Title

Leg length change after curved periacetabular osteotomy and its impact on the clinical outcomes

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Abstract

***Background*:** Curved periacetabular osteotomy (CPO) is one of the periacetabular osteotomies for the treatment of acetabular dysplasia. Several complications have been described after CPO, however, there have been no reports on the leg length change (LLC). This study aimed to investigate the LLC after CPO and its impact on the clinical outcomes.

***Methods*:** This study was a retrospective review of 70 consecutive hips in 67 patients with symptomatic acetabular dysplasia who underwent CPO between March 2016 and April 2019. Preoperative and postoperative leg lengths were measured using anteroposterior radiographs, and the clinical outcomes were evaluated based on the Harris hip score (HHS) and Medical Outcomes Survey 36-item Short Form Health Survey (SF-36).

***Results*:** The mean LLC (and standard deviation) after CPO was −0.08 ± 3.10 mm. The mean HHS significantly improved from 73.5 points to 91.9 points ($P < 0.001$). The physical component and role component scores of SF-36 significantly improved from 35.1 to 46.1 ($P < 0.001$) and from 39.5 to 47.0 ($P < 0.001$), respectively. No significant differences were found between the pre- and postoperative mental component scores of SF-36. Additionally, among 70 hips, 35 hips exhibited leg length elongation (0 to plus

6.82 mm) after CPO, whereas 35 hips exhibited leg length shortening (0 to minus 6.23 mm). No significant differences were found in HHS and SF-36 between the leg elongation group and leg shortening group.

Conclusions**:** The mean LLC after CPO was −0.08 ± 3.10 mm, and this change does not affect the postoperative clinical outcomes.

Keywords:

curved periacetabular osteotomy

leg length change

acetabular dysplasia

Introduction

Acetabular dysplasia of the hip is one of the major causes of hip osteoarthritis [1]. Several osteotomies, such as femoral intertrochanteric or subtrochanteric varus osteotomy [2,3] and periacetabular osteotomy (PAO) [4-8], have been reported for the surgical treatment of symptomatic acetabular dysplasia. The success rates of varus osteotomy ranged from 67.6% to 93.8% [9,10], in which postoperative leg length change (LLC) has been reported to be observed around 0 to minus 40 mm [11-13]. Although good clinical outcomes have been reported [12], Patient Reported Outcome Measures (PROMs) has not been evaluated for the postoperative leg shortening.

Curved periacetabular osteotomy (CPO) is one of the PAOs that uses an anterior approach, and the success rates of CPO range from 94.3% to 96.8% [4,14-16]. The complications after CPO have been reported to be nonunion of the ischial or pubic osteotomy site [17], stress fractures of the inferior ramus of the pubis or ischium [18], injury to the lateral femoral cutaneous nerve [18], and narrowing of the bony birth canal [19]. However, there have been no reports on the LLC after CPO.

This study aimed to investigate the LLC after CPO and evaluate its effects on the clinical outcomes, including PROMs.

Materials and Methods

Our institutional review board approved this study. We performed a retrospective review of 74 hips in 71 consecutive patients with symptomatic acetabular dysplasia who underwent CPO between March 2016 and April 2019. The exclusion criteria were: 1) history of trauma or previous surgery; 2) deformity of the femoral head; 3) lost to follow-up. One hip was excluded owing to a Perthes-like deformity of the femoral head. In addition, three hips were lost to follow-up because 1 patient moved to another prefecture, 1 studied abroad, and 1 was admitted to another hospital for another disease. The final study cohort included 70 hips in 67 patients (follow-up rate, 95.9%). There were 5 males and 62 females with a mean age of 37 years (range, 15–60) at the time of surgery. The mean body mass index (BMI) was 22.9 kg/m^2 (range, 16.8–34.1). The mean follow-up was 12.2 months (range, 12–17) (Table 1). Notably, 3 patients underwent bilateral operations. All hips had a primary operation and had no histories of trauma.

In our institution, indications for CPO include acetabular dysplasia with symptoms, such as pain, that is tolerable but uncomfortable and has caused some limitations in daily activities for >5 months; a lateral center-edge angle (LCEA) [20] of <25° on anteroposterior (AP) radiographs in the supine position; improvement in joint congruency on an AP pelvic radiograph with the hip in abduction; and closed triradiate cartilage and age <65 years at the time of surgery [18]. Because the previous studies have reported a poor clinical outcome of CPO in patients with Tönnis grade 2 or 3 osteoarthritis [21-24], CPO was only indicated for patients with Tönnis grade 0 or 1 osteoarthritis. All surgical procedures were performed by two senior orthopedic surgeons at a single institution.

Surgical Technique and Postoperative Rehabilitation

CPO was performed in the supine position. An anterior incision was made from the distal border of the anterior superior iliac spine (ASIS) and extended distally for approximately 8 cm along the tensor fasciae latae. The ASIS was then osteotomized and retracted medially with the inguinal ligament and sartorius muscle. The iliopsoas muscle was then partially detached around the iliac osteotomy site and retracted medially along with the femoral artery, vein, and nerve. Using a power drill, a C-shaped osteotomy line was started proximal to the anterior inferior iliac spine, ending at the distal part of the quadrilateral surface. The ischium was osteotomized using an image intensifier when the chisel touched the innominate groove. Osteotomy of the superior ramus of the pubis was performed just medial to the iliopubic eminence and at an inclination of 30° to the sagittal line to medialize the femoral head. Finally, osteotomy of the quadrilateral surface was performed using a curved chisel (Fig. 1). The acetabular fragment was rotated laterally to make the weight-bearing area horizontal and fixed with three poly-L-lactic acid screws (Osteotrans Plus; Takiron Co., Osaka, Japan) without iliac bone graft (Fig. 2). The osteotomized ASIS was then repositioned and fixed with two titanium cannulated cancellous screws.

