Changes in Alignment of Ipsilateral Knee on Computed Tomography after Total Hip Arthroplasty for Developmental Dysplasia of the Hip

De-gang Yu, MD†, Jing-wei Zhang, MD†, Chen Xu, MD, Jia-wei Xu, MD, Hui-wu Li, MD, Zhen-an Zhu, MD, Feng-xiang Liu, MD, Yuan-qing Mao, MD

Shanghai Key Laboratory of Orthopaedic Implants, Department of Orthopaedic Surgery, Shanghai Ninth People’s Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Objective: To assess the changes in alignment of ipsilateral knee joint after total hip arthroplasty (THA) for patients with developmental dysplasia of the hip (DDH).

Methods: Thirty-four patients with DDH (38 hips) who underwent THA between February and December 2008 were included in the study: 4 men and 30 women with a mean age of 56.2 years. According to Crowe classification, 11 patients were grade I, 12 were grade II, 9 were grade III, and 6 were grade IV. Computed tomography scans were performed from the anterior superior iliac spine to the tibial tubercle before surgery and at last follow-up. Femoral anteversion angle, leg lengthening, and knee alignment, including patellar tilt angle, lateral patellar displacement, and tibiofemoral rotation angle, were measured on computed tomography scans, and their relationships were analyzed.

Results: The mean follow-up period was 51.5 months (range, 39–70 months). There were no intraoperative fractures, and no infections occurred during the follow-up period. One patient developed deep venous thrombosis and another suffered from femoral nerve palsy. The mean preoperative Harris Hip Score was 48.9 ± 7.5 and improved to 91.2 ± 8.3 by the last follow-up (P < 0.001). There was no sign of prosthetic loosening in all hips. Postoperatively, mean leg lengthening was 26.08 ± 21.81 mm (P < 0.001), femoral anteversion decreased 9.03° ± 12.80° (P < 0.001), and patellar tilt, lateral patellar displacement, and tibiofemoral rotation increased by 3.58° ± 4.96° (P < 0.001), 1.78 ± 3.36 mm (P = 0.002), and 2.56° ± 3.37° (P < 0.001), respectively. Postoperative increase in patellar tilt and lateral patellar displacement had significant linear relationships with the decrease in femoral anteversion (r = 0.621, P < 0.001 and r = 0.437, P = 0.0037, respectively). These results revealed that patellofemoral alignment would change more with the decrease in femoral anteversion. Postoperative increase in external rotation of the tibia had significant positive linear relationships with leg lengthening (r = 0.34, P = 0.037) and the decrease in femoral anteversion (r = 0.693, P < 0.001). These results revealed that the external rotation of the proximal tibia would increase with the leg lengthening or the decrease of femoral anteversion. Postoperative changes in patellar tilt and lateral patellar displacement had no significant linear relationships with leg lengthening (P = 0.795 and P = 0.082, respectively).

Conclusions: Total hip arthroplasty for DDH could induce changes in alignment of ipsilateral patellofemoral and tibiofemoral joints, with increases in patellar tilt and displacement, and increases in external rotation of the tibia. These secondary alterations still existed at medium-term follow-up after surgery, which should be considered during THA for patients with DDH. Extended follow-up is necessary to evaluate long-term changes in the knee joint.

Key words: Developmental dysplasia; Knee; Knee alignment; Total hip arthroplasty

Address for correspondence Yuan-qing Mao, MD, Shanghai Key Laboratory of Orthopaedic Implants, Department of Orthopaedic Surgery, Shanghai Ninth People’s Hospital, Shanghai Jiao Tong University School of Medicine, 639 Zhizaoju Road, Shanghai 200011, China Tel: 0086-21-63139920; Fax: 0086-21-63139920; Email: doctormaoyuanqing@163.com

†De-gang Yu and Jing-wei Zhang contributed equally to this work.

