



# Long-term outcomes of Phemister bone grafting for patients with non-traumatic osteonecrosis of the femoral head

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## Abstract

**Background** Phemister procedure is an effective treatment for early stage osteonecrosis of femoral head (ONFH). Since the long-term results of the Phemister procedure are less reported in the literature, the purpose of this study was to investigate the long-term outcomes of this bone grafting technique in patients with earlier stages of ONFH.

**Methods** From 1994 to 2010, 29 hips with pre-collapsed or early collapsed (< 2 mm) ONFH treated by Phemister procedure were evaluated. Among them, nine hips were Association Research Circulation Osseous (ARCO) stage IIA, 13 stage IIB, 4 stage IIC, and 3 stage IIIA. The mean age was 38.9 years. The mean follow-up was 14 years (1–21 years). Survivorship was analyzed with conversion to total hip arthroplasty (THA) as the endpoint.

**Results** At the final follow-up, 10 hips underwent THA at a mean of ten years (1–18 years). The overall clinical success rate for hip preserving was 65.5%, and radiological success rate was 31%. The mean Harris Hip Score improved from 50.3 to 76.1. The survival of hips was significantly inferior in female patients ( $P < 0.01$ ), ARCO stage III disease ( $P = 0.03$ ), lateral type lesion ( $P < 0.01$ ), and necrotic index  $\geq 0.67$  ( $P < 0.01$ ). The Cox proportional hazards model showed that gender, ARCO stage, and necrotic index were independent risk factors for conversion to THA.

**Conclusion** The study showed acceptable results without complication in patients receiving Phemister procedure for early stage ONFH at a mean follow-up of 14 years. As a head-preserving procedure, Phemister technique is worthwhile for young patients to postpone the need for THA.

**Keywords** Phemister procedure · Osteonecrosis of femoral head · Non-vascularized bone grafting · Core decompression · Hip-preserving procedure

## Introduction

Osteonecrosis of femoral head (ONFH) is a debilitating disease that affects the hips of young adults [1]. Without appropriate interventions for joint preservation in earlier stages, 70–80% of the disease progresses to collapse of femoral head and advanced arthritis within one to five years [2–4]. Several joint-preserving procedures have been proved safe and effective to prevent or delay disease advancement, allowing a portion of the patients to retain their native joints and postpone hip

arthroplasty [3, 5–7]. In 1949, D.B. Phemister described a technique using a non-vascularized bone graft to treat ONFH [8]. It involved removing a 7- to 9-mm-diameter cylindrical core from the femoral head and neck and then replaced the cavity by a cortical graft harvested from the tibia, fibula, or ilium [7]. The theoretical benefits behind this technique are (1) decompression of the avascular lesions, (2) debridement of the weak necrotic bone down to good viable bleeding bone, (3) support of subchondral surface with cortical strut grafting, (4) and providing a scaffold for repair and remodeling of subchondral bone [9]. Abundance of studies has proved that the Phemister procedure and the similar bone grafting techniques were effective to hold disease progression and could defer the timing of total hip arthroplasty (THA) in young age [3, 7, 9–11].

In general, the best candidates of patients indicated for the Phemister procedure are those who have pre-collapse (Association Research Circulation Osseous (ARCO) stages I

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and II) or early post-collapse disease (ARCO IIIA), where the articular surface is intact or with less than 2 mm of depression of the femoral head [3, 7]. However, controversies remained regarding the indications and the long-term outcomes, and lower success rates were reported with longer follow-up. Smith et al. reported the longest follow-up of a cohort with ONFH treated with cortical strut grafting [12]. After a mean follow-up of 14 years, 77% of hips required THA. Other mid-term to long-term studies of the Phemister procedure showed variable success rates [13–17]. Most of these study populations consisted of the hips with both early and advanced stages of ONFH, thus were possibly confounded by imprecise patient selection and surgical indication.

Because the long-term results of the Phemister procedure specific to patients with earlier stages of ONFH are less reported

in the literature, the study retrospectively reviewed a group of patients with pre-collapse (ARCO stages I and II) or early post-collapse disease (ARCO IIIA) undergoing Phemister bone grafting with a mean of 14-year follow-up. Potential patient-related or radiological factors that may portend successful or unsuccessful surgical outcomes are also investigated.