On the first postoperative day, active motion exercises were started. At 2 weeks, 20-kg partial weight-bearing was allowed using two crutches or a walker, followed by an increase of 10 kg in weight every 2 weeks. Full weight-bearing was allowed at 3 months and returning to heavy work as well as sports activities were allowed at 6 months postoperatively.

Clinical Evaluations

A clinical assessment based on the Harris hip score (HHS) [25] and the Medical Outcomes Survey 36-item Short Form Health Survey (SF-36) [26] was conducted preoperatively and at 1 year postoperatively. The HHS assesses four categories using a 100-point scale: pain, function, range of motion, and absence of deformity. The SF-36 is widely used as a generic measure of quality of life. This self-reported outcome measure calculates eight subscales and three overall summary scores according to the patients' responses to 36 questions. Subscales include physical functioning (PF), role physical (RP), bodily pain, general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). The summary scores include physical component score (PCS), mental component score (MCS), and role component score (RCS). There is a high correlation between PCS and PF; MCS and three subscales (GH, VT, and MH); and RCS and three subscales (RP, SF, and RE) [27]. These component scores are calibrated so that 50 is the average score or norm. Furthermore, we evaluated the incidence of lateral femoral cutaneous nerve injury at 1 year postoperatively.

Radiographic Evaluations

AP radiographs were taken in the supine position and standardized by the tube-to-film distance to be 120 cm, and the tube was oriented perpendicularly to the table. In addition, central beam was directed towards the mid-point between the upper border of the symphysis and a horizontal line connecting the anterior superior iliac spines. Radiographic evaluations included measurement of the LCEA and acetabular roof obliquity (ARO) [28], head lateralization index (HLI) [29] (Fig. 3), and LLC (Fig. 4) on the AP radiographs at the same time as the clinical assessment pre- and postoperatively. Furthermore, we evaluated the incidences of nonunion of the ischium, pubis, and ilium, and the presence of stress fractures of the inferior ramus of the pubis or ischium on radiographs. The AP radiographs at 1 year postoperatively were performed at a mean of 12.2 ± 0.9 months (range, 12–17 months) postoperatively. We measured the distance between the center of the femoral head and the bottom of the obturator foramen because the teardrop was moved after CPO, and the LLC was defined as the difference preoperatively and one year postoperatively (Fig. 4). To eliminate magnification errors, we measured the distance between two points: the bilateral lateral and medial edges of the obturator foramen (Fig.5). Leg length elongation was defined as an LLC of >0 mm, and leg length shortening was defined as an LLC of <0 mm.

Patients who exhibited leg length elongation on radiographs were assigned to the leg length elongation group (E group), whereas those who exhibited leg length shortening on radiographs were assigned to the leg length shortening group (S group). Measurements of radiographs were performed independently by two orthopedic surgeons. In addition, the same observer reviewed the radiographs three times on different days, and the average values were calculated. We assessed intra- and interobserver reliabilities for LLC. Intraobserver reliabilities of LLC were 0.93, and interobserver reliabilities of LLC were 0.91.

Statistical Analysis

The Mann−Whitney *U* test was used to compare patients' characteristics, clinical scores, and radiographic data between the two groups (E and S groups). The Wilcoxon signed-rank test was used to compare changes in radiographic parameters within the same group. The chi-square test was used to compare categorical data such as sex. The Pearson's correlation coefficient was used to calculate the correlation between the LLC and radiographic data (i.e, the pre- and postoperative LCEA and correction of the LCEA, the pre- and postoperative ARO and correction of the ARO, and the pre- and postoperative HLI). The intraclass correlation analysis was used to calculate the intraobserver and interobserver reliability of the LLC measurement. SPSS version 20.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. P value of <0.05 was considered statistically significant.

Results

The mean distance between the center of the femoral head and the bottom of the obturator foramen was 50.99 mm preoperatively and 51.07 mm postoperatively (Fig. 6); the mean ± standard deviation LLC after CPO was −0.08 ± 3.10 mm (range: −6.23 to 6.82 mm). The pre- and postoperative radiographic data and clinical evaluations are presented in Table 2. The distance between the lateral and medial edges of the obturator foramen did not change pre- and postoperatively, indicating that there was no magnification error. We also confirmed that the shape of the obturator foramen was not changed in all cases. The mean LCEA, ARO, and HLI improved significantly. The mean preoperative HHS was 73.5 points, which improved to a mean of 91.9 points postoperatively ($P < 0.001$). The mean pain and function scores improved from 24.6 points to 38.7 points ($P < 0.001$) and from 41.3 points to 44.5 points ($P < 0.001$), respectively. The PCS and RCS of SF-36 improved significantly from 35.1 to 46.1 ($P < 0.001$) and from 39.5 to 47.0 ($P < 0.001$). No significant differences were found between the pre- and postoperative MCS of SF-36. No correlations were found between the postoperative LLC and the radiographic data; pre- and postoperative LCEA and correction of LCEA; pre- and postoperative ARO and correction of ARO ($r = -0.17$ to 0.18) (Table 3).