Disclosure: This work was supported by grants from the National Natural Science Foundation of China (Nos. 81301590 and 81572158). Received 16 November 2017; accepted 10 April 2018

Orthopaedic Surgery 2019;11:397–404 • DOI: 10.1111/os.12462
This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.
Introduction

Total hip arthroplasty (THA) is an effective method for relieving pain and improving function for adult development dysplasia of the hip (DDH) when end-stage osteoarthritis develops. THA for DDH has been shown to result in excellent outcomes. However, anterior knee pain and changes at patellofemoral joints after THA in DDH patients have been reported. Moreover, postoperative patella dislocation was observed recently in our follow-up study. Therefore, some negative changes in the knee joints may be induced by THA, which should be considered during operations for patients with DDH, but these secondary changes are still not well defined at present. Abnormal alignment of the knee joint plays an important role in both the development and progression of osteoarthritis, and abnormal alignment of the knee joint is an independent risk factor for knee osteoarthritis progression. Only when changes in the knee joints in such patients are fully defined can improvement measures be taken.

Generally, THA for patients with DDH differs from that for patients with common primary coxarthrosis because of acetabular and femoral anatomical abnormalities. For patients with DDH, upward displaced hips should be reduced to the anatomical center and femoral anteversion should be adjusted for ideal biomechanical load bearing, to correct leg length discrepancy, and to reduce the risk of impingement, dislocation, and other complications after THA. The durability of arthroplasty in these patients is better with the restoration of an anatomic hip center. Therefore, the anatomical hip structure changed significantly; two main changes were reduction in femoral anteversion and leg lengthening after THA operation in patients with DDH.

It has been suggested that anatomical changes at the hip joint are associated with abnormalities in the ipsilateral knee joint and femoral anatomical abnormalities. For patients with DDH, upward displaced hips should be reduced to the anatomical center and femoral anteversion should be adjusted for ideal biomechanical load bearing, to correct leg length discrepancy, and to reduce the risk of impingement, dislocation, and other complications after THA. The durability of arthroplasty in these patients is better with the restoration of an anatomic hip center. Therefore, the present study aimed: (i) to determine the medium-term alterations in alignment of the ipsilateral knee joints based on CT scans in patients with DDH who underwent THA; (ii) to measure femoral anteversion angle, leg lengthening, and knee alignment, including patellar tilt angle, lateral patellar displacement, and tibiofemoral rotation angle, on CT scans preoperatively and at last follow-up; and (iii) to analyze their relationships.

Patients and Methods

Inclusion and Exclusion Criteria

This was a single center retrospective study of patients with DDH who underwent THA between February and December 2008. The inclusion criteria were: (i) adult patients with DDH having extreme impairment of daily activity; (ii) patients who underwent THA; (iii) outcome measures are Harris hip score (HHS), the amount of leg lengthening (LL), and the angle of femoral anteversion (FA); and (iv) retrospective study. The exclusion criteria were: (i) previous hip surgery; and (ii) lack of integral imaging data.

Patients’ Data

Forty-eight consecutive THA were performed in forty-four patients with DDH between February and December 2008. A total of 10 patients were excluded from this study because of previous hip surgery (5 hips) or lack of preoperative CT scanning (5 hips). The remaining 34 patients (38 hips) were included in the study, including 4 men and 30 women with a mean age of 56.2 years (range, 29–76 years). According to Crowe classification, 11 (32.4%, 11/34) of these were Crowe grade I, 12 (35.3%, 12/34) were Crowe grade II, 9 (26.5%, 9/34) were Crowe grade III, and 6 (17.7%, 6/34) were Crowe grade IV. This study was approved by the local institutional review board. All investigations were conducted in accordance with the ethical principles of research. Informed consent for this study was obtained from all patients.

Computed tomography Scanning

Computed tomography evaluation was performed using the Hitachi Radix Turbo (Tokyo, Japan) (120 kVp, 200 mA, 5-mm collimation, 5 mm/s table speed, and 5-mm resolution index) device. CT scans were performed before surgery and at the last follow-up. By using axial sections passing from the anterior superior iliac spine to the tibial tubercle, all patients...
underwent 1-mm interval CT scans in the supine position, with the hips and knees fully extended and the lower limbs as horizontal and parallel as possible.

