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ORIGINAL ARTICLE

Clinico-radiological factors affecting the joint space narrowing after transtrochanteric anterior rotational osteotomy for osteonecrosis of the femoral head

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Abstract
Purpose The purpose of this study was to investigate the factors that affect the joint space narrowing after transtrochanteric anterior rotational osteotomy (ARO) for osteonecrosis of the femoral head (ONFH).
Methods We reviewed 39 cases (43 hips) of ONFH in patients who underwent ARO between 2000 and 2004. Their mean age was 42 years (23–61) at the time of surgery. The mean follow-up period was 7.3 years (3–10). The following clinical and radiological factors were investigated: the preoperative stage, localization and extent of the necrotic lesion, and the postoperative intact ratio (transposed intact articular surface of the femoral head to the weight-bearing surface of the acetabulum). The 43 hips were divided into two groups: a joint space narrowing (JSN) group and a non-joint space narrowing (non-JSN) group.
Results Thirty-seven hips (86 %) were categorized as non-JSN and six (14 %) as having JSN. The preoperative Japanese Orthopaedic Association score was significantly higher in the non-JSN group than in the JSN group ($P = 0.01$). In the non-JSN group, the rate of early stage disease was significantly higher than in the JSN group ($P = 0.03$). The postoperative intact ratio was significantly higher in the non-JSN group than in the JSN group ($P = 0.002$). A multivariate analysis revealed that the postoperative intact ratio was an independent predictor of the progression of joint space narrowing after ARO, and the cutoff point was 39.2 %.
Conclusion The results of this study suggest that the postoperative intact ratio is one of factors determining the progression of joint space narrowing after ARO and that an approximately 40 % or higher postoperative intact ratio is recommended to prevent joint space narrowing.

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Introduction

Osteonecrosis of the femoral head (ONFH) often occurs in young and middle-aged adults [1, 2]. The natural history of ONFH generally involves a progressive femoral head collapse and secondary osteoarthritic changes, which often require surgical treatment [1, 3]. Since the necrotic lesion is generally localized in the anterosuperior aspect of the femoral head, transtrochanteric anterior rotational osteotomy (ARO) has been developed as one of the joint-preserving procedures for these patients [4, 5].

Several authors have reported that the postoperative intact ratio (the transposed intact articular surface of the femoral head to the weight-bearing surface of the acetabulum) is one of the important factors correlated with the progressive collapse after ARO [5–9]. Miyanishi et al. [9] reported that the minimum postoperative intact ratio to prevent the progressive collapse after ARO was 34 %. On the other hand, some patients treated by ARO gradually show the progression of joint space narrowing without progressive collapse, eventually leading to the deterioration of the hip joint function, even though the postoperative intact ratio is over 34 % [6, 9, 10]. To date, there have been no reports evaluating the factors affecting the progression of joint space narrowing after ARO.

In this study, we investigated the factors that correlate with the progression of joint space narrowing without progressive collapse after ARO.

Materials and methods

Patient selection

Institutional Review Board approval at our institution was obtained for this retrospective study. ARO was performed on 59 hips in 55 patients for the treatment of ONFH between January 2000 and December 2004 at our institution. Four of the hips already showed osteoarthritic changes preoperatively (advanced stage), and six hips showed progressive collapse soon after the procedure (mean 0.9 years, range 0.5–1.5). These ten hips were excluded from this study in order to evaluate the progression of joint space narrowing without progressive collapse. Six patients who were lost the follow-up within 3 years were also excluded from the analysis. Therefore, we reviewed 43 hips in 39 patients who underwent ARO for the treatment of ONFH (follow-up rate 87.8 %).

Clinical evaluation

The patients included 30 males (33 hips) and 9 females (10 hips) with a mean age of 42 years (23–61) at the time of surgery. Their mean body mass index (BMI) was 22.7 kg/m^2 (16.6–32.8). The mean follow-up period was 7.3 years (3–10). The contralateral treatment was ARO in 14 hips, transtrochanteric curved varus osteotomy in 1, prosthetic replacement in 3, and no operation in 25.

