Total Hip Arthroplasty After Rotational Acetabular Osteotomy for Developmental Dysplasia of the Hip

TAKAHIRO NEGAYAMA (negayama.takahiro@kagawa-u.ac.jp)
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka https://orcid.org/0000-0001-9219-4401

Ken Iwata
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

Masashi Shimamura
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

Teppei Senda
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

Tasuku Mashiba
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

Yoshio Kaji
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

Tetsuji Yamamoto
Kagawa University Faculty of Medicine Graduate School of Medicine: Kagawa Daigaku Igakubu Daigakuin Igakukei Kenkyuka

---

Research Article

Keywords: rotational acetabular osteotomy, developmental dysplasia, total hip arthroplasty, bone defect, hip center

Posted Date: April 4th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1418490/v1

Abstract

Background: Total hip arthroplasty after osteotomy is more technically challenging than primary total hip arthroplasty, especially with regards to cup placement. This is due to bone morphological abnormalities caused by acetabular bone loss and osteophyte formation. This study aimed to investigate the clinical and radiological outcomes of total hip arthroplasty after rotational acetabular osteotomy compared with primary total hip arthroplasty, focusing mainly on acetabular deformity and cup position.

Methods: The study included 22 hips that had undergone rotational acetabular osteotomy and 22 hips in an age and sex-matched control group in total hip arthroplasties performed between 2005 and 2020. We analyzed cup abduction and anteversion angle, lateral, anterior, and posterior cup center-edge angle, hip joint center position, femoral anteversion angle, and presence of acetabular defect using postoperative radiography and computed tomography. Operative results and clinical evaluations were also analyzed.

Results: The clinical evaluation showed that the postoperative range of motion was lower in total hip arthroplasty after rotational acetabular osteotomy than in primary total hip arthroplasty. The lateral cup center-edge angle was significantly higher and the posterior cup center-edge angle was significantly lower in the total hip arthroplasty after rotational acetabular osteotomy, suggesting a posterior bone defect existed in the acetablum. In total hip arthroplasty after rotational acetabular osteotomy, the hip joint center was located significantly superior and lateral to the primary total hip arthroplasty.

Conclusions: In total hip arthroplasty after rotational acetabular osteotomy, the cup tended to be placed in the superior and lateral positions, where there was more bone volume. The deformity of the acetabulum and the high hip center should be considered for treatment success because they may cause cup instability, limited range of motion, and impingement.

Background

Developmental dysplasia of the hip (DDH) is the main cause of secondary hip osteoarthritis [1]. A variety of osteotomies are routinely performed due to the progression of osteoarthritis in younger patients when symptomatic DDH is left untreated [2]. Rotational acetabular osteotomy (RAO) is commonly used for the surgical treatment of symptomatic acetabular dysplasia in Japan [3]. Although many positive postoperative outcomes of RAO have been reported [4, 5], in some cases, the progression of osteoarthritis requires that total hip arthroplasty (THA) is performed as well [6, 7].

THA after osteotomy is more technically challenging than primary THA due to previous surgeries, abnormal bone morphology caused by bone defects, osteophyte formation, and other soft tissue problems such as anatomical positional changes [8]. Several studies on THA after RAO have reported clinical results comparable to those of primary THA, although technical considerations are necessary [8, 9]. For example, bone grafting is often required due to bone loss, and subesquent postoperative cup migration has been reported [10], making THA after RAO more challenging than initial THA or THA after other osteotomies. Acetabular bone coverage is important for cup stability in THA after RAO owing to the tendency for bone defects in the anterior-posterior direction [11]. Previous studies have investigated acetabular defects in DDH by measuring the anteroposterior angle using computed tomography (CT) [12]; however, no study has investigated acetabular defects in THA after osteotomy in the anteroposterior direction. The aim of this study was to determine the clinical outcomes and radiographic evaluation, including CT, of THA after RAO compared to those of primary THA.