**Surgical Procedure**

All operations were performed by the senior surgeon (Zhu). The procedure has been described in detail in our previous studies\(^5\,16\,17\). Briefly, a posterolateral approach was used in all cases. The elongated capsule and all osteophytes around the acetabulum were removed to expose the true acetabulum. The acetabular component was placed at the level of the reamed anatomical location. The technique without femoral shortening osteotomy in patients with high dislocations was used to avoid leg length discrepancy. The femoral component was selected as the one that best matched the broached intramedullary canal with the anteversion carefully controlled. If it was difficult to reduce the hip, direct leverage was applied to the greater trochanter using an elevator, which obtained purchase on the bone below the acetabulum. When the modular femoral head reached the level of the acetabular component, the reduction was achieved by externally rotating the leg. During the procedure, the hip and knee were always held in flexion to relax the sciatic nerve and reduce the tension on the soft tissues. This position was maintained postoperatively for several days to avoid damage to the nerve.

Cementless prostheses were used in all hips, including 21 Secur-Fit stems and Trident cups (Stryker Corporation, New Jersey, USA), and 17 Wagner Cone stems and TM Continuum cups (Zimmer Biomet, Indiana, USA). Ceramic-on-polyethylene interfaces were chosen in 37 hips (21 from Stryker Corporation, New Jersey, USA and 16 from Zimmer Biomet Corporation, Indiana, USA); metal-on-polyethylene couple was chosen in 1 hip (Zimmer Biomet Corporation, Indiana, USA).

**Postoperative Treatment**

Antibiotics were routinely administered for 1 to 3 days to prevent infection. The rehabilitation program varied according to soft tissue tension. In general, patients were allowed partial weight-bearing from 1 day to 1 week after the surgery and then full weight-bearing at 1 to 6 weeks. If the soft tissue was very tight after leg lengthening, the hip and knee flexion position was maintained for several days postoperatively and then extended gradually over the course of 1 to 2 weeks. After regaining full extension, walking exercises with crutches and full weight-bearing were initiated.

**Follow-up and Assessment**

Outpatient follow-ups were performed 1, 3 and 6 months and 1 year after surgery. Subsequently, yearly follow-ups were performed. Clinical and imageological assessment were performed.

**Harris Hip Score**

The Harris Hip Score was used to assess the hip joint function of each patient prior to surgery and at each follow-up examination after surgery\(^18\).

**Radiographic Assessment**

A series of radiographs of the pelvis were obtained at each follow-up visit and were carefully assessed for loosening of the prosthesis. The stability of the acetabular components was assessed radiographically using the method of DeLee and Charnley\(^19\) and that of the femoral components using the method of Gruen et al.\(^20\).

**Amount of Leg Lengthening**

The amount of leg lengthening was measured as the change in the vertical distance between the line joining the tear drops and the most medial tip of the lesser trochanter (Fig. 1).

**Angle of Femoral Anteversion**

The angle of femoral anteversion was measured according to the method of Pierchon et al.\(^21\), compensating for the rotational angle of the femur as defined by the intersection angle formed by the axis of the femoral neck and a tangent to the posterior borders of the medial and lateral condyles (Fig. 2).

**Patellar Tilt Angle**

The relationships of the patella relative to the femoral condyles are referred to as the patellar tilt angle (PTA) (Fig. 3A and 3B) and lateral patellar displacement (LPD) (Fig. 3C). The PTA is the angle between the slope of the lateral patellar facet and the line connecting the two most posterior points of the femoral condyles\(^22\).

![Fig. 1](image)

Fig. 1 The amount of leg lengthening was measured as the change in the vertical distance (h). A, The vertical distance (h) between the line joining the tear drops (a) and the most medial tip of the lesser trochanter (b) was measured on preoperative computed tomography (CT) scans. B, The vertical distance (h) between the line joining the tear drops (a) and the most medial tip of the lesser trochanter (b) was measured on postoperative CT scans.
Lateral Patellar Displacement
The LPD is the parallel distance between the highest tip of the medial femoral condyle and the medial tip of the patella²³.

Tibiofemoral Rotation
Tibiofemoral rotation (TFR) is the angle between the line connecting the two most posterior points of the femoral condyles and the line connecting the two most posterior points of the tibia condyles²⁴(Fig. 3A and 3D). A tangent on the posterior border of the tibia was placed distally to the femorotibial joint and proximal to the fibulotibial joint. The TFR angle represents the position of the proximal tibial epiphysis relative to the distal end of the femur in non-weight bearing, resting position with the knee in full extension.

