Total hip arthroplasty after rotational acetabular osteotomy for developmental dysplasia of the hip: a retrospective observational study

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Abstract

Background: Total hip arthroplasty after osteotomy is more technically challenging than primary total hip arthroplasty, especially concerning cup placement. This is attributed 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 those of 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 of patients who underwent total hip arthroplasties between 2005 and 2020. We analyzed cup abduction and anteversion; 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 flexion range of motion was lower in total hip arthroplasty after rotational acetabular osteotomy than in primary total hip arthroplasty, although no significant difference was noted in the postoperative total Japanese Orthopedic Association hip score. The operative time was significantly longer in the rotational acetabular osteotomy group than in the control group, but there was no significant difference in blood loss. 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 acetabulum. 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.

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Keywords: Rotational acetabular osteotomy, Developmental dysplasia, Total hip arthroplasty, Bone defect, Hip center

**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 total hip arthroplasty (THA) 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 subsequent 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, to the best of our knowledge, no study to date has investigated the acetabular defects in THA after osteotomy in the anteroposterior direction. This study aimed to determine the clinical outcomes and radiographic evaluation, including CT, of THA after RAO and compare them with those of primary THA.

**Methods**

This was a retrospective observational study that compared two groups of patients. The ethics Committee of the University of Kagawa authorized the study design after all participants gave their informed permission (Approval code: 29–213). Between 2005 and 2020, THA was performed on 22 hips in 20 patients who had previously undergone RAO. RAO was performed in patients aged<50 years with painful DDH up to Tönnis grade 1 [13]. 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. THA in the left and right hips, in patients who underwent bilateral THA, was performed at different time points. For comparison, propensity score matching was used to identify 21 age- and sex-matched hips from 21 patients who had undergone THA for osteoarthritis secondary to DDH without undergoing prior hip surgery. These patients were included in the control group. Surgery was performed in 14 hips using the posterior approach and in seven hips using the direct anterior approach. Cementless stems and cups were used in all cases. In the RAO group, the following stems were used: S-ROM stems (DePuy Synthes, West Chester, PA, USA; 12 hips), Initia stems (Kyocera, Kyoto, Japan; four hips), Accolade II stems (Stryker Corp., Kalamazoo, MI, USA; two hips), Wagner cone stem (Zimmer Biomet, Warsaw, IN, USA; two hips), and Corail stems (DePuy Synthes; one hip); the following cups were used: Pinnacle cups (DePuy Synthes; 13 hips), SQRUM cups (Kyocera; four hips), Trident HA cups (Stryker; two hips), and Continuum cups (Zimmer Biomet; two hips). In the control group, J-taper stems (Kyocera; 18 hips) and S-ROM stems (DePuy Synthes; three hips), and SQRUM (Kyocera; 18 hips) and Pinnacle (Kyocera; three hips) cups were used. In patients with posterior wall defects of the acetabulum with the posterior center-edge (CE) angle less than 0 degrees, the bulk bone was grafted; the extracted femoral head bone of the patient was used as the bone graft, prepared to fit the bone defect. 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. The operative time, blood loss, and complications obtained from medical records were reviewed.

The Japanese Orthopedic Association (JOA) hip score [14] 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 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 PCE angle were defined as the angles 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) [15]. As the teardrop had moved after osteotomy, the position of the contralateral teardrop was used as a reference if no contralateral RAO was performed, and the CT finding 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 duration after THA, or method. RAO and THA were separated by an average of 17.3 years.

**Operative results**

The operative results are summarized in Table 2. The mean operative times were 173 and 130 min in the RAO

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**Fig. 1** Postoperative computed tomography of THA. The LCE angle (*) is defined as shown in the postoperative coronal computed tomography image of THA (a). The ACE (**) and PCE angles (***) are defined as shown in the postoperative sagittal computed tomography image (b) THA: total hip arthroplasty; LCE: lateral cup center-edge; ACE: anterior cup center-edge; PCE: posterior cup center-edge

**Fig. 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. THA: total hip arthroplasty
and control groups, respectively. The RAO group had a significantly longer operative time than the control group ($p < 0.001$; 95% CI, 22.2–64.2 min). The operative blood loss did not differ significantly between the two groups ($p = 0.24$).

