Original Article

A preliminary evaluation of raising the center of rotation in total hip arthroplasty for the patients with developmental dysplasia of the hip

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Background: Total hip arthroplasty is an effective treatment for developmental dysplasia of the hip (DDH). However, there are still debated issues in total hip arthroplasty (THA) for DDH patients. Placing the acetabular cup according to the anatomic center of rotation (COR) in THA is not always the perfect choice for the DDH patients. We raised the COR in THA in order to get better press fit and coverage for the acetabular cup. This study aims to evaluate the clinical results of raising the COR in total hip arthroplasty for the patients with developmental dysplasia of the hip.

Methods: A retrospective analysis was carried out in 16 DDH patients (19 hips) who received THA in our department from March 2015 to January 2016. The COR was raised in THA for all the 19 hips. We evaluated the vertical distance between COR of acetabular cup and anatomic COR, horizontal distance between COR of acetabular cup and anatomic COR, coverage for acetabular cup, preoperative Harris hip score and postoperative Harris hip score.

Results: The mean follow-up time of 16 cases (19 hips) DDH was 16 months (range, 4–22 months). The mean vertical distance between COR of acetabular cup and anatomic COR was 1.07±0.26 cm (range, 0.68–1.48 cm). The mean horizontal distance between COR of acetabular cup and anatomic COR was 0.24±0.11 cm (range, 0.10–0.51 cm). The mean coverage for acetabular cup was 88.3% (range, 79.8–97.7%). The mean preoperative Harris hip score was 51.9±13.9 (range, 36.4–75.8), and the mean postoperative Harris hip score was 85.5±6.5 (range, 75.6–95.8), and there is significant difference between the two groups (P<0.01).

Conclusions: Raising the COR in THA for DDH patients is a feasible option when the coverage for acetabular cup was poor. A detailed preoperative plan is the crucial step to get good coverage for acetabular cup and minor limb length discrepancy.

Keywords: Developmental dysplasia of the hip (DDH); total hip arthroplasty; center of rotation (COR)

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Introduction

Total hip arthroplasty is an effective treatment for Developmental dysplasia of the Hip (DDH) (1,2). It can improve the DDH patients' symptoms such as pain of the hip, limping and restricted range of motion of hip. However, there are still debated issues in total hip arthroplasty (THA) for DDH patients (3). A lot of DDH patients suffered dislocation of the hip, and reconstructing

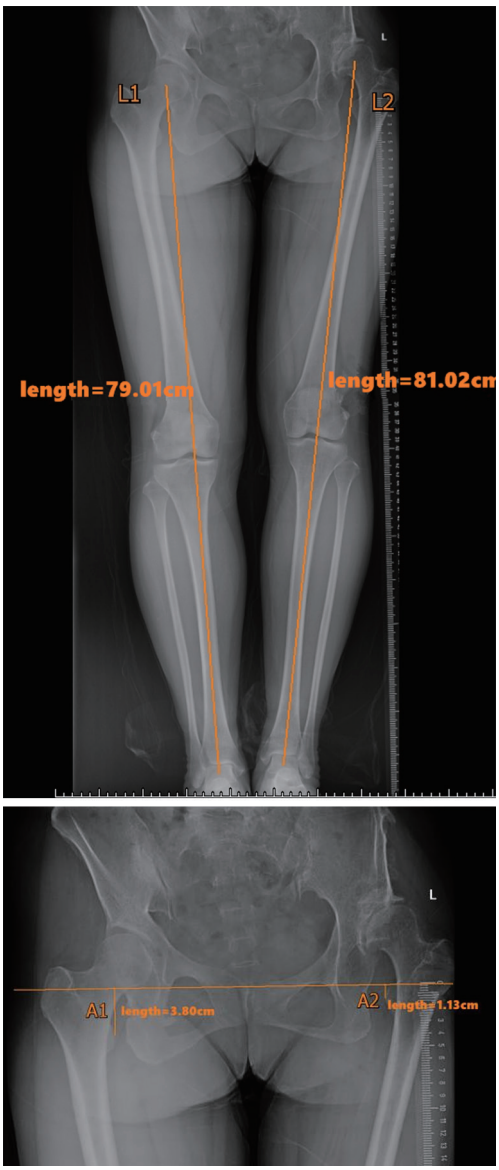

Figure 1 Difference of the distance between COR and the center of ankle hole: difference of distance between the center of femur head and the center of ankle hole plus difference of distance between the teardrop of acetabulum and ipsilateral lesser trochanter. LLD = (L1–L2) + (A1–A2). COR, center of rotation; LLD, limb length discrepancy.

an ideal center of rotation (COR) is one of the main goals of the operation (4,5). Placing the acetabular cup according to the anatomic COR in THA is not always the perfect choice for the DDH patients, because some patients can't get a good coverage for acetabular cup due to the dysplasia of the acetabulum. We raised the COR in THA in order to get better press fit and coverage for the acetabular cup. In this study, a retrospective analysis was carried out to evaluate the effect of raising the COR in THA for DDH patients.