Clinical Complications
The clinical complications, such as intraoperative fracture, infection, deep venous thrombosis and the function of the sciatic and femoral nerves, were recorded.

Statistical Analysis
All statistical analyses were performed on a personal computer using SPSS software for Windows (version 17.0; SPSS, Chicago, IL, USA). The Shapiro–Wilk test was used to verify that preoperative and postoperative HHS, LL, FA, PTA, LPD, and TFR were normal distributions. Student’s t-test
was used to compare preoperative and postoperative HHS, LL, FA, PTA, LPD, and TFR. Linear regression analyses were used to statistically evaluate the relationship between the changes of FA and LL with that of PTA, LPD, and TFR. A P-value of <0.05 was considered to represent a significant difference.

**Results**

**Clinical Results**
The mean follow-up period was 51.5 months (range, 39–70 months). No patients required revision during the follow-up period. The mean preoperative HHS was 48.9 ± 7.5 and improved to 91.2 ± 8.3 (P < 0.001) by the last follow-up.

**Radiographic Results**
The radiological stability of the acetabular and femoral components was assessed and there was no definite sign of prosthetic loosening in all hips. The detailed CT measurement results are listed in Table 1.

### TABLE 1 Image measurement results

| Parameters | Preoperation | Postoperation | Values changed | t-value | P-value* |
|------------|--------------|---------------|----------------|---------|----------|
| LL (mm)    | 10.12 ± 25.75| 36.19 ± 7.05  | 26.08 ± 21.81  | −7.37   | <0.001   |
| FA (°)     | 25.10 ± 14.20| 16.07 ± 7.77  | 9.03 ± 12.80   | 4.35    | <0.001   |
| PTA (°)    | 16.01 ± 5.05 | 12.43 ± 4.87  | 3.58 ± 4.96    | 4.45    | <0.001   |
| LPD (mm)   | 3.42 ± 3.45  | 1.64 ± 4.81   | 1.78 ± 3.36    | 3.27    | 0.002    |
| TFR (°)    | 4.06 ± 3.60  | 6.61 ± 4.70   | 2.56 ± 3.37    | −4.67   | <0.001   |

FA, femoral anteversion angle; LL, leg lengthening; LPD, lateral patellar displacement; PTA, patellar tilt angle; TFR, tibiofemoral rotation. *Student’s t-test. All values are expressed as the mean ± standard deviation.

The Amount of Leg Lengthening
The preoperative and postoperative vertical distances between the line joining the tear drops and the most medial tip of the lesser trochanter were 10.12 ± 25.75 mm and 36.19 ± 7.05 mm, respectively. The average amount of LL was 26.08 ± 21.81 mm (P < 0.001).

The Angle of Femoral Anteversion
The preoperative and postoperative FA were 25.10° ± 14.20° and 16.07° ± 7.77°, respectively. The postoperative FA decreased 9.03° ± 12.80° (P < 0.001).

Patellar Tilt Angle
The preoperative and postoperative PTA were 16.01° ± 5.05° and 12.43° ± 4.87°, respectively. The postoperative PTA reduced 3.58° ± 4.96° (P < 0.001), which means that the patellar tilt increased.

Lateral Patellar Displacement
The preoperative and postoperative LPD were 3.42 ± 3.45 mm and 1.64 ± 4.81 mm, respectively. The

---

Fig. 4 The postoperative changes in tibiofemoral rotation had significant positive linear relationships with the changes in leg lengthening (A) and femoral anteversion (B).
postoperative LPD reduced $1.78 \pm 3.36 \text{ mm} (P = 0.002)$, which means that the patella was displaced laterally.

**Tibiofemoral Rotation**
The preoperative and postoperative TFR were $4.06^\circ \pm 3.60^\circ$ and $6.61^\circ \pm 4.70^\circ$, respectively. The average TFR increased $2.56^\circ \pm 3.37^\circ (P < 0.001)$ postoperatively, which means that the proximal tibia rotated externally relative to the distal femur postoperatively.