After CPO, 35 of 70 hips exhibited leg length elongation (0 to minus 6.82 mm), whereas

35 hips exhibited leg length shortening (0 to plus 6.23 mm). There were 35 hips in the E group (2 males and 33 females) and 35 hips in the S group (3 males and 32 females). No significant differences were found in the patients' characteristics (sex, age, and BMI) and radiographic data (pre- and postoperative LCEA and correction of LCEA; pre- and postoperative ARO and correction of ARO; pre- and postoperative HLI) between the two groups (Table 4). In clinical evaluations, both the HHS and any component of SF-36 indicated no significant differences between the two groups (Table 5). There was no correlation between the absolute LLC value and the change in the HHS and any component of the SF-36 (Fig. 7).

In the present study, there was no surgical site infection or nonunion of the osteotomy site of the ilium. The incidence of ischial nonunion was 7.1% (5/70 hips) and that of pubic nonunion was 20.0% (14/70 hips). The incidence of stress fractures of the inferior ramus of the pubis or ischium was 7.1% (5/70 hips), but bone union was confirmed at 1 year after CPO in all cases. Lateral femoral cutaneous nerve injury was observed in 30 of 70 (42.9%) patients at 1 year postoperatively.

Discussion

There have been no reports on the LLC after PAO using an anterior approach, including Bernese PAO [5], University of Colorado PAO [8], and CPO. Alternatively, in PAO using lateral approach, such as rotational acetabular osteotomy (RAO), the mean LLC has been reported to be + 3.5 mm (range: −8 to 20 mm) [30] when the inner cortex of the ilium was cut. In addition, the mean LLC has been reported to be + 5 mm (range: −6 to 19 mm) when the inner cortex of the ilium was not cut but iliac bone grafting was performed [31]. Our results showed almost similar LLC with their results.

In this study, the range of LLC after CPO was −6.23 to 6.82 mm. This variation may be caused by the following two reasons. One could be that the center of the iliac osteotomy line was not completely aligned with the center of the femoral head. To prevent LLC after CPO, it is necessary to adjust each center to the same point. However, it was difficult to draw such iliac osteotomy line intraoperatively. Another reason could be that the iliac osteotomy line was not completely spherical. When both convex sides were matched, some degree of leg elongation could be observed. Conversely, matching of both concave sides may result in leg shortening.

This study adopted the SF-36 to assess the effect of LLC on the mental health status after CPO. The postoperative MCS was well maintained at the same level with the preoperative score, and MCS showed no significant difference between the E and S groups. Thus, we believe that the degree of LLC in this study did not directly affect mental health status.

There are several limitations in this study. First, the required 1-year clinical and radiographic evaluations were performed from 12–17 months postoperatively. Based on computed tomography, the fusion of iliac osteotomy site has been confirmed at 1 year after CPO in all cases [17]. Thus, this difference in the timing was unlikely to affect the LLC measurement. Second, LLC was evaluated only using AP radiographs, and the anterior–posterior tilt of the pelvis could not be precisely evaluated. Therefore, we confirmed that the shape of the obturator foramen was not changed in all cases. Third, the SF-36 has no direct question regarding LLC. Because no patients complained about the LLC at the time of outpatient interview, we believe that LLC has not directly affected the mental health status.

Conclusion

The mean LLC after CPO was −0.08 ± 3.10 mm, and this change does not affect the postoperative clinical outcomes.

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Table 1. Patients' characteristics

	n = 70 (67 patients)
Age at surgery (years)	37.0 ± 12.6 (15 to 60)
Sex, male:female (no, of hips)	5:65
Body mass index (kg/m^2)	22.9 ± 3.2 (16.8 to 34.1)
Mean follow-up (months)	12.2 ± 0.9 (12 to 17)

All data are expressed as the mean ± standard deviation (range).

Table 2. Radiographic measurements and clinical evaluations pre- and postoperatively

Parameters	Preoperative	Postoperative	P-value
Radiographic measurements			
Leg length change	–0.08 ± 3.10 mm (–6.23 to 6.82)		
Lateral center-edge angle (°)	12.8± 0.9 (–6.9 to 29.6)	36.7 ± 8.1 (19.1 to 57.2)	< 0.001
Acetabular roof obliquity (°)	17.7 ± 5.8 (5.7 to 29.9)	–2.7 ± 6.8 (–19.2 to 14.6)	< 0.001
Head lateralization index	0.68 ± 0.07 (0.56 to 0.87)	0.62 ± 0.09 (0.45 to 0.83)	< 0.001
Clinical evaluations			
Harris Hip Score (full score)			
Total (100)	73.5 ± 11.7 (39 to 96)	91.9 ± 7.1 (68 to 100)	< 0.001
Pain (44)	24.6 ± 7.7 (10 to 40)	38.7 ± 4.6 (30 to 44)	< 0.001
Function (47)	41.3 ± 5.7 (22 to 47)	44.5 ± 3.6 (34 to 47)	< 0.001
SF-36			
Physical component score	35.1 ± 11.1 (4.2 to 60.0)	46.1 ± 9.2 (25.4 to 72.0)	< 0.001
Mental component score	51.6 ± 11.9 (20.7 to 78.6)	53.0 ± 9.4 (33.0 to 72.0)	0.30

Role component score	39.5 ± 17.0 (–2.4 to 68.0)	47.0 ± 13.4 (2.5 to 63.1)	< 0.001

All data are expressed as the mean ± standard deviation (range).