The clinical assessments were performed based on the Japanese Orthopaedic Association (JOA) score [11] preoperatively and at the time of the final follow-up. The following clinical factors were examined: sex, age, BMI, treated side, contralateral condition and contralateral treatment. The etiology of osteonecrosis was associated with corticosteroid treatment in 23 hips, alcohol abuse in 16 hips, corticosteroid use plus alcohol abuse in 3 hips and a consequence of trauma in 1 hip.

Radiological evaluation

According to the classification of the Japanese Investigation Committee of the Ministry of Health, Labour and Welfare [12], 35 hips were classified as stage 3A, which means the collapse of the femoral head was less than 3 mm; 8 were classified as stage 3B, indicating a collapse of 3 mm or more. The localization of the necrotic lesion was type C1 in 13 hips, which means that the necrotic area occupied more than two-thirds of the weight-bearing portion but did not extend to the acetabular edge, and was type C2, thus indicating that the necrotic area occupied more than two-thirds and extended to the acetabular edge, in 30 hips.

The following factors were investigated radiologically: the extent of the necrotic lesion, the progression of joint space narrowing and the postoperative intact ratio. The extent of the necrotic lesion was assessed by the method reported by Nam et al. [13] (Fig. 1). Briefly, we measured the largest mediolateral diameter of the femoral head (R) and the longest mediolateral length of the necrotic lesion (A) on anteroposterior plain radiographs, and the largest anteroposterior diameter of the femoral head (H) and the longest anteroposterior length of the necrotic lesion (B) on frog-leg lateral plain radiographs. The two-dimensional extent of a necrotic lesion was determined using the equation: % area $= (A \times B/R \times H) \times 100$. The progression of joint space narrowing was evaluated by comparing the postoperative anteroposterior and frog-leg radiographs with final follow-up radiographs. Positive joint space narrowing was defined as 1 mm or more progression, which was applied based on the previous reports on the association between clinical symptoms and joint space narrowing [14–17]. The postoperative intact ratio was measured according to the method of Sugioka from the supine anteroposterior radiograph taken 1 month after surgery (Fig. 2) [6]. All radiographic evaluations were assessed using the ImageJ software program (National Institutes of Health, USA). Radiographs were taken using the same technique throughout this study period, on which the standardized positions of the beam and radiographic penetration were adopted [18].

Statistical analyses

All 43 hips were divided into two groups: those with joint space narrowing (JSN group) and those without (non-JSN group) based on the findings of the progression of joint space narrowing. All radiographs were evaluated by two observers (G.Z. and S.I.). The process was repeated twice in a blinded manner. Intra- and interobserver variabilities were calculated using kappa statistics or Spearman's correlation coefficient.

The age, BMI, follow-up period, preoperative JOA score, extent of the necrotic lesion and postoperative intact ratio were compared between the two groups using unpaired t tests. Fisher's exact probability test or the chi-square test was used with regard to the sex, treated side, stage, type, contralateral condition, contralateral treatment and etiology of ONFH. P values <0.05 were considered to be significant. A multivariate analysis was performed using a logistic regression model. Variables that had a P value <0.2 (the postoperative intact ratio, preoperative JOA