**Linear Regression Analyses**
Linear regression and statistical tests were performed using the postoperative change in PTA, LDP, and TFR as dependent variables and the change in FA or the amount of LL as independent variables. The results revealed that the postoperative change in TFR had significant positive linear relationships with the amount of LL ($r = 0.34, P = 0.037$) and the change in FA ($r = 0.693, P < 0.001$), as shown in Fig. 4. These statistically significant results revealed that the external rotation of the proximal tibia would increase with the leg lengthening or the decrease of FA. The postoperative changes in PTA and LDP had significant linear relationships with the change in FA ($r = 0.621, P < 0.001$ and $r = 0.437, P = 0.0037$, respectively), as shown in Fig. 5. These results revealed that patellofemoral alignment would change more with the decrease in femoral anteverision. The postoperative changes in PTA and LDP had no significant linear relationships with LL ($P = 0.795$ and $P = 0.082$, respectively).

**Complications**
There were no intraoperative fractures, and no infections occurred during the follow-up period. One patient developed deep venous thrombosis in his right lower extremity on day 2 after the operation; this condition resolved after muscle contraction exercises and anticoagulation treatment with low molecular-weight heparin. One patient suffered from femoral nerve palsy with weakness of knee extension. This patient recovered completely after 3 months with conservative treatment, and the HHS was 87 at the last follow-up of 56 months.

**Discussion**
Recently, several studies have reported the changes in alignment of lower limbs after THA for DDH on radiographs\textsuperscript{3,4,13}. However, the present study is the first to demonstrate that the patellofemoral and tibiofemoral relationships were changed on CT scans at medium-term follow-up (51.5 months) after THA operation on patients with DDH.

**Patellofemoral Alignment**
With respect to the patellofemoral alignment after THA for DDH, the present study demonstrated that the patellofemoral alignment changed, with the patella tilt increasing by $3.58^\circ \pm 4.96^\circ$ and lateral displacement increasing by $1.78 \pm 3.36 \text{ mm}$ compared with preoperatively. It has been demonstrated that the patellofemoral relationship could be influenced by iliotibial band (ITB) tightness and leg rotation. ITB tightness increased with leg lengthening after THA in patients with DDH. As the ITB attaches to the lateral retinaculum of the patella, increasing the ITB tension could increase lateral tilt and translation of the patella\textsuperscript{25,26}. Tokuhara observed an increased lateral tilt phenomenon after THA in patients with DDH, which was related to the amount of leg lengthening and disappeared within 3 months\textsuperscript{3}. However, in the current study,
the lateral tilt phenomenon still existed after 51.5 months of follow-up, and no linear relationship was found between the change in PTA and variations in leg lengthening. Patellofemoral dysfunction has also been related to abnormal femoral rotation. Eckhoff (1994) reported that anterior knee pain in adults was associated with increased femoral antever- sion. Souza (2010) suggested that altered patellofemoral joint kinematics in women with patellofemoral pain appears to be related to excessive femoral rotation, and control of femur rotation may be important in restoring normal patellofemoral joint kinematics. Similarly, the current study revealed a significant relationship between the changes in patellofemoral alignment and the decrease in femoral anteversion after THA for DDH patients.

**Tibiofemoral Alignment**

With respect to the tibiofemoral alignment, the present study is the first to report that the tibia rotates externally relative to the femur after THA for DDH, which is related to the change in leg lengthening and femoral antever sion. Several previous studies found that femoral malrotation changed the coronal alignment of the lower extremity and the center of force in the tibiofemoral joint, and the leg external rotation could switch its center of force towards the medial condyle. These findings suggest that lower limb torsion disorders are not merely cosmetic issues but could be risk factors inducing gonarthrosis, which may alter the tibiofemoral kinematics and lead to abnormal pressure in the tibiofemoral compartment and cartilage damage. Kenawey’s study demonstrated that when decreasing cadaveric femoral antever sion, the joint tibiofemoral compartment contact pressure was increased, but increasing the femoral antever sion decreased the medial pressure. Duparc’s study suggested that external rotation of the leg induces shear stresses on the medial compartment cartilage and alters the load distribution on the tibial plateau. Taken together, the present findings demonstrated that decreased femoral anteversion after THA for DDH patients may change the tibiofemoral alignment and increase the probability of gonarthrosis.