Methods

This was a retrospective observational study that compared two groups of patients. The ethics review board authorized the study design after all participants gave their informed permission (Approval code: 29–213). Between 2005 and 2020, THA was done on 22 hips in 20 patients who had previously undergone RAO. One patient was excluded because he could not be reexamined for more than 1 year; thus, 21 hips of 19 patients were included in the study. For comparison, propensity score matching was used to identify 21 age and sex-matched hips from 21 patients who had done THA for osteoarthritis secondary to DDH without prior hip surgery as the control group. Surgery was performed in 14 hips using the posterior approach and in 7 hips using the direct anterior approach. Cementless stems and cups were used in all cases, and in patients with acetabular defects, the bulk bone of the femoral head was grafted. In cases of bony impingement, the osteophytes of the acetabulum, anterior inferior iliac spine, and femoral greater trochanter were resected as much as possible. In patients who did not undergo bone grafting, hip range of motion training and full-load gait training began the day after surgery. In cases where bone grafting was used, partial loading began after 4 weeks of unloading. Operative time, blood loss, and complications obtained from medical records were reviewed.

The Japanese Orthopaedic Association (JOA) hip score [13] was used to evaluate hip joint function preoperatively and at the final observation. The JOA hip score was assessed by 40 points for pain, 20 points for range of motion, 20 points for gait, and 20 points for activities of daily living, for a total of 100 points. Radiological evaluation included investigation of cup abduction and anteversion angle, cup center-edge (CE) angle, hip joint center position, femoral anteversion angle, and presence of acetabular defect. Cup inclination and anteversion angles were evaluated using radiography immediately after surgery.

The lateral cup CE (LCE) angle was defined as the angle between the vertical line drawn from the center of the femoral head and the outer edge of the cup and acetabular contact using the coronal view of the CT of the hip (Fig. 1). The anterior cup CE (ACE) angle and the posterior cup CE (PCE) angle were defined as the angle between the vertical line drawn from the center of the femoral head and the anterior and posterior edges of the cup and acetabular contact using a slice of the CT sagittal section at the center of the femoral head (Fig. 1). The hip joint center position was defined as the vertical and horizontal distance from the lower edge of the teardrop (Fig. 2) [14]. As the teardrop had moved after the osteotomy, the position of the contralateral teardrop was used as a reference if no contralateral RAO was performed, and the CT before RAO was used as a reference if contralateral RAO was performed.

All analyses were performed using GraphPad Prism 9 software (GraphPad, San Diego, CA, USA). The mean and standard deviation of continuous variable distributions were reported. Frequencies and percentages were used to report categorical variables. The chi-square test was used to assess the statistical differences between the groups, while the unpaired t-test was used to examine the continuous outcomes. Statistical significance was set at $p < 0.05$. Differences between groups are reported with 95% confidence intervals (CIs).

Results

Patient Demographics

Table 1 shows the demographics of the patients prior to surgery. There were no significant differences between the two groups in terms of age at THA, sex, follow-up length after THA, or method. RAO and THA were separated by an average of 17.3 years.

Table 1
Patient demographics in the after RAO and control groups.

	After RAO (n = 21)	Control (n = 21)	P-value
Number of patients (hips)	21	21	
Sex (male/female)	0/21	0/21	1.0
Interval between RAO to THA (years)	17.3 ± 7.2	N/A	
Follow-up period after THA (years)	7.1 ± 4.2	6.5 ± 1.9	0.54
Age at THA (years)	57.2 ± 9.2	60.6 ± 6.4	0.17
Surgical approach (PL/DAA)	14/7	12/9	0.53
Data are presented as mean ± standard deviation or number.			
RAO: rotational acetabular osteotomy; THA: total hip arthroplasty; PL: posterior lateral; DA: direct anterior			

Operative Results

The operative results are summarized in Table 2. The mean operative time was 173 min in the RAO group and 130 min in the control group. The RAO group had a significantly longer operative time than the control group. ($p < 0.001$; 95% CI 22.2 min to 64.2 min). The operative blood loss did not differ significantly between the two groups ($p = 0.24$).

Table 2
Operative results and clinical evaluation findings in the after RAO and control groups.

	After RAO (n = 21)	Control (n = 21)	P-value
Operative time (min)	172.1 ± 34.0	130.1 ± 23.2	< 0.001
Operative blood loss (g)	346.8 ± 215.8	312.1 ± 247.9	0.24
JOA score (preoperative)			
Total (points)	40.7 ± 9.2	40.2 ± 6.4	0.37
Pain (points)	6.7 ± 5.6	7.2 ± 4.5	0.88
ROM (points)	12.2 ± 3.1	11.5 ± 3.9	0.35
Gait (points)	10.3 ± 3.0	10.8 ± 2.8	0.88
Activity of daily living (points)	11.6 ± 2.1	10.7 ± 1.2	0.06
JOA score (last follow-up)			
Total (points)	93.0 ± 3.7	95.6 ± 4.2	0.13
Pain (points)	38.5 ± 2.3	39.2 ± 1.9	0.67
ROM (points)	16.4 ± 2.1	17.9 ± 1.6	0.03
Gait (points)	19.0 ± 1.4	19.3 ± 2.3	0.46
Activity of daily living (points)	19.1 ± 1.2	19.2 ± 1.4	0.90
Bone grafting	2 (9.5)	0 (0)	0.15

Data are presented as mean ± standard deviation or number (%).