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 values at the final follow-up examination were 16.4 and 17.9 points in the RAO and control groups, respectively. There was a significant difference in the ROM at the final follow-up examination between the two groups ($p < 0.03$; 95% CI, -2.87–-0.15 points). The flexion range

### 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             | 0.54    |
| Follow-up period after THA (years) | 7.1±4.2           | 6.5±1.9         |         |
| Age at THA (years)            | 57.2±9.2          | 60.6±6.4        | 0.17    |
| Surgical approach (PL/DA)     | 14/7              | 12/9            | 0.53    |

Data are presented as mean ± standard deviations or numbers

RAO Rotational acetabular osteotomy, THA Total hip arthroplasty, PL Posterior lateral, DA Direct anterior

### 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    |
| ROM (preoperative)            |                   |                 |         |
| Flexion (°)                   | 80.0±13.1         | 86.6±6.9        | 0.08    |
| Extension (°)                 | -2.2±3.0          | -3.6±5.1        | 0.30    |
| Abduction (°)                 | 19.7±7.0          | 17.9±9.1        | 0.50    |
| Adduction (°)                 | 12.2±3.0          | 9.5±5.8         | 0.09    |
| ROM (last follow-up)          |                   |                 |         |
| Flexion (°)                   | 92.2±6.8          | 99.2±8.3        | 0.02    |
| Extension (°)                 | -0.5±1.2          | -0.3±1.1        | 0.16    |
| Abduction (°)                 | 28.6±3.2          | 30.3±3.4        | 0.15    |
| Adduction (°)                 | 9.2±2.4           | 10±3.2          | 0.40    |
| Bone grafting                 | 2 (9.5)           | 0 (0)           | 0.15    |

Data are presented as mean ± standard deviations or numbers (%)

RAO Rotational acetabular osteotomy, JOA Japanese Orthopedic Association, ROM Range of motion
of motion at the final follow-up examination was lower in the RAO group than that in the control group ($p < 0.02$; 95% CI, -12.8–1.2°), although no significant differences were noted in extension, abduction, or adduction. 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, 1.5–10.8°), 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–-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, 4.05–12.6 mm); the vertical distance was 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, 2.45–9.65 mm), being 35.8 mm in the RAO group and 29.7 mm in the control group. The femoral anteversion angle did not differ significantly between the two groups preoperatively ($p = 0.30$) or postoperatively ($p = 0.20$).

### 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 | 345±10.3 | 0.20    |

Data are presented as mean ± standard deviations.