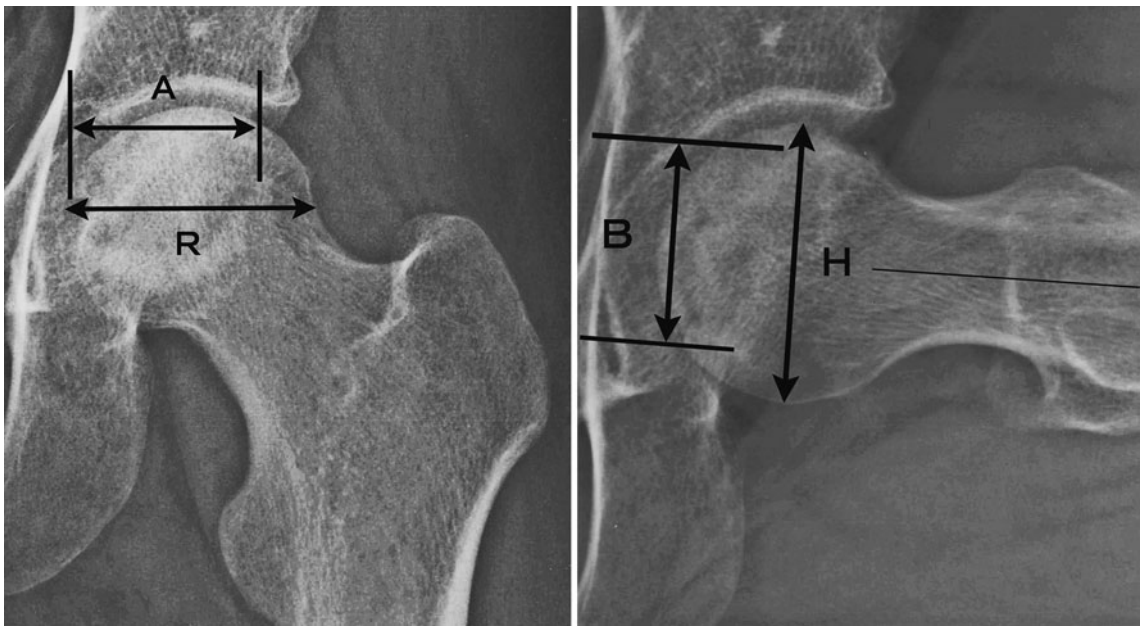

Fig. 1 The extent of the necrotic portion was determined using the equation: % extent = ($A \times B/R \times H$) × 100. R = the largest mediolateral diameter of the femoral head, H = the largest anteroposterior diameter of the femoral head, A = the longest mediolateral length of the necrotic lesion and B = the longest anteroposterior length of the necrotic lesion

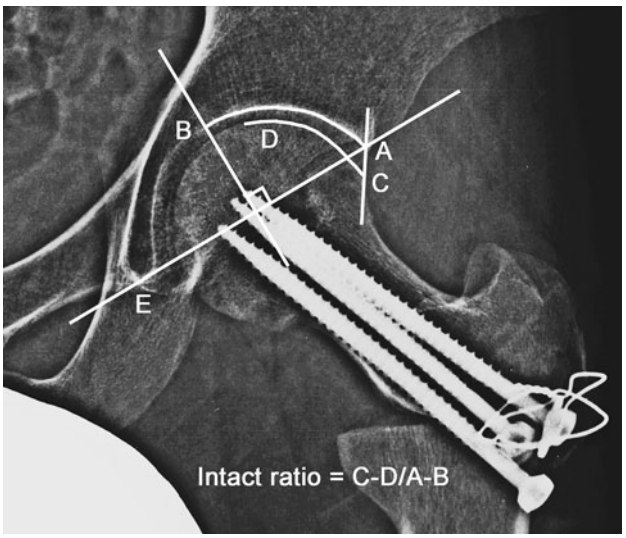

Fig. 2 Point B was determined by drawing a perpendicular line from the midpoint of A (the edge of the acetabulum) and E (the lowest point of the teardrop) to the acetabular roof. Point C represents the lateral edge of the load-bearing portion. Point D represents the medial edge of the intact articular surface. The length between A and B represents the load-bearing portion of the acetabulum (A–B), and the length between C and D represents the intact area of the femoral head contacting the load-bearing portion of the acetabulum (C–D). The postoperative intact ratio is expressed as the ratio of C–D/A–B

score, preoperative stage, contralateral treatment, extent of necrotic lesion) were included in the multivariate analysis, which was performed as described in previous studies [9, 14]. To assess the cutoff point of the postoperative intact ratio predicting the progression of the joint space narrowing, the receiver operating characteristic (ROC) curve was used [19]. Kaplan–Meier survival curves in which the progression of joint space narrowing was the end point were produced using the cutoff point of the postoperative intact ratio. The statistical analysis was performed using the log rank test between the group with values higher than the cutoff point and the group with lower values. These statistical analyses were performed using the JMP 9.0 software package (SAS Institute, USA).