Table 3. Correlations between the postoperative LLC and radiographic data

	Correlation coefficient, r	P-value
Lateral center-edge angle (°)		
Preoperative	–0.08	0.47
Postoperative	0.07	0.56
Correction	0.18	0.12
Acetabular roof obliquity (°)		
Preoperative	0.06	0.62
Postoperative	–0.08	0.47
Correction	–0.17	0.14
Head lateralization index		
Preoperative	–0.08	0.49
Postoperative	–0.14	0.24

Table 4. Characteristics and radiographic measurements pre- and postoperatively of patients in the E and S groups

Parameters	Elongation group (n = 35)	Shortening group (n = 35)	P-Value
Sex, male:female (no, of hips)	2:33	3:32	0.50
Age at surgery (years)	35.5 ± 13.0 (17 to 55)	38.9 ± 12.3 (15 to 60)	0.26
Body mass index (kg/m^2)	22.8 ± 3.3 (18.0 to 30.2)	23.0 ± 3.2 (18.0 to 30.2)	0.78
Mean follow-up (months)	12.3 ± 0.9 (12 to 17)	12.2 ± 0.9 (12 to 16)	0.40
Radiographic measurement			
Lateral center-edge angle (°)			
Preoperative	11.7 ± 8.1 (–6.3 to 23.9)	14.0 ± 7.6 (–6.9 to 29.6)	0.22
Postoperative	36.5 ± 7.1 (19.1 to 51.9)	36.9 ± 6.8 (24.0 to 57.2)	0.83
Correction	24.9 ± 5.4 (15.4 to 36.6)	22.9 ± 7.1 (8.1 to 36.8)	0.19
Acetabular roof obliquity (°)			
Preoperative	18.5 ± 5.9 (9.1 to 29.9)	16.9 ± 5.6 (5.7 to 28.5)	0.27
Postoperative	–2.5 ± 7.2 (–18.1 to 14.6)	–2.9 ± 6.5 (–19.2 to 6.6)	0.83

Correction	–21.0 ± 4.9 (11.5 to 30.8)	–19.8 ± 5.6 (6.8 to 35.6)	0.35
Head lateralization index			
Preoperative	0.69 ± 0.08 (0.57 to 0.89)	0.69 ± 0.07 (0.56 to 0.86)	0.64
Postoperative	0.62 ± 0.09 (0.47 to 0.83)	0.63 ± 0.09 (0.45 to 0.79)	0.57

All data are expressed as the mean ± standard deviation (range).

Table 5. Harris hip score and SF-36 1 year postoperatively in the E and S groups

	Elongation group (n = 35)	Shortening group (n = 35)	P-Value
Harris hip score (points)			
Preoperative	73.0 ± 10.3 (45 to 96)	73.9 ± 13.1 (39 to 96)	0.73
Postoperative	92.7 ± 6.6 (78 to 100)	91.1 ± 7.6 (68 to 100)	0.30
SF-36 (points)			
Physical component score			
Preoperative	35.3 ± 10.8 (14.0 to 62.0)	35.0 ± 11.5 (4.2 to 59.1)	0.92
Postoperative	46.1 ± 7.5 (31.1 to 65.1)	46.1 ± 10.7 (25.4 to 60.4)	0.98
Mental component score			
Preoperative	50.7 ± 11.4 (20.7 to 73.9)	52.6 ± 12.5 (23.4 to 78.6)	0.51
Postoperative	54.0 ± 9.4 (33.0 to 72.0)	52.1 ± 9.2 (34.1 to 70.4)	0.34
Role component score			
Preoperative	39.2 ± 16.0 (1.4 to 68.0)	40.0 ± 18.1 (–2.4 to 66.9)	0.85
Postoperative	45.8 ± 12.6 (13.3 to 63.1)	48.1 ± 14.3 (2.5 to 61.8)	0.45

All data are expressed as the mean ± standard deviation (range).

Figure Legends

Fig.1. Three-dimensional bone models of the pelvis.

Graphics showing the osteotomy line of curved periacetabular osteotomy (red line). A. Medial view of the pelvis. A c-shaped osteotomy line is started proximal to the anteroinferior iliac spine, ending in the distal part of the quadrilateral surface. B. Lateral view of the pelvis.

Fig.2. Pre- and postoperative three-dimensional bone models of the pelvis on anteroposterior view.

A. Preoperative pelvis. B. Postoperative pelvis. The acetabular fragment is rotated laterally to make the weight-bearing area horizontal and fixed with three poly-L-lactic acid screws without iliac bone graft.

Fig. 3. Diagrams showing the methods of measuring in radiological assessment

A. α = lateral center-edge angle (°) **B.** β = acetabular roof obliquity (°) **C.** Radiographic indices measured from AP radiographs: distance between the bilateral Kohler ilioischial lines (t) and distance from each Kohler ilioischial line to the center of the femoral head (a). Head lateralization index (HLI) was calculated using the following formula: HLI = a / t / 2.

Fig. 4. To measure the leg length change, the distance between the center of the femoral head and the bottom of the obturator foramen was examined (d) preoperatively and (d') postoperatively. Leg length change is the value obtained by subtracting (d) from (d').