RAO: rotational acetabular osteotomy; JOA: Japanese Orthopaedic Association; ROM: range of motion

The RAO group's JOA hip score increased from 40.7 points preoperatively to 93.0 points postoperatively, while the control group's JOA hip score increased from 40.2 points preoperatively to 95.6 points postoperatively. Between the two groups, there was no significant difference in total postoperative JOA hip scores ($p = 0.13$). The ROM at the final follow-up was 16.4 and 17.9 points for the RAO and control groups, respectively. There was a significant difference in the ROM at the final follow-up between the two groups ($p < 0.03$; 95% CI -2.87 points to -0.15 points). Two patients in the RAO group required bulk bone grafting at the posterior wall of the acetabulum (Fig. 3).

Radiographic Findings

The radiographic findings are summarized in Table 3. There was no significant difference in cup inclination ($p = 0.58$) and anteversion angle ($p = 0.24$) between the two groups. The LCE angle was significantly different between the two groups ($p = 0.01$; 95% CI 1.5° to 10.8°), with a 35.5° angle in the RAO group and a 29.3° angle in the control group. The PCE angle was also significantly different between the two groups ($p < 0.001$; 95% CI -80° to -45.5°), with a 44.4° angle in the RAO group and a 107.2° angle in the control group. There was no significant difference in the ACE angle between the two groups ($p = 0.15$). These data suggest that the RAO group exhibited more bony coverage laterally but less bony coverage posteriorly than the control group. The position of the center of the hip joint differed significantly in vertical distance ($p < 0.001$; 95% CI 4.05 mm to 12.6 mm), being 29.6 mm in the RAO group and 22.3 mm in the control group. There was also a significant difference in the horizontal distance between the two groups ($p = 0.002$; 95% CI 2.45 mm to 9.65 mm), being 35.8 mm in the RAO group and 29.7 mm in the control group. The cup was placed in the upper and lateral sides in the RAO group compared with the placement in the control group. The femoral anteversion angle did not differ significantly between the two groups preoperatively ($p = 0.30$) or postoperatively ($p = 0.20$). In both groups, there were no complications of fracture, dislocation, infection, or neurovascular injury.

Table 3
Radiographic findings in the after RAO and control groups.

	After RAO (n = 21)	**Control (n = 21)**	**P-value**
Cup angle			
Inclination (°)	36.3 ± 5.3	36.8 ± 3.5	0.58
Anteversion (°)	17.9 ± 9.6	21.4 ± 5.2	0.24
Cup CE angle			
LCE (°)	35.5 ± 4.8	29.3 ± 7.9	0.01
ACE (°)	64.4 ± 6.0	59.9 ± 8.4	0.15
PCE (°)	44.4 ± 26.7	107.2 ± 12.0	< 0.001
Hip joint center			
Vertical distance (mm)	29.6 ± 7.2	22.3 ± 4.8	< 0.001
Horizontal distance (mm)	35.8 ± 6.0	29.7 ± 4.2	0.002
Femoral anteversion			
Preoperative (°)	33.6 ± 17.5	29.2 ± 10.1	0.30
Postoperative (°)	41.2 ± 12.9	34.5 ± 10.3	0.20
Data are presented as mean ± standard deviation.			
RAO: rotational acetabular osteotomy; LCE: lateral cup CE; PCE: posterior cup CE; ACE: anterior cup CE			

Discussion

This study revealed that the postoperative JOA score of THA after RAO was comparable to that of the control group. In addition, radiologically, the RAO group showed increased lateral coverage of the acetabulum and characteristic bone defect in the posterior wall of the acetabulum due to the excessive anterior rotation of the osteotomy fragment. Hence, the cup was required to be positioned on the upper and lateral sides where there was more bone mass, which may cause limited range of motion and bony impingement.