**Combined Antever sion for Total Hip Arthroplasty**

To avoid potential problems in the knee joint, we believe that the concept of “combined antever sion” might be helpful, which has been proved to reduce the risk of dislocation and impingement after THA for DDH in our previous studies. Using the concept of “combined antever sion,” it may be a wise choice not to fully correct the femoral antever sion by increasing the antever sion of the acetabular cup. Accordingly, the increases in patellar tilt and displacement and increases in external rotation of tibia after THA for DDH might be reduced.

**Limitations of the Study**

One limitation to this study is that the number of patients was relatively small, especially the number of Crowe III and IV, which makes the results less meaningful. However, high dislocation DDH is uncommon. This is the first study that demonstrated medium-term changes in ipsilateral bio femoral rotational and patellofemoral alignment after THA for DDH.

**Conclusion**

Total hip arthroplasty is a proven method to treat DDH, but it can also be a potentially double-edged sword. THA operation for DDH could induce secondary changes in ipsilateral knee joint alignment, with alteration in both patellofemoral and tibiofemoral relationships. These abnormal phenomena should be further investigated. However, knee osteoarthritis may develop over a long period of time, and additional long-term studies are needed to evaluate whether THA operation may induce knee osteoarthritis in patients with DDH.

**References**

1. Colo E, Rijnen WH, Gardeniers JW, van Kampen A, Schreurs BW. Satisfying results of primary hip arthroplasty in patients with hip dysplasia at a mean followup of 20 years. Clin Orthop Relat Res, 2016, 474: 2462–2468.
2. Abdel MP, Stryker LS, Trousdale RT, Berry DJ, Cabanela ME. Uncemented acetabular components with femoral head autograft for acetabular reconstruction in developmental dysplasia of the hip: a concise followup report at a mean of twenty years. J Bone Joint Surg Am, 2014, 96: 1878–1882.
3. Tsukahara Y, Kadoya Y, Kim M, Shoudou M, Kanno T, Masuda T. Anterior knee pain after total hip arthroplasty in developmental dysplasia. J Arthroplasty, 2011, 26: 955–960.
4. Kilicarslan K, Yalcin N, Cicek H, Cila E, Yildirim H. What happens at the tibiofemoral joint, and the leg external rotation could change in PTA and variations in leg lengthening. Several previous studies found that femoral malrotation changed the coronal alignment of the lower extremity and the center of force in the tibiofemoral joint, and the leg external rotation could switch its center of force towards the medial condyle. Duparc’s study suggested that external rotation of the leg induces shear stresses on the medial compartment cartilage and alters the load distribution on the tibial plateau.
5. Li H, Xu J, Qu X, Mao Y, Dai K, Zhu Z. Comparison of total hip arthroplasty with and without femoral shortening osteotomy for unilateral mild to moderate high hip dislocation. J Arthroplasty, 2017, 32: 849–856.
6. Tanamas S, Hanna FS, Ciucuttini FM, Wluka AE, Berry P, Urquhart DM. Does knee malalignment increase the risk of development and progression of knee osteoarthritis? A systematic review. Arthritis Rheumatol, 2009, 61: 459–467.
7. Greber EM, Peit CE, Gilliland JM, Anderson MB, Erickson JA, Peters CL. Challenges in total hip arthroplasty in the setting of developmental dysplasia of the hip. J Arthroplasty, 2017, 32: 538–544.
8. Pagnano W, Hanssen AD, Lewallen DG, Shaughnessy WJ. The effect of superior placement of the acetabular component on the rate of loosening after total hip arthroplasty. J Bone Joint Surg Am, 1996, 78: 1004–1014.
9. Boissonneault A, Lynch JA, Wise BL, et al. Association of hip and pelvic geometry with tibiofemoral osteoarthritis: multicenter osteoarthritis study (MOST). Osteoarthr Cartil 2014, 22: 1129-1135.