Fig. 5. On anteroposterior radiographs, to eliminate magnification errors, we measured the distance between two points: **A.** the bilateral lateral edges of the obturator foramen and **B.** the bilateral medial edges of the obturator foramen pre- and postoperatively.

Fig. 6. Graph showing the distance between the center of the femoral head and the bottom of the obturator foramen pre- and postoperatively. The mean preoperative value was 50.99 mm (range: 40.10 to 68.70 mm) and the mean postoperative value was 51.07 mm (range: 36.75 to 69.41 mm) (Wilcoxon signed-rank test; $n = 70$, $p = 0.82$).

Fig. 7. Graphs showing the correlation between the absolute LLC value and the changes in the clinical scores. LLC: leg length change, HHS: Harris Hip Score, PCS: physical component score, MCS: mental component score, RCS: role component score.

Fig. 1

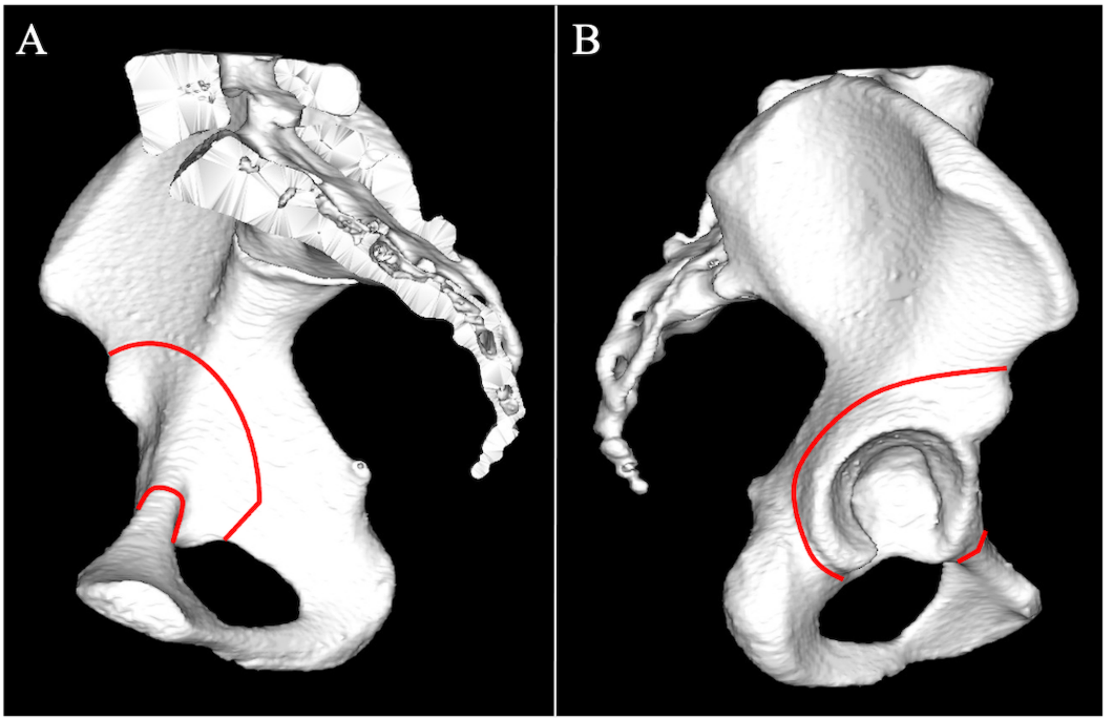


Fig. 2

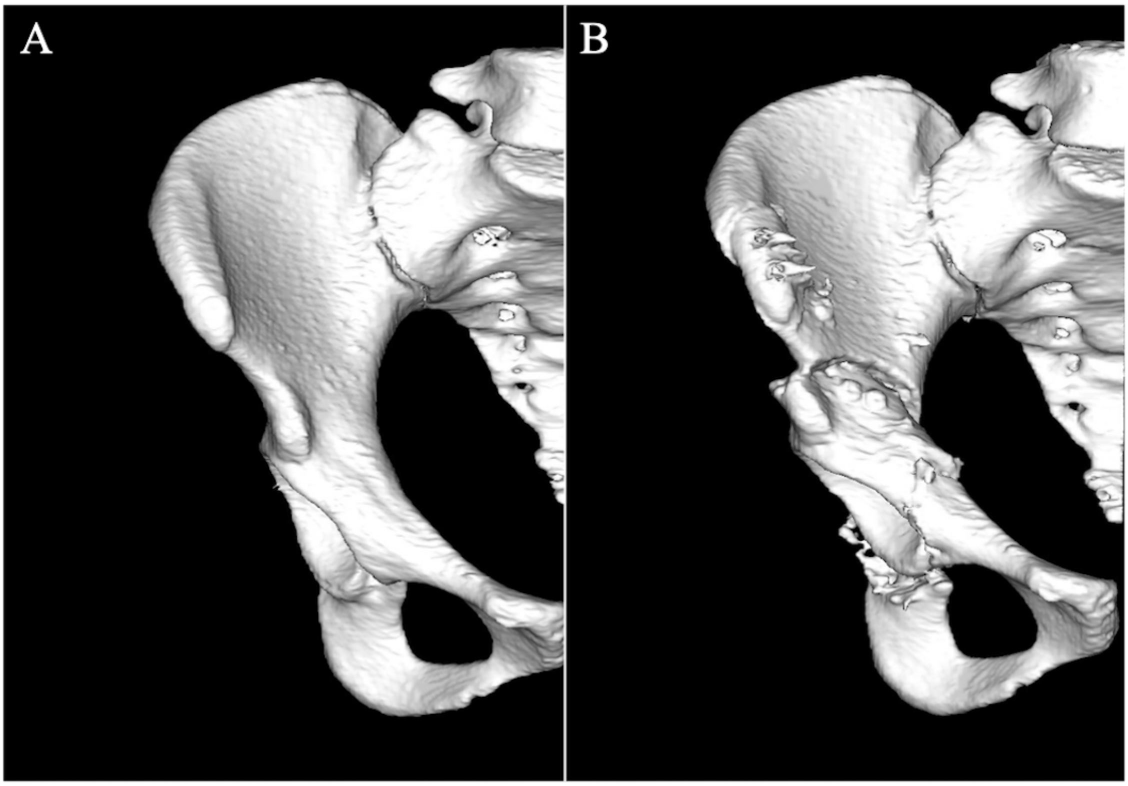


Fig. 3

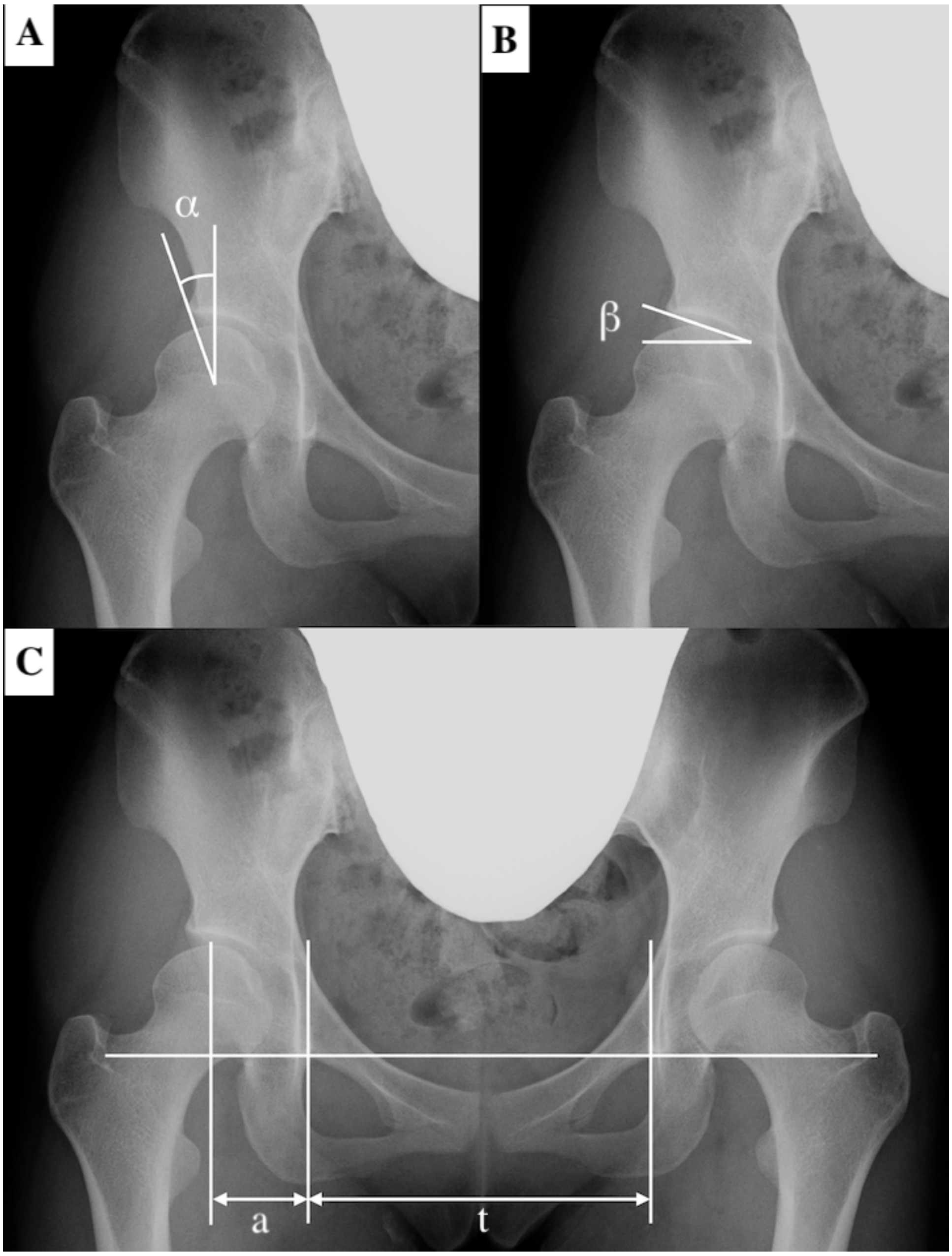


Fig. 4

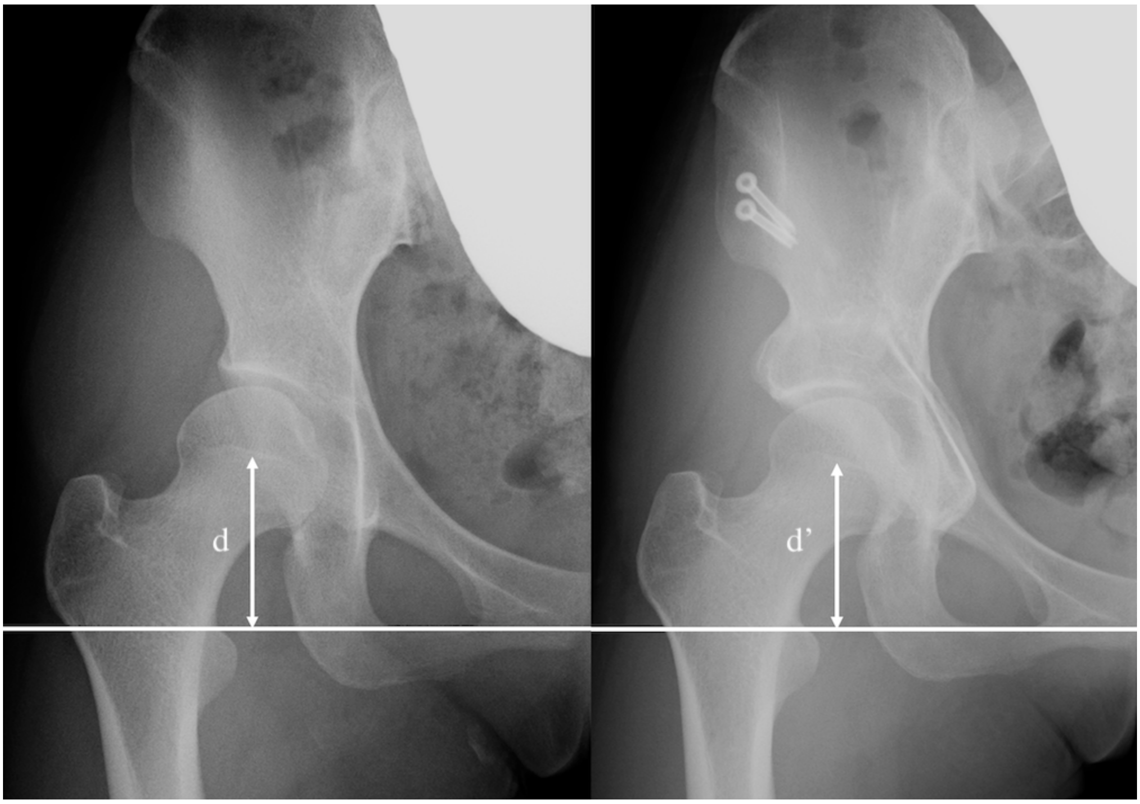


Fig. 5

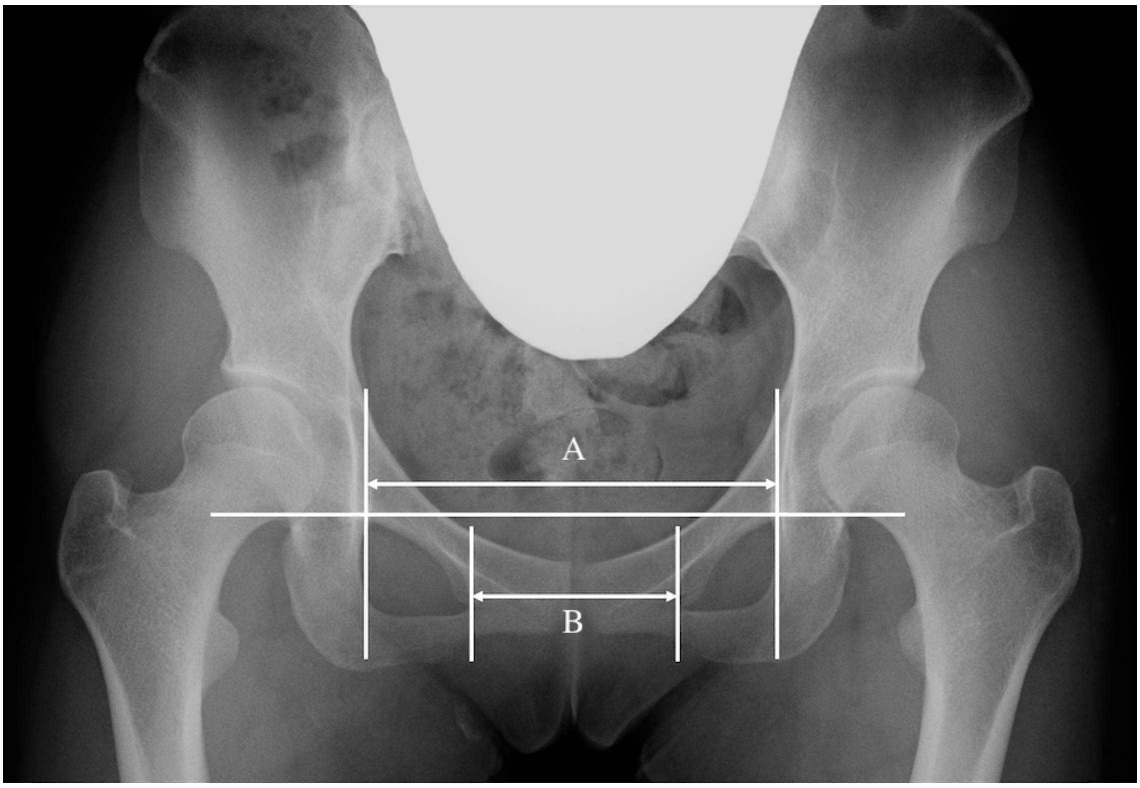


Fig. 6

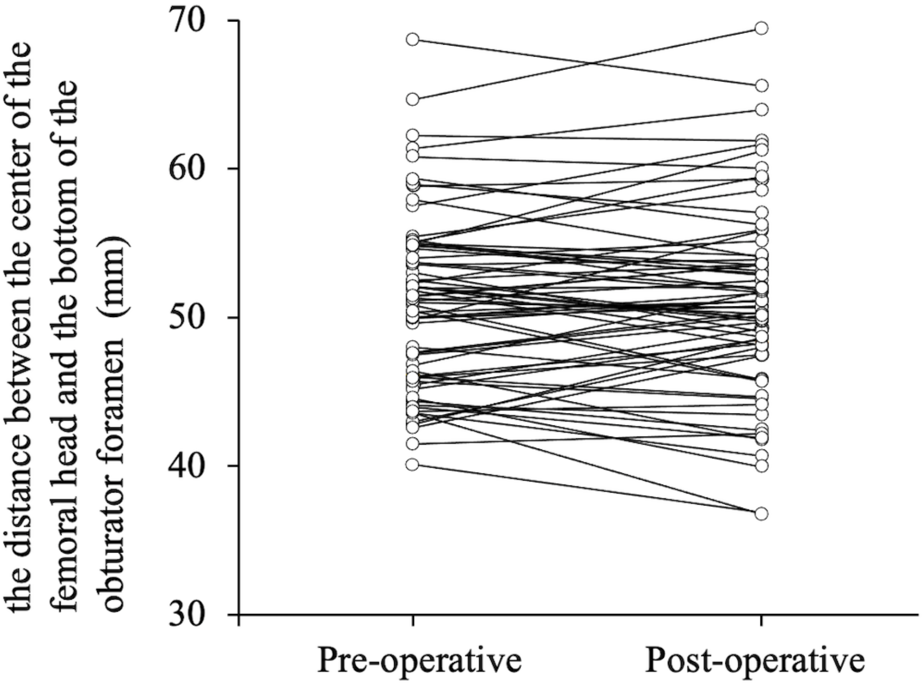