## Materials and methods

From 1994 to 2010, we treated 51 hips in 46 patients by Phemister procedure. The diagnosis of ONFH was confirmed by radiographs and MRI in all patients [6, 18]. The inclusion criteria of this retrospective review consisted of patients with pre-collapsed (ARCO stages I and II) or early collapsed

**Table 1** Demographic and clinical characteristics of the study patients

	Total sample No.	Clinical success (N = 19)	Failure (THA, N = 10)	P value
Gender (M/F)	22/7	17/2	5/5	<b>0.02</b>
Mean age, years	38.89 ± 10.31			
≥ 40 years/< 40 years		10/9	5/5	0.9
Mean BMI	23.65			
≥ 25/< 25		7/12	3/7	0.71
Etiology				0.62
Idiopathic	7	5	2	
Corticosteroids	11	8	3	
Alcohol	11	6	5	
ARCO stage				<b>0.04</b>
Stage IIA	9	8	1	
Stage IIB	13	8	5	
Stage IIC	4	3	1	
Stage IIIA	3	0	3	
ARCO stage				<b>0.01</b>
Stage II	26	19	7	
Stage III	3	0	3	
Kerboul angle				0.15
Small	8	7	1	
Medium	10	7	3	
Large	11	5	6	
Necrotic index				< <b>0.01</b>
< 0.67	19	17	2	
≥ 0.67	10	2	8	
Lesion location				<b>0.03</b>
Central/lateral	14/15	12/7	2/8	
Uni/Bil	19/5			
Pre-op HHS		51.79 ± 8.42	47.4 ± 5.89	0.14
Post-op HHS		83.32 ± 6.63	62.5 ± 12.12	< <b>0.01</b>
HHS increase		31.53 ± 7.01	15.1 ± 2.36	< <b>0.01</b>

The significance of data are presented in bold text

(ARCO IIIA) ONFH. Patients with one of the following conditions were excluded: (1) ONFH with advanced femoral head collapse (worse than ARCO IIIA or collapse > 2 mm), (2) previous traumatic injury or infection to the index hip, (3) continuous use of corticosteroid because of underlying medical disease, and (4) ever received any other types of surgical treatment. The study was conducted with a waiver of patient consent but approved by the Institution Review Board of the hospital.

