case presentation of controlled fracture of medial wall for THA

a: A 54-year-old woman was diagnosed with DDH Crowe III on the radiograph of the pelvis preoperatively. 
b: The radiograph of the pelvis after surgery immediately showed the rate of cup coverage was 86%, the rate of medial protrusion was 52% and the Leg-length discrepancy was 0.38 cm. 
c: The radiograph of the pelvis at 1-year follow-up showed the medial wall was bony union and no aseptic loosening of the component. 
d: The radiograph of the pelvis at 76-month follow-up showed no aseptic loosening and migration of the component.
Case presentation of structural autograft with bulk femoral head for THA a: A 51-year-old woman was diagnosed with DDH Crowe III on the radiograph of the pelvis preoperatively. b: The radiograph of the pelvis after surgery immediately showed the rate of cup coverage was 95% and the Leg-length discrepancy was 0.16 cm. c: The radiograph of the pelvis at 1-year follow-up showed the interface between the graft
and the host bone had been obscure and no aseptic loosening of the component. d: The radiograph of the pelvis at 84-month follow-up showed incorporation of grafted bone, no aseptic loosening and migration of the component.