Results

The mean preoperative JOA was 60.7 points (33–79), which improved to 87.9 (51–100) at the final follow-up ($P < 0.001$). An examination of the final follow-up anteroposterior and frog-leg radiographs assigned 6 hips to the JSN group and 37 to the non-JSN group (Fig. 3). The data from the two groups are summarized in Table 1. There was a significant difference in the preoperative JOA score between the two groups ($P = 0.013$). The rate of stage 3A was significantly higher in the non-JSN group than in the JSN group ($P = 0.033$). In the non-JSN group, the postoperative intact ratio was significantly higher than in the JSN group ($P = 0.002$). Although the number of JSN group was small, a sensitivity analysis of the JSN group basically supported these significant differences between the two groups. Two of the six hips in the JSN group were

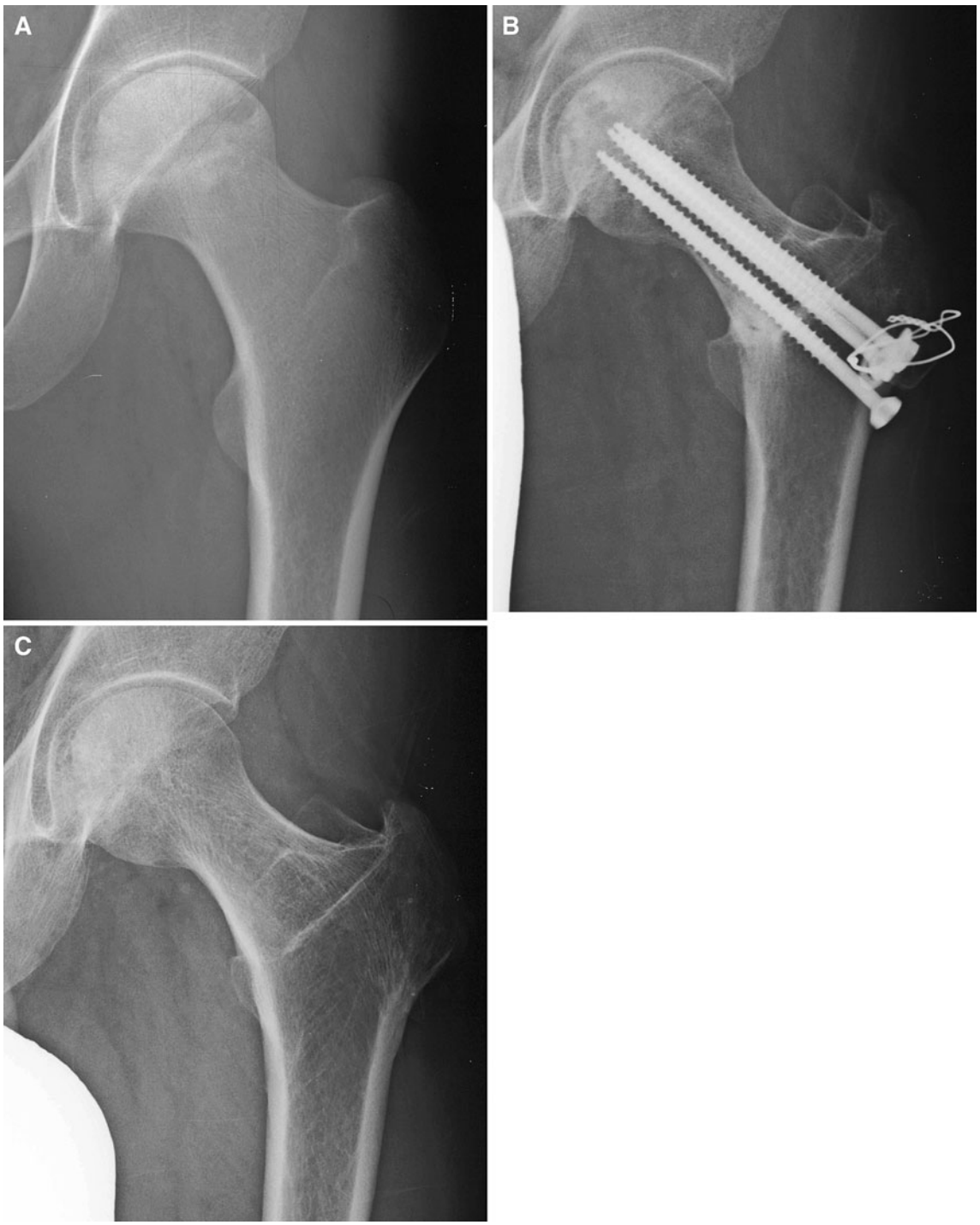

Fig. 3 **a** Antero-posterior radiographs of a 25-year-old male with steroid-induced osteonecrosis of the femoral head. A preoperative radiograph. The left hip was classified as stage 3A and type C2. **b** After 85° anterior rotational osteotomy, a postoperative intact ratio of 65.3 % was obtained on postoperative anteroposterior radiographs. **c** A radiograph taken 9 years after the operation showed no progression of joint space narrowing

converted to total hip arthroplasty at a mean of 6.5 years (6 and 7) after the operation.

A multivariate analysis between the two groups demonstrated that the postoperative intact ratio was an independent predictor of the progression of joint space narrowing after ARO (Table 2). The cutoff point of the postoperative intact ratio to prevent joint space narrowing was 39.2 % (sensitivity 100 %, specificity 83.8 %). Kaplan–Meier survival curves with the end point of joint space narrowing are shown in Fig. 4. There was a significant