Methods

We reviewed the 49 DDH patients from March 2015 to January 2016, 34 of them are Crowe type I and type II, among the 34 patients, 16 patients (19 hips) the COR was raised. There are 2 males and 14 females in the 16 patients, and the mean age was 46.9±13.6 years (range, 22–69 years). Of the 19 hips, 12 hips were diagnosed as Crowe type I DDH and 7 hips were diagnosed as Crowe type II DDH. The mean preoperative Harris hip score was 51.9±13.9 (range, 36.4–75.8). Ceramic-on-ceramic was used for all the cases. DePuy Corail femoral prosthesis was used in two hips. DePuy S-Rom modular femoral prosthesis was used in 14 hips. LINK LCU femoral prosthesis was used in three hips.

Preoperative planning

Before operation, the radiographic analysis included an anteroposterior view of the pelvis, a frontal full view of the two lower limbs and CT scan of hips.

Lower limb length discrepancy (LLD) measurement: many DDH patients have length discrepancy on femur and tibia in addition to the dislocation of the hip. We measured the distance between the center of femur head and the center of ankle (L) and got difference L (L1–L2) at first, and then measured the vertical distance between the teardrop of acetabulum and ipsilateral lesser trochanter (A) and got difference A (A1–A2). The total LLD is the sum of difference L and difference A [(L1–L2) + (A1–A2)] (*Figure 1*).

Location of anatomic COR

Ranawat's triangle method is used to determine the anatomic COR in the anteroposterior view of the pelvis (6). Point A is located five millimeters lateral to the intersection of Kohler's line (KK) and interteardrop line. A vertical line is drawn through point A and a point (B) is marked at one-fifth the height of the pelvis. A horizontal line is drawn through point B and a point (C) is marked at a distance equal to AB. An isosceles triangle was completed by connecting points A, B and C. The midpoint of line AC is the anatomic COR (*Figure 2*).

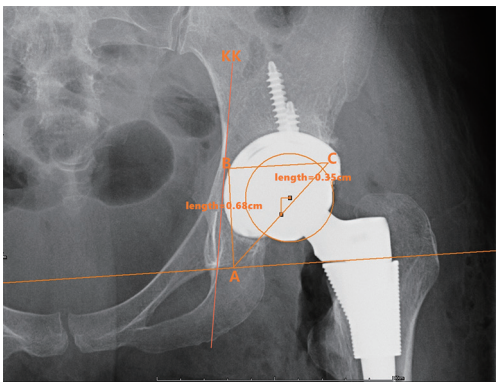

Figure 2 Determine the anatomic center of rotation in the anteroposterior view of the pelvis by Ranawat's triangle method: point A is located five millimeters lateral to the intersection of Kohler's line (KK) and interteardrop line. A vertical line is drawn through point A and a point (B) is marked at one-fifth the height of the pelvis. A horizontal line is drawn through point B and a point (C) is marked at a distance equal to AB. An isosceles triangle was completed by connect points A, B and C. The midpoint of line AC is the anatomic center of rotation.

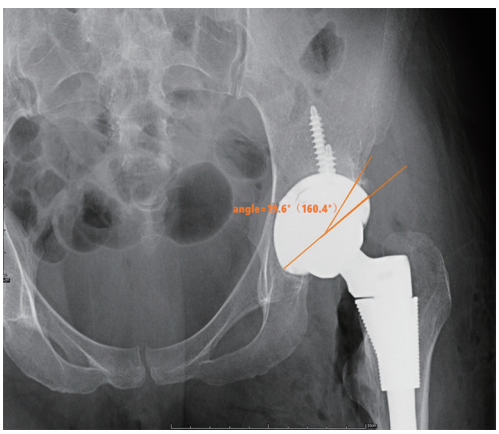

Figure 3 The coverage of acetabular cup was measured by setting the COR of the acetabular cup as center. COR, center of rotation.

Location of the reconstructing COR

We used the prosthesis template to get an appropriate size for acetabular cup, and then adjusted the position of the proper prosthesis template to get good coverage for the acetabular cup. When the size and position of the cup have been determined, we could know the point of COR.