**RAO** Rotational acetabular osteotomy, **LCE** Lateral cup CE, **PCE** Posterior cup CE, **ACE** Anterior cup CE

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![Fig. 3](image_url)  Preoperative and postoperative X-ray and CT images of THA after RAO. Preoperative and postoperative anteroposterior radiographs of THA for a patient with hip osteoarthritis who underwent RAO 20 years ago (a, b). This is the axial section of CT image. Defects in the posterior wall of the acetabulum are observed (arrow) (c). This is the axial section of a CT image of a patient in the control group. There is no bone defect of acetabulum (arrow) (d). This is the sagittal section of a 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 (e). CT: computed tomography; RAO: rotational acetabular osteotomy; THA: total hip arthroplasty.
are factors that complicate THA after RAO when com-
in the posterior acetabular wall with large osteophytes
and radiographic evaluation. In addition, bone defects
placement is difficult and may affect the operative time
can affect clinical outcomes remains unknown, but cup
has been reported that THA after RAO is more challeng-
compared with primary THA [22, 23]. Furthermore, it
has been reported that THA after RAO is more challeng-
ing to perform due to bone deformity and the operative
time is significantly longer than that of primary THA
[8, 24]. As mentioned above, whether a previous RAO
can affect clinical outcomes remains unknown, but cup
placement is difficult and may affect the operative time
and radiographic evaluation. In addition, bone defects
in the posterior acetabular wall with large osteophytes
are factors that complicate THA after RAO when com-
pared with that after Chiari osteotomy and shelf acetabu-
plasty [10]. As shown in these reports, bone defects in
the acetabular wall are characteristics of RAO. However,
there are no reports that have examined bone coverage
in the anterior–posterior direction in CT after THA, as
the ACE and PCE angles. In this study, the osteotomy
fragments were rotated anteriorly to increase the ante-
rior bony coverage, resulting in a significantly lower PCE
angle than that in the control group; thus, the 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 to the control group, the
hip center was laterally and superiorly positioned in the
RAO group. This was thought to be the result of plac-
ing 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 ace-
tabular bone defect and cup position should be carefully
considered when performing THA after RAO. Regard-
ing the angle of cup placement, osteosclerosis and osteo-
phytes around the acetabulum after osteotomy can make
the surgery more difficult [9], and acetabular retroversion
and posterior wall defects can reduce the cup antever-
sion angle [25, 26]. We have addressed these limitations
by performing careful preoperative surgical planning and
adequate fluoroscopic confirmation of the cup angle. In
addition, the direct anterior approach was used in some
cases, which allowed more accurate placement of the cup
by stabilizing the pelvis in the supine position and using a
cup alignment guide based on the anterior superior iliac
spine.

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 charac-
teristic bone defect in the posterior wall of the acetabu-
um because of the excessive anterior rotation of the
osteoarthrosis leading to THA [18, 19]. Whether a pre-
vious RAO has an impact on the clinical outcomes of
subsequent THA remains controversial. Interestingly,
previous studies have reported no significant differ-
ences in postoperative clinical, operative time, blood
loss, or cup inclination angle [20, 21]. In contrast, stud-
ies have reported that THA after RAO decreases the
postoperative Harris hip score and patient satisfaction
compared with primary THA [22, 23]. Furthermore, 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 [29–31].
Although the cup needs to be placed as close to the
original acetabulum as possible, there is no significant
difference in clinical outcomes or implant survival if
the center of the head is not higher than 35 mm above
the inferior edge of the teardrop in primary THA [32].
We allowed slight elevation of the center of the hip,
as we thought that it was better to fix the cup without
bone grafting in the superior part of the loading area
to achieve cup stability. However, when performing
THA after RAO, the osteotomy fragment is rotated
more anteriorly. Thus, the possibility of impingement
of the anterior acetabular osteophyte, cup, or ante-
rior inferior iliac spine with the femur is even higher
with a high hip center. Therefore, careful preoperative
planning and intraoperative confirmation of impinge-
ment and resection of the impinging bone are nec-
essary. This bony impingement could be the reason
for the poorer postoperative range of motion in the
THA after RAO group compared with that in the con-
control group. Although it is necessary to reduce the leg
length difference as much as possible when elevating
the hip center, the two patients with bilateral THA in
this study had good postoperative outcomes with no leg length difference.

Although it has been known that bone defects in the anterior and posterior acetabular walls occur after RAO, to the best of our knowledge, this study is the first to evaluate bone defects in the anterior and posterior acetabular walls when performing THA after RAO using sagittal sections of CT. Since the PCE angle is significantly reduced in THA after RAO, the posterior defect of the acetabulum and cup stability should be carefully considered when performing THA.

However, 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 because of unmeasured factors. Second, only a few years had passed since surgery in some cases of patients and, therefore, long-term follow-up data of such patients are 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.

**Abbreviations**

DDH: Developmental dysplasia of the hip; RAO: Total hip arthroplasty; CT: Computed tomography; JOA: Japanese Orthopaedic Association; CE: Center-edge; LCE: Lateral cup center-edge; ACE: Anterior cup center-edge; PC: Posterior cup center-edge.

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**Authors’ contributions**

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

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**Availability of data and materials**

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

**Declarations**

**Ethics approval and consent to participate**

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.

**Competing interests**

The authors declare that they have no competing interests.

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