Table 1 The results of the univariate analyses between the two groups

	JSN group (6 hips)	Non-JSN group (37 hips)	*P* values
Follow-up period	6.7 ± 0.76	7.4 ± 0.30	0.411
Gender			
Male	4	29	0.543
Female	2	8	
Mean age in years	39.8 ± 4.74	42.4 ± 1.91	0.621
Body mass index (kg/m^2)	23.6 ± 1.47	22.5 ± 0.59	0.502
Treated side			
Right	2	22	0.232
Left	4	15	
Contralateral condition			
ON present	3	20	0.853
ON absent	3	17	
Contralateral treatment			
ARO	1	13	0.052
Varus osteotomy	1	0	
Prosthetic replacement	1	2	
No operation	3	22	
Etiology of the ON			
Steroid	4	19	0.825
Alcohol	2	14	
Steroid plus alcohol	0	3	
Trauma	0	1	
Preoperative JOA score	51.3 ± 3.88	62.3 ± 1.56	0.013
Preoperative stage			
3A	3	32	0.033
3B	3	5	
Preoperative type			
C1	1	12	0.435
C2	5	25	
Extent of necrotic lesion (%)	56.4 ± 4.62	48.5 ± 1.89	0.125
Postoperative intact ratio (%)	34.6 ± 5.43	54.4 ± 2.19	0.002

JSN joint space narrowing, *ON* osteonecrosis, *ARO* transtrochanteric anterior rotational osteotomy, *JOA* Japanese Orthopaedic Association

Table 2 The results of the multivariate analyses determined using a logistic regression model

	Likelihood ratio	*P* values
Postoperative intact ratio	5.811	0.016
Preoperative stage	3.749	0.053
Contralateral treatment	6.767	0.080
Extent of necrotic lesion	1.965	0.161
Preoperative JOA score	0.546	0.460

JOA Japanese Orthopaedic Association

difference between the survival rates of the two groups using the log rank test ($P = 0.0006$).

The results of intra- and interobserver variability are shown in Table 3. The intraobserver variability ranged from 0.8093 to 1, and the interobserver variability ranged

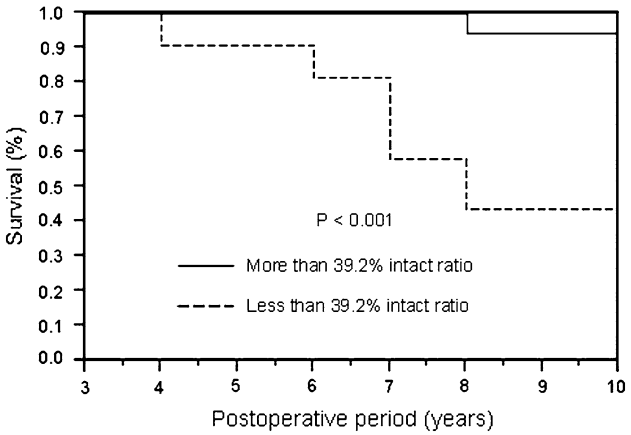

Fig. 4 The Kaplan–Meier survival curve shows the radiological survival rate according to the postoperative intact ratio. The end point is the time when the joint space narrowing was observed