RAO is a joint-preserving surgery in which the acetabulum is osteotomized into a spherical shape and rotated laterally to increase the coverage of the femoral head by the acetabulum to improve joint congruity. It is commonly performed in young and adolescent patients with DDH [15, 16]. While positive postoperative outcomes of RAO have been reported [4], there are cases of advanced osteoarthritis leading to THA [17, 18]. It has been reported that THA after RAO is more challenging to perform due to bone deformity and the operative time is significantly longer than that of primary THA [8]. In addition, bone defects in the posterior acetabular wall with large osteophytes are factors that complicate THA after RAO when compared with after Chiari osteotomy and shelf acetabuloplasty [10]. As shown in these reports, bone defects in the acetabular wall are characteristic of RAO. However, there are no reports that have examined bone coverage in the anterior-posterior direction in CT after THA, as ACE and PCE angles. In this study, the osteotomy fragments were rotated anteriorly to increase the anterior bony coverage, resulting in a significantly lower PCE angle than that in the control group; thus, posterior acetabular bone defect was more likely to occur. It has been reported that in THA after RAO, the cup was often placed more laterally compared to that in primary THA [8]. When comparing the RAO group to the control group, the hip center was laterally and superiorly positioned in the RAO group. This was thought to be the result of placing the cup in the superolateral region, where there was more bone volume, according to the shape of the RAO acetabulum. These results suggest that the posterior acetabular bone defect and cup position should be carefully considered in THA after RAO.

Bulk bone grafting is useful for acetabular defects [19, 20]; however, dislocation of grafted bone can occur in bulk bone grafting for bone defects after RAO [10]. We performed bulk bone grafting for a posterior acetabular bone defect, and the grafted bone survived without any postoperative dislocation. While it is necessary for the cup to be placed in an area of high bone mass to obtain good initial fixation, care should be taken in high placement. Elevating the center of the hip increases the bone coverage of the cup, but it also decreases the range of motion and is a risk factor for dislocation and THA failure [21–23]. Although the cup requires placing as close to the original acetabulum as possible, there is no difference in clinical outcomes or implant survival if the center of the head is no higher than 35 mm above the inferior edge of the teardrop in primary THA [24]. However, in THA after RAO, the osteotomy fragment is rotated more anteriorly, so the possibility of impingement of the anterior acetabular osteophyte, cup, or anterior inferior iliac spine with the femur is even higher with a high hip center. Therefore, careful preoperative planning and intraoperative confirmation of impingement and resection of the impinging bone are necessary. These were thought to be the reasons why the postoperative range of motion of THA after RAO was worse than that of the control group.

Although it has been known that bone defects in the anterior and posterior acetabular walls occur after RAO, this study is the first to evaluate bone defects in the anterior and posterior acetabular walls in THA after RAO using sagittal sections of CT. There were various limitations in this study. First, this was a retrospective study and patients were not randomized. There was no significant difference in patient background in terms of sex, age, follow-up period after THA, or surgical approach, although there could be bias due to unmeasured factors. Second, some patients are only a few years post-operative, and long-term follow-up data for such patients is not yet available. Because of the strong deformation of the acetabulum in these patients compared to those with primary THA, we will continue to follow-up the survival rate of THA, especially the cup survival rate, dislocation rate, and clinical evaluation over time.

Conclusion

The clinical results of THA after RAO were comparable to those of primary THA. Preoperative planning should be tailored to the acetabular deformity with attention to bone defects in the posterior wall of the acetabulum and dislocation due to impingement.

Abbrevations

DDH: Developmental dysplasia of the hip RAO

THA: total hip arthroplasty

CT: computed tomography

JOA: Japanese Orthopaedic Association

CE: center-edge

LCE: lateral cup center-edge

ACE: anterior cup center-edge

PCE: posterior cup center-edge

Declarations

Ethics approval and consent to participate: The ethics review board of our univaresity (the Ethics Committee of the University of Kagawa) authorized the study design after all participants signed an informed consent form for participation in the study (Approval code: 29-213).

Consent for publication: Not applicable.

Availability of data and material: The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: Not applicable.

Authors' contributions: TN wrote this article. TN, KI, MS, TS, YT conceived and designed the study, analysed and interpreted the data. TM, YK were involved in the data analysis. All authors critically revised the report, commented on drafts of the manuscript, and approved the final report.

Acknowledgements: We would like to thank Editage (www.editage.com) for their assistance in editing the English manuscript.