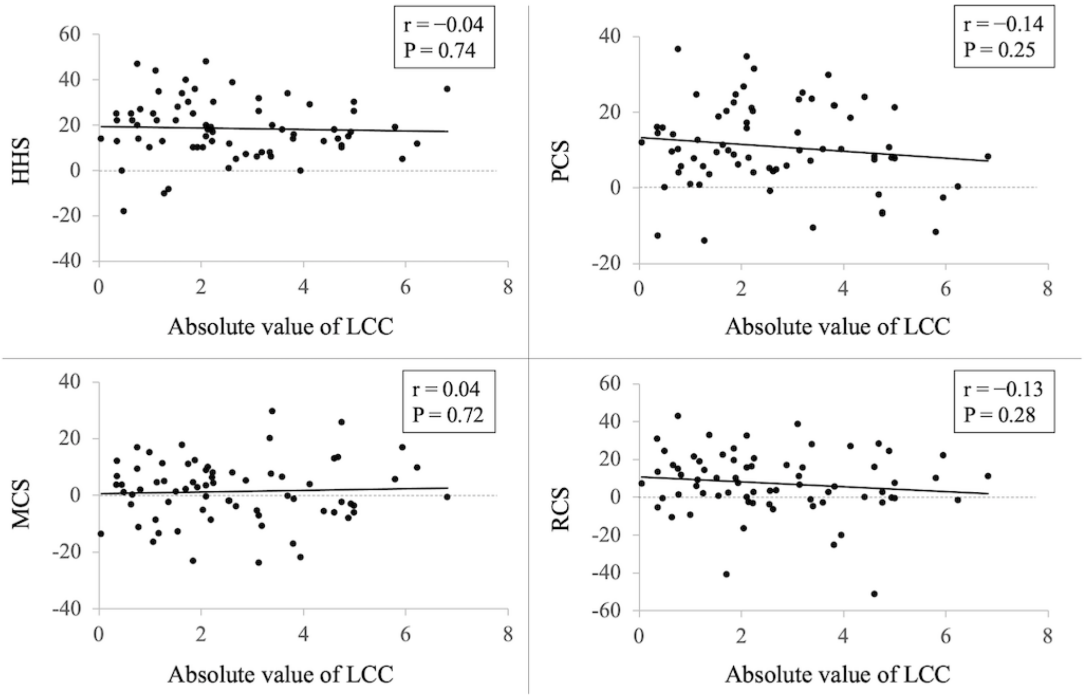

the distance between the center of the femoral head and the bottom of the obturator foramen (mm)
70
60
50
40
30
Pre-operative
Post-operative

Fig. 7



r = −0.04
P = 0.74
HHS
Absolute value of LCC
r = −0.14
P = 0.25
PCS
Absolute value of LCC
r = 0.04
P = 0.72
MCS
Absolute value of LCC
r = −0.13
P = 0.28
RCS
Absolute value of LCC