Table 3 The intra- and interobserver variability for evaluations of radiographs

Parameter	Kappa				*R*
	Stage	Type	Joint space narrowing	Extent of necrotic lesion	Postoperative intact ratio
Intraobserver					
Observer 1	1	0.8448	0.9518	1	0.8093
Observer 2	0.9496	1	1	0.9267	0.8802
Interobserver					
First assessment	0.8014	0.7971	0.8118	0.8300	0.7851
Second assessment	0.8526	0.8448	0.7640	0.7598	0.7616

from 0.7598 to 0.8526, which were considered to be in good agreement for all radiological assessments.

Discussion

The results of this study demonstrated that the postoperative intact ratio is one of the factors determining the progression of joint space narrowing after ARO. Miyanishi et al. [9] reported that the minimum postoperative intact ratio to prevent the progression of the collapse after ARO was 34 %. Recently, Zhao et al. [14] reported that the minimum ratio was 33.6 % to prevent the progression of collapse after transtrochanteric curved varus osteotomy, and that the minimum ratio necessary to prevent both the progression of collapse and joint space narrowing was 41.9 %. The present study found a postoperative intact ratio of approximately 40 % to be necessary to prevent joint space narrowing after ARO.

Some of the patients with a postoperative intact ratio of less than 39.2 % may have experienced the progression of joint space narrowing in this study because of the postoperative instability and incongruity of the hip joint. Hiranuma et al. [20] reported that 40 % of patients after ARO showed joint instability and incongruity, which can lead to osteoarthritic changes. At the same time, they also noted that these conditions did not always cause osteoarthritic changes if the femoral head obtained a sufficient postoperative intact ratio. Therefore, both joint instability and incongruity after rotational osteotomy could influence the progression of joint space narrowing in some patients. On the other hand, one female patient with a postoperative intact ratio greater than 39.2 % showed progression of joint space narrowing in the present study. She was overweight with a BMI of 30 kg/m^2 and also had a transtrochanteric curved varus osteotomy in the contralateral ONFH. Ha et al. [21] suggested a high BMI to be one of the factors associated with unsatisfactory clinical results after ARO. In that case, both high BMI and bilateral ONFH involvement may have caused overload to the treated hip joint resulting in the observed gradual joint space narrowing.

Other authors have reported that the preoperative stage correlated with the radiological outcome after transtrochanteric rotational osteotomy [10, 20, 21]. Hosokawa et al. [10] reported that there was a high rate of conversion to total hip arthroplasty in the patients with ONFH after ARO who had already shown osteoarthritic changes (stage 4) preoperatively. Similarly, our study demonstrated that the preoperative stage tended to correlate with the progression of joint space narrowing after ARO ($P = 0.053$). Therefore, the osteotomy should be performed during the early stage, in stage 3A or stage 3B.

Both joint space narrowing and osteophyte formation have been commonly recognized as osteoarthritic changes. Several authors have reported that osteophyte formation often occurs in patients after transtrochanteric rotational osteotomy [8, 20]. However, Hisatome et al. [22] reported that osteophytes that were developed in the anterior and lateral directions helped to achieve stability of the femoral head inside the acetabulum. Osteophyte formation itself after ARO does not always cause a worsening of the clinical results. Therefore, the present study evaluated joint space narrowing after ARO as a parameter of osteoarthritic change.

The limitation of this study is that the follow-up period may have been too short to assess the osteoarthritic changes after ARO. However, previous reports showed that many of the osteoarthritic changes after ARO for patients with ONFH were observed within 3 years [23, 24]. In this study, the mean follow-up period was over 6 years and was not significantly different between the two groups.

The results of this study suggest that the postoperative intact ratio is one of the factors determining the progression of joint space narrowing after ARO, and that an approximately 40 % or higher postoperative intact ratio is recommended to prevent joint space narrowing.

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Conflict of interest All authors have no conflict of interest to other groups.

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