Informed Consent: All patients gave written informed consent.

References

1. Murphy SB, Kijewski PK, Millis MB, Harless A. Acetabular dysplasia in the adolescent and young adult. Clin Orthop Relat Res. 1990;261:214–23. https://doi.org/10.1097/00003086-199012000-00023.
2. Beck EC, Gowd AK, Paul K, Chahla J, Marquez-Lara AJ, Rasio J, Irie T, Williams J, Nho SJ. Pelvic osteotomies for acetabular dysplasia: Are there outcomes, survivorship and complication differences between different osteotomy techniques? J Hip Preserv Surg. 2021;7:764–76. https://doi.org/10.1093/jhps/hnab009.
3. Yasunaga Y, Ochi M, Terayama H, Tanaka R, Yamasaki T, Ishii Y. Rotational acetabular osteotomy for advanced osteoarthritis secondary to dysplasia of the hip. J Bone Joint Surg Am. 2007;89:246–55. https://doi.org/10.2106/jbjs.g.00246.
4. Min BW, Kang CS, Lee KJ, Bae KC, Cho CH, Choi JH, Sohn HJ, Sin HK. Radiographic progression of osteoarthritis after rotational acetabular osteotomy: Minimum 10-year follow-up outcome according to the Tönnis grade. Clin Orthop Surg. 2018;10:299–306. https://doi.org/10.4055/cios.2018.10.3.299.
5. Cho YJ, Kim KIl, Kwak SJ, Ramteke A, Yoo MC. Long-term results of periacetabular rotational osteotomy concomitantly with arthroscopy in adult acetabular dysplasia. J Arthroplasty. 2020;35:2807–12. https://doi.org/10.1016/j.arth.2020.05.045.
6. Nozawa M, Maezawa K, Matsuda K, Kim S, Shitoto K, Kurosawa H. Rotational acetabular osteotomy for secondary osteoarthritis after surgery for developmental dysplasia of the hip. HSS J. 2009;5:137–42. https://doi.org/10.1007/s11420-009-9119-6.
7. Tomioka M, Inaba Y, Kobayashi N, Tezuka T, Choe H, Ike H, Saito T. Ten-year survival rate after rotational acetabular osteotomy in adulthood hip dysplasia. BMC Musculoskelet Disord. 2017;18:191. https://doi.org/10.1186/s12891-017-1556-7.

8. Ito H, Takatori Y, Moro T, Oshima H, Oka H, Tanaka S. Total hip arthroplasty after rotational acetabular osteotomy. J Arthroplasty. 2015;30:403–6. https://doi.org/10.1016/j.arth.2014.10.002.
9. Yuasa T, Maezawa K, Nozawa M, Kaneko K. Total hip arthroplasty after previous rotational acetabular osteotomy. Eur J Orthop Surg Traumatol. 2015;25:1057–60. https://doi.org/10.1007/s00590-015-1657-7.
10. Tamaki T, Oinuma K, Miura Y, Shiratsuchi H. Total hip arthroplasty after previous acetabular osteotomy: Comparison of three types of acetabular osteotomy. J Arthroplasty. 2016;31:172–5. https://doi.org/10.1016/j.arth.2015.07.018.
11. Ma Y, Luo D, Cheng H, Xiao K, Chai W, Li R, Zhang H. Is cup positioning easier in DDH patients previously treated with Bernese periacetabular osteotomy? J Orthop Surg Res. 2020;15:501. https://doi.org/10.1186/s13018-020-02001-0.
12. Ito H, Matsuno T, Hirayama T, Tanino H, Yamanaka Y, Minami A. Three-dimensional computed tomography analysis of non-osteoarthritic adult acetabular dysplasia. Skeletal Radiol. 2009;38:131–9. https://doi.org/10.1007/s00256-008-0601-x.
13. Chiba D, Yamada N, Mori Y, Oyama M, Ohtsu S, Kuwahara Y, Baba K, Tanaka H, Aizawa T, Hanada S, Itoi E. Mid-term results of a new femoral prosthesis using Ti-Nb-Sn alloy with low Young’s modulus. BMC Musculoskelet Disord. 2021;22:987. https://doi.org/10.1186/s12891-021-04879-1.
14. Fukui K, Kaneuji A, Sugimori T, Ichiseki T, Matsumoto T. A radiological study of the true anatomical position of the acetabulum in Japanese women. Hip Int. 2011;21:311–6. https://doi.org/10.5301/HIP.2011.8395.
15. Yasunaga Y, Ochi M, Yamasaki T, Shoji T, Izumi S. Rotational acetabular osteotomy for Pre- and early osteoarthritis secondary to dysplasia provides durable results at 20 years. Clin Orthop Relat Res. 2016;474:2145–53. https://doi.org/10.1007/s11999-016-4854-8.
16. Kaneuji A, Sugimori T, Ichiseki T, Fukui K, Takahashi E, Matsumoto T. Rotational acetabular osteotomy for osteoarthritis with acetabular dysplasia: Conversion rate to total hip arthroplasty within twenty years and osteoarthritis progression after a minimum of twenty years. J Bone Joint Surg Am. 2015;97:726–32. https://doi.org/10.2106/JBJS.N.00667.
17. Yasunaga Y, Tanaka R, Mifuji K, Shoji T, Yamasaki T, Adachi N, Ochi M. Rotational acetabular osteotomy for symptomatic hip dysplasia in patients younger than 21 years of age: Seven- to 30-year survival outcomes. Bone Joint J. 2019;101–B:390–5. https://doi.org/10.1302/0301-620X.101B4.BJJ-2018-1200.R1.
18. Shoji T, Saka H, Inoue T, ‘Kato Y, Fujiwara Y, Yamasaki T, Yasunaga Y, Adachi N. Preoperative T2 mapping MRI of articular cartilage values predicts postoperative osteoarthritis progression following rotational acetabular osteotomy. Bone Joint J. 2021;103–B:1472–8. 10.1302/0301-620X.103B9.BJJ-2021-0266.R1.
19. Kim M, Kadowaki T. High long-term survival of bulk femoral head autograft for acetabular reconstruction in cementless THA for developmental hip dysplasia. Clin Orthop Relat Res. 2010;468:1611–20. https://doi.org/10.1007/s11999-010-1288-6.