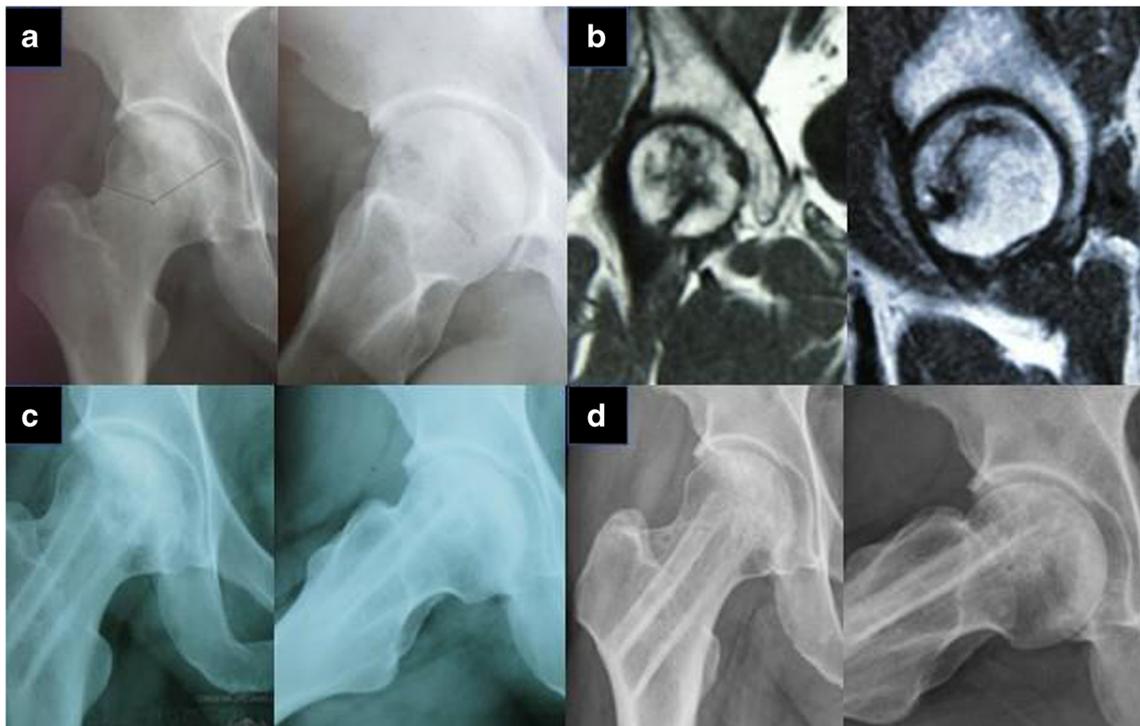
### Surgical procedure

The patients were placed in the hemilithotomy position on the fracture table. The location of the necrosis was identified on MRI and plain film. Under fluoroscopic guidance, a guide pin was drilled from the lateral aspect of proximal femur above the lesser trochanter into the anterolateral necrotic area of the femoral head. The second pin was drilled 1.5 to 2 cm distal to the first one and also toward the anterolateral necrotic area. The pins should disperse slightly away from each other at the tip near the subchondral cortex to maximize as much support on weight-bearing area as possible [19]. A trephine reamer was drilled along the guide pins deep to the subchondral area but not beyond the cortex to create two 10-mm-diameter bone tunnels through which the necrotized lesion and the

surrounding sclerotic bone were scraped off by a long curette. Few morsellized fibular head allografts were packed into the cavities after debridement of the necrotic bones. Then two fibular strut allografts were made in cylinder shape, with a length of 9 cm and diameter of 10 mm. The allografts were trimmed to fit snugly the size of bone tunnels and tapped into femoral head deep to the subchondral bone. After the surgery, the patients were instructed to ambulate by crutches with non-weight-bearing on the operated limb for 3 months, followed by partial weight-bearing for another 3 months. Activities with higher demand and impact loading were avoided for at least one year.

### Radiographic parameters

Disease staging and the size of the necrotic lesions were assessed by the ARCO classification system [20]. The combined Kerboul angle was used to classify the lesions into small ( $\leq 150^\circ$ ), medium ( $150\text{--}200^\circ$ ), and large ( $\geq 200^\circ$ ) in size [4]. The necrotic index described by Koo et al. also intended to quantify the extent of necrosis based on the midcoronal and midsagittal MRI [21]. The location of the lesion was defined using a system initially described by Ohzono et al. [1] and later modified by Kang et al. [22]. A central type lesion occupied the medial two-thirds or less of the weight-bearing



**Fig. 1** A 42-year-old male patient, with alcohol-related right hip ONFH. **a** Pre-operative radiography AP and lateral view. **b** Pre-operative MRI showing ARCO IIB lesion and necrotic index 35%. **c** Immediate post-operative radiography showing the placement of the fibular allografts to

the necrotic region at the subchondral area. **d** Follow-up radiography at 21 years after the Plemister procedure, showing good sphericity of the femoral head, remodeling of the allograft with host bone, and healed osteonecrotic lesion