10. Kandemir U, Yazici M, Alpaslan AM, Surat A. Morphology of the knee in adult patients with neglected developmental dysplasia of the hip. J Bone Joint Surg Am, 2002, 84: 2249–2257.
11. Li H, Qu X, Wang Y, Dai K, Zhu Z. Morphological analysis of the knee joint in patients with hip dysplasia. Knee Surg Sports Traumatol Arthrosc., 2013, 21: 2081–2088.
12. Zhang Z, Zhang H, Luo D, Cheng H, Xiao K, Hou S. Coronal plane alignment of the lower limbs in patients with unilateral developmental hip dislocation. Int Orthop, 2018, 42: 2761–2769.
13. Akiyama K, Nakata K, Kitada M, et al. Changes in axial alignment of the ipsilateral hip and knee after total hip arthroplasty. Bone Joint J 2016, 98-B: 349-358.
14. Akiyama K, Nakata K, Kitada M, Yamamura M, Owaki H, Fuji T. Chronological changes in axial alignment of the ipsilateral hip and knee after total hip arthroplasty. J Arthroplasty, 2018, 33: 415–422.
15. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am, 1979, 61: 15–23.
16. Zhao X, Zhu ZA, Xie YZ, Yu B, Yu DG. Total hip replacement for high dislocated hips without femoral shortening osteotomy. J Bone Joint Surg Br, 2011, 93: 1189–1193.
17. Li H, Yuan Y, Xu J, Chang Y, Dai K, Zhu Z. Direct leverage for reducing the femoral head in total hip arthroplasty without femoral shortening osteotomy for Crowe Type 3 to 4 dysplasia of the hip. J Arthroplasty, 2018, 33: 794–799.
18. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am, 1969, 51: 737–755.
19. DeLee JG, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop Relat Res, 1976, 121: 20–32.
20. Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res, 1979, 141: 17–27.
21. Pierchon F, Pasquier G, Cotten A, Fontaine C, Clarisse J, Duquennoy A. Causes of dislocation of total hip arthroplasty. CT study of component alignment. J Bone Joint Surg Br, 1994, 76: 45–48.
22. Biedert RM, Gruhl C. Axial computed tomography of the patellofemoral joint with and without quadriceps contraction. Arch Orthop Trauma Surg, 1997, 116: 77–82.
23. Schutzer SF, Ramsby GR, Fulkerson JP. The evaluation of patellofemoral pain using computerized tomography. A preliminary study. Clin Orthop Relat Res, 1986, 204: 286–293.
24. Duparc F, Thominie JM, Simonet J, Biga N. Femoral and tibial bone torsions associated with medial femoro-tibial osteoarthritis. Index of cumulative torsions. Orthop Traumatol Surg Res, 2014, 100: 69–74.
25. Kang SY, Choung SD, Park JH, Jeon HS, Kwon OY. The relationship between length of the iliotibial band and patellar position in Asians. Knee, 2014, 21: 1135–1138.
26. Merican AM, Anis AA. Iliotibial band tension affects patellofemoral and tibiofemoral kinematics. J Biomech, 2009, 42: 1539–1546.
27. Eckhoff DG, Montgomery WK, Kilcoyne RF, Stamm ER. Femoral morphometry and anterior knee pain. Clin Orthop Relat Res, 1994, 302: 64–68.
28. Souza RB, Draper CE, Fredericson M, Powers CM. Femur rotation and patellofemoral joint kinematics: a weight-bearing magnetic resonance imaging analysis. J Orthop Sports Phys Ther, 2010, 40: 277–285.
29. Bretin P, O'Loughlin PF, Suero EM, et al. Influence of femoral malrotation on knee joint alignment and intra-articular contract pressures. Arch Orthop Trauma Surg, 2011, 131: 1115–1120.
30. Lindsey JD, Krieg JC. Femoral malrotation following intramedullary nail fixation. J Am Acad Orthop Surg, 2011, 19: 17–26.
31. Kenawey M, Liodakis E, Kettek C, Ostermeier S, Horn T, Hankemeier S. Effect of the lower limb rotational alignment on tibiofemoral contact pressure. Knee Surg Sports Traumatol Arthrosc, 2011, 19: 1851–1859.
32. Zhang J, Wang L, Mao Y, Li H, Ding H, Zhu Z. The use of combined anteversion in total hip arthroplasty for patients with developmental dysplasia of the hip. J Arthroplasty, 2014, 29: 621–625.
33. Zhang J, Wei J, Mao Y, Li H, Xie Y, Zhu Z. Range of hip joint motion in developmental dysplasia of the hip patients following total hip arthroplasty with the surgical technique using the concept of combined Anteversion: A Study of Crowe I and II Patients. J Arthroplasty, 2015, 30: 2248–2255.