Surgical procedure

All the procedures were performed using the same standard posterior approach to the hip, then the acetabular labrum and osteophytes were properly removed. We reconstruct the acetabulum with the preoperative planed COR and size. Acetabular reaming was performed until the medial wall was touched, taking care to avoid using larger reamer as the coverage may be poor even the COR has been raised. After the acetabular cup was implanted, we used two acetabular screws to increase the stability of acetabular cup, and then fixed the acetabular liner. A box chisel was used to remove the remaining portions of the lateral aspect of the femoral neck and the medial portion of the greater trochanter, and then reaming of femoral canal and femoral broaching was finished sequentially. A trial head and neck components fitting onto the broach handle was applied to perform the reduction and check the stability of the hip. The surrounding soft tissue could be properly released if the reduction was difficult. If S-ROM prosthesis was applied, anteversion of the femoral prosthesis could be adjusted to get an ideal stability.

Antibiotic prophylaxis and anticoagulant prophylaxis were routinely applied. The patients were asked to keep the operated limb at a neutral position with the knee and hip flexed. Follow-up was carried out at 3, 6, 12 months after surgery. We evaluated Harris hip score and take an anteroposterior view of the pelvis. The COR was also determined by Ranawat's triangle method (*Figure 2*). The vertical and horizontal distance between the COR of the acetabular cup and the anatomical COR was measured on the anteroposterior view of the pelvis. The coverage of acetabular cup was measured by setting the COR of the acetabular cup as center (*Figure 3*).

Statistical methods

IBM SPSS 19 and Kingsoft WPS form were used for data statistics analysis. Preoperative and postoperative Harris hip scores, the distance between the COR of the acetabular cup and the anatomical COR and coverage of the acetabular cup was presented by the form of mean ± standard deviation. Comparison of preoperative and postoperative Harris hip scores was made by using *t*-test for matching design data. $P<0.01$ was considered statistically significant.

Results

All cases were followed up and the average follow-up time was 16 months (range, 4–22 months). The mean preoperative Harris hip score was 51.9±13.9 (range, 36.4–75.8), and mean postoperative Harris hip scores was at last follow-up was 85.5±6.5 (range, 75.6–95.8). The comparison between preoperative and postoperative Harris hip scores showed significant difference (P<0.01). The mean preoperative LLD was 1.97±1.30 cm (range, 0.50–3.76 cm), and the mean postoperative LLD was 0.76±0.43 cm (range, 0.12–2.30 cm). The comparison between preoperative and postoperative LLD showed significant difference (P<0.01). The vertical distance between the COR of the acetabular cup and the anatomical COR was 1.07±0.26 cm (range, 0.68–1.48 cm), and the horizontal distance between the COR of the acetabular cup and the anatomical COR was 0.24±0.11 cm (range, 0.10–0.51 cm). The coverage of the acetabular cup was 88.3% (range, 79.8–97.7%).

Review of X-ray showed that all patients had ideal implant position without displacement. In one case, a splitting fracture of the lesser trochanter occurred when the femoral prosthesis was implanted. The fracture was fixed with a cerclage wire. This patient was released to full weight-bearing walking at 6 weeks after surgery, and the fracture was healed at the 3 months after surgery.

Discussion

Dealing with the acetabulum is difficult in THA surgery for DDH patients. According to the traditional view, the acetabular cup should be placed in the true acetabulum to reconstruct an anatomical COR, in order to obtain normal biomechanical characteristics (5,7). But reconstructing an anatomical COR is not suitable for all DDH patients because of the acetabular dysplasia (8). In patients with light femoral dislocation and relatively normal acetabulum, the acetabular cup can be placed in the true acetabulum. In patients with shallow acetabulum, the acetabular cup can't get enough bone coverage if it is placed in the true acetabulum (9). Previous studies have shown that coverage of at least 70–75% was necessary for the initial stability of acetabular cup (10). One way to solve the problem is to carry out structural bone grafts, which has been reported the literature and has shown different clinical effects. Kobayashi *et al.* (11) performed acetabular bone graft by using the femoral head in 30 patients with a total of 37 hips. Average follow-up of 19 years showed that all the bone grafts were healed and no prostheses failed. Harris *et al.* (12) performed acetabular bone graft by using the femoral head in 11 patients with a total of 13 hips. Follow-up of more than 1 year showed that 11 hips had achieved good clinical outcome, and a long time follow-up showed the incidence of acetabular failure was 29% (13).

The drawback of this technique is bone absorption which can cause the instability of acetabular cup in a long term (14), and the procedure of bone graft will undoubtedly prolong the operation time. Some surgeons have attempted to use bone cement to fix the acetabular cup, but they did not get satisfactory clinical outcome at follow-up (15).