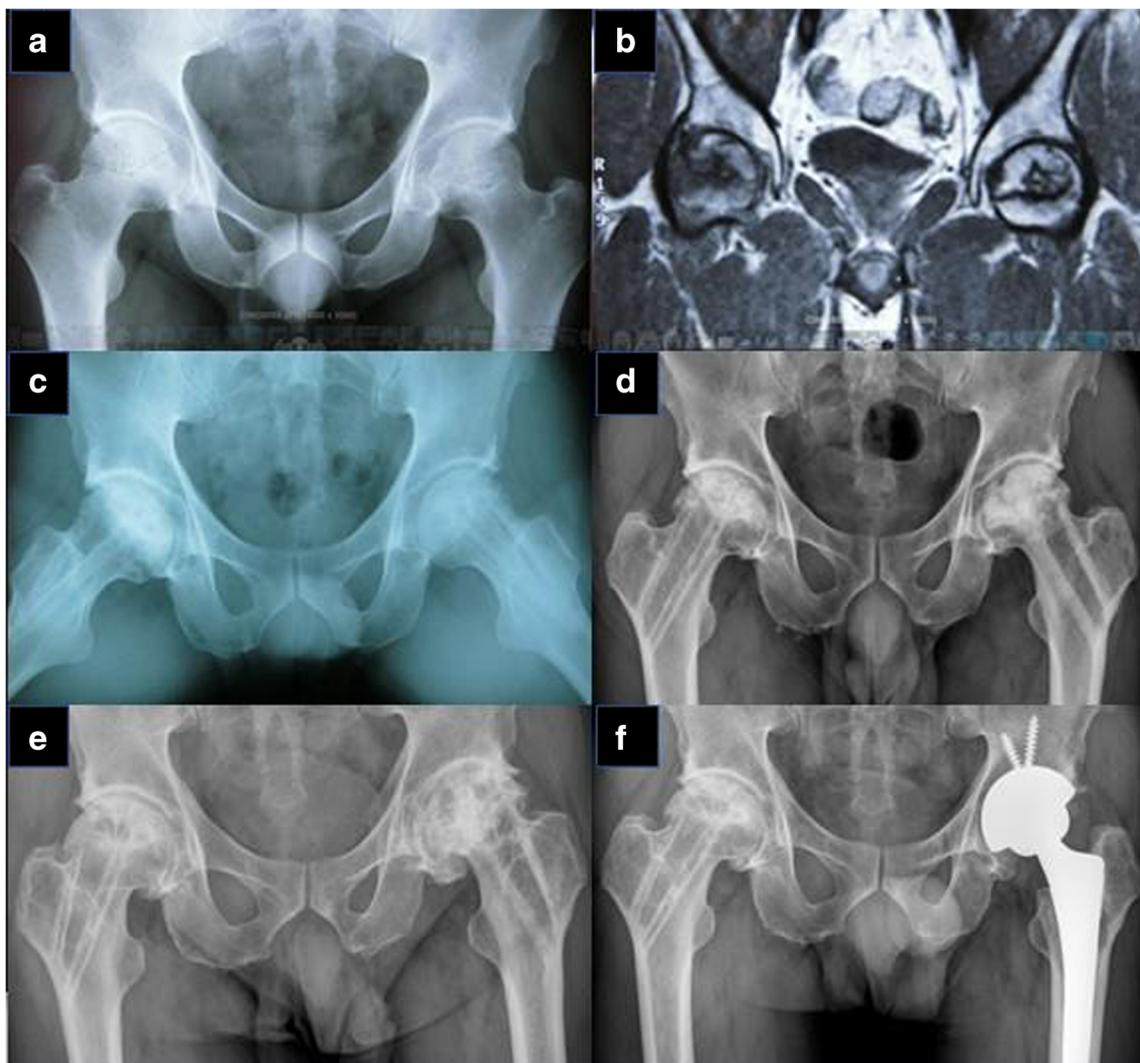
portion, and a lateral type lesion occupied more than the medial two-thirds of the weight-bearing portion.

## Outcomes

Conversion to THA was defined as the endpoint of clinical outcome. The procedure was clinically successful if the patients favourably preserved the native hip joint without conversion to THA. A new occurrence of collapse by 2 mm on femoral head from ARCO stage II to ARCO stage III, or continual collapse of femoral head from ARCO stage IIIA, or the appearance of joint space narrowing and arthritic change was defined as a radiographic progression.