20. Saito S, Ishii T, Mori S, Hosaka K, Nemoto N, Tokuhashi Y. Long-term results of bulk femoral head autograft in cementless THA for developmental hip dysplasia. Orthopedics. 2011;34:88. https://doi.org/10.3928/01477447-20101221-15.
21. Kiyama T, Naito M, Shitama H, Maeyama A. Effect of superior placement of the hip Center on Abductor Muscle Strength in total hip arthroplasty. J Arthroplasty. 2009;24:240–5. https://doi.org/10.1016/j.arth.2008.08.012.
22. Komiyama K, Fukushi JI, Motomura G, Hamai S, Ikemura S, Fujii M, Nakashima Y. Does high hip centre affect dislocation after total hip arthroplasty for developmental dysplasia of the hip? Int Orthop. 2019;43:2057–63. https://doi.org/10.1007/s00264-018-4154-x.
23. Kannan A, Madurawe C, Pierrepont J, McMahon S. Does total hip arthroplasty with high hip centre in dysplasia compromise acetabular bone stock? Hip Int. 2021;52:11207000211059442. https://doi.org/10.1177/11207000211059442.
24. Murayama T, Ohnishi H, Okabe S, Tsurukami H, Mori T, Nakura N, Uchida S, Sakai A, Nakamura T. 15-year comparison of cementless total hip arthroplasty with anatomical or high cup placement for Crowe I to III hip dysplasia. Orthopedics. 2012;35:e313–8. https://doi.org/10.3928/01477447-20120222-28.
25. **Legend to the figures and tables**.

Figures

Figure 1

Postoperative computed tomography of THA

LCE angle (*) is defined as shown in the postoperative coronal computed tomography image of THA (A). ACE (**) and PCE angle (***) is defined as shown in the postoperative sagittal computed tomography image (B)

Figure 2

Postoperative anteroposterior X-ray radiogram of THA

The vertical distance (*) is defined as the distance from the lower edge of the bilateral the tear drops to the center of the hip joint. The horizontal distance (**) is defined as the distance of the horizontal direction from the lower edge of the tear drop to the hip joint center

Figure 3

Postoperative anteroposterior X-ray radiogram of THA for a patient with hip osteoarthritis who underwent RAO 20 years ago (A)

This is the sagittal section of CT image. Bulk bone graft (arrow) was performed because of the fear of insufficient fixation of the cup due to bone defect in the posterior wall of the acetabulum (B)