Placing the acetabular cup at a higher position is usually used for DDH patients with in bilateral high dislocation. The reduction of these patients can be very difficult, and the risk of nerve injury and vessel injury is high when performing reduction. As the development of acetabulum is poor, the bone is not sufficient enough to support acetabular cup. In these patients, placing the acetabular cup at a higher position is an alternative to reduction by femoral osteotomy. The patients will get better coverage of acetabular cup. In order to reduction, femoral osteotomy is a choice, another way is placing the acetabular cup at a higher position and which will also get better coverage. But on the other hand, the patients will suffer weakness of the lower limbs due to the relaxation of abductor muscle if cup COR higher than anatomic COR. In addition, in the zone above the acetabulum, the bone mass is decreasing. Antoniades *et al.* (16) reported that the position with highest bone mass is at 35±3 mm above the tear-drop. The bone mass will decrease by 24% when the position rising by 1 cm, and the bone mass will decrease by 48% when the position rising by 2 cm. So, we suggested that the reconstructing COR should be as near to the anatomical COR as possible for DDH patients, on condition that the acetabular can get enough coverage.

After adjusting the anteroposterior view of the pelvis by the PACS system (*Figure 4*), we used the prothesis template to determine reconstructing COR referring to the coverage of cup. Of note: Placing the cup higher is to get a better coverage, so ream as deep as possible until the medial wall was touched.

Reducing LLD of lower limbs is one of the main objectives of THA for DDH patients. We wondered whether raising COR will affect LLD correction. Huang *et al.* (17), found there was no significant difference between preoperative and postoperative lower limb length when using big size prosthesis for the raised acetabular cup. The postoperative LLD is not obvious. We found that the

Figure 4 Adjusting the anteroposterior view of the pelvis by the PACS system.

difference between the affected limb and the contralateral limb depended on not only the proximal femur, but also the whole femur and tibia. Luo *et al.* (18) reported that, the distance between the lesser trochanter to the malleolus medialis was extended in the DDH limb compared to the contralateral limb in 24 cases out of 28 DDH patients, and the difference was 12.1 mm (range, 0.6–29.3 mm); the distance was shortened in 4 cases out of 28 DDH patients, and the difference was 4.6 mm (range, 1.5–9.7 mm). This is why we evaluated LLD by measuring the length of total lower limb, instead of measuring the distance between the lesser trochanter to the tear drop. In our patients, the preoperative LLD was 1.97±1.30 cm (range, 0.5–3.76 cm), and the postoperative LLD was 0.76±0.43 cm (range, 0.12–2.30 cm). The LLD was corrected by surgery. There was significant difference between preoperative and postoperative LLD.

Placing the acetabular cup at the anatomical COR can theoretically result in the best function of soft tissues (19), but clinical studies showed raising the COR moderately had no obvious disadvantage on the postoperative function. Fukui *et al.* (20) evaluated the abductor lever arm of abductors and Trendelenburg sign in 100 female DDH patients who received THA with anatomic COR and 100 female DDH patients who received THA with raised COR, and they found no significant differences between these two groups. They suggested that the raised COR will not decrease the torque of abductors when the vertical distance between the COR and tear drop is within 30mm. If the raised COR is in an applicable range, we believe that it is possible to avoid weakness of abductors by postoperative exercise. In our patients, the preoperative Harris hip score was 51.9±13.9 (range, 36.4–75.8), and mean postoperative Harris hip scores was at last follow-up was 85.5±6.5 (range, 75.6–95.8). The comparison between preoperative and postoperative Harris hip scores showed significant difference ($P<0.01$). No patients showed a Trendelenburg sign after surgery.

At present the location of the acetabular cup in THA for DDH patients is still a debatable issue. There are many studies presented that raising COR will not affect the survival of the prosthesis and the function of the operated hip. For the patients with shallow acetabulum, raising the COR is a feasible alternative surgical method if the acetabular cup can't get enough coverage at the anatomical COR. Before the operation, there should be a detailed plan for each patient. The radiographic analysis should include anteroposterior view of the pelvis, a frontal full view of the two lower limbs and CT scan of hips to evaluate the bone mass. The length of lower limb and the planed reconstructing COR should be measured on an X-ray film of frontal full view of the 2 lower limbs, and the postoperative LLD should be calculated. The limitation of this study is the relatively small number of cases and short time of follow-up. Only Crowe type II DDH patients were enrolled in this study, but no Crowe type III, IV DDH patients were enrolled in this study. There was no patient who received THA with anatomical COR enrolled as controls in this study. Further studies are necessary to clarify this debating issue.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoj.2018.06.07). WC serves as an unpaid Associate Editor of *Annals of Joint* from Jun 2018 to May 2020. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by Chinese PLA general hospital Ethics Committee (No. S2016-032-02).

Written informed consent was obtained from the patient for publication of this manuscript and any accompanying images.

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