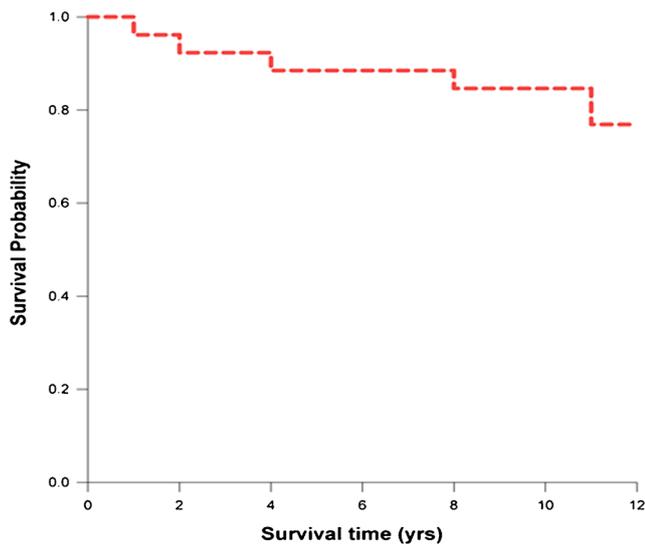
## Statistical analysis

The  $\chi^2$  test or Fisher's exact test was used when analyzing the differences of categorical variables between patients of clinical success and clinical failure. Differences of HHS between patients of clinical success and clinical failure were compared by the Wilcoxon-Mann-Whitney test. Statistical differences in survival rate were compared using log-rank analysis of Kaplan-Meier survival curves with the end point of conversion to THA. The Cox proportional hazards model was used to analyze the independent factors associated with clinical failure. All tests were two-sided, and  $P < 0.05$  was considered significant. All statistical comparisons were made using the Statistical Package for Social Sciences (SPSS) (version 20; SPSS Inc., Chicago, IL).



**Fig. 2** A 45-year-old male patient, with alcohol-related bilateral hips ONFH. **a** Pre-operative radiograph. **b** Pre-operative MRI showing ARCO IIB–IIC lesions and necrotic index 42% on right hip and 75% on left hip. **c** Immediate post-operative radiography. **d** Follow-up radiography at post-operative ten years showing collapse of left femoral head

subchondral surface. **e** Follow-up radiography at post-operative 15 years showing advanced second arthritis on left hip, which was converted to THA. **f** Follow-up radiography at post-operative 19 years showing preserved right hip joint congruency without further collapse of femoral head



**Fig. 3** Survival curve of clinical failure with conversion to THA as the endpoint

**Results**

At the final follow-up, 29 hips in 24 patients were available for evaluation, of which nine hips were ARCO stage IIA, 13 stage IIB, 4 stage IIC, and 3 stage IIIA. The patients were 24~58 years of age (mean, 38.9 ± 10.31). There were 22 male and seven female hip joints. ONFH was idiopathic in seven hips, secondary to steroid use in 11 hips, and associated with alcohol use in 11 hips. The mean follow-up was 14 years (range, 1~21 years). There were no significant differences between patients of clinical success and clinical failure in terms of the proportion of age ≥ 40 years, BMI ≥ 25 kg/m<sup>2</sup>, and aetiology. However, significant differences were noted regarding ARCO stage, necrotic index, and the location of lesion between the two groups (Table 1).

For the entire group, the mean pre-operative HHS was 50.3 points (range, 34~65 points). The post-operative score was 76.1 points (range, 34~93 points). The improvement in HHS was higher in the group of clinical success. Hips that required THA had 47.4 points pre-operatively and 62.5 points post-

**Table 2** The analytic results and survival rate of hips conversion to THA

Index	No. of hips	Failure (THA)	Survival rate (5 years)	Survival rate (12 years)	<i>P</i> value (log-rank)
Overall sample	29	10	88.5% (6.3)	76.9% (8.3)	
Gender					<b>&lt; 0.01</b>
Male	22	5	100% (0)	95% (4.9)	
Female	7	5	50% (20.4)	16.7% (15.2)	
Age					0.94
≥ 40 years	15	5	84.6% (10)	76.9% (11.7)	
< 40 years	14	5	92.3% (7.4)	76.9% (11.7)	
BMI					0.24
≥ 25	10	3	100% (0)	88.9% (10.5)	
< 25	19	7	82.4% (9.3)	70.6% (11.1)	
Etiology					0.82
Idiopathic	7	2	100% (0)	83.3% (15.2)	
Corticosteroids	11	3	90% (9.5)	70% (14.5)	
Alcohol	11	5	80% (12.7)	80% (12.7)	
ARCO stage					<b>0.03</b>
Stage II	26	7	95.7% (4.3)	82.6% (7.9)	
Stage III	3	3	33.3% (27.2)	33.3% (27.2)	
Kerboul angle					0.11
Small + medium	18	4	93.8% (6.1)	87.5% (8.3)	
Large	11	6	80% (12.7)	60% (15.5)	
Necrotic index					<b>&lt; 0.01</b>
< 0.67	19	2	94.7% (57.1)	94.7% (57.1)	
≥ 0.67	10	8	77.8% (13.9)	44.4% (16.6)	
Lesion location					<b>&lt; 0.01</b>
Central	14	2	100% (0)	100% (0)	
Lateral	15	8	80% (10.3)	60% (12.7)	

The significance of data are presented in bold text

operatively, for a mean gain of 15.1 points. Those hips that did not require hip replacement had 51.8 points pre-operatively and 83.3 points post-operatively, for a mean gain of 31.5 points.

### Conversion to THA

Totally, ten hips underwent THA at a mean of ten years (range, 1–18 years) after the Phemister procedure. Three THAs occurred within five years, one between five and ten years and six after ten years (Figs. 1 and 2). The overall clinical successful rate for hip preserving was 65.5% (Fig. 3). Table 2 summarized the analytic results and survival rate of hips conversion to THA with regard to patient-related and radiographic factors. Hips were more prone to failure in female patients ( $P < 0.01$ ), ARCO stage III disease ( $P = 0.03$ ), necrotic index  $\geq 0.67$  ( $P < 0.01$ ), and lateral type lesion ( $P < 0.01$ ). However, no significant difference was found in survivorship curves when stratified by age  $\geq 40$  years ( $P = 0.94$ ), BMI  $\geq 25$  kg/m<sup>2</sup> ( $P = 0.24$ ), and aetiology of ONFH ( $P = 0.82$ ) (Table 2).

The Cox proportional hazards model showed that gender ( $P < 0.01$ ; hazard ratio [HR], 0.03; 95% confidence interval [CI], 0.004–0.278), ARCO stage ( $P = 0.02$ ; HR, 8.02; 95% CI, 1.42–45.36), and necrotic index ( $P = 0.03$ ; HR, 11.33; 95% CI, 1.32–97.21) were independent risk factors for conversion to THA (Figs. 4 and 5). Instead, age  $\geq 40$  years, BMI  $\geq 25$  kg/m<sup>2</sup>, aetiology of ONFH, and Kerboul angle were not correlated to the risk of conversion to THA (Table 3).

### Radiographic progression

At a mean of 14-year follow-up, 20 of 29 hips (69%) were classified as radiographic progression (Fig. 6). The mean time to radiographic progression was 6.3 years (range, 4 months–17 years). Among the 20 hips with evidence of

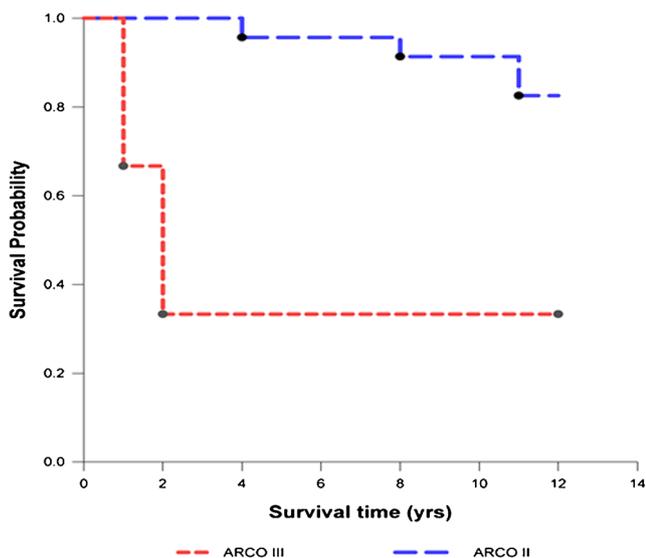


Fig. 4 Survival curve of clinical failure by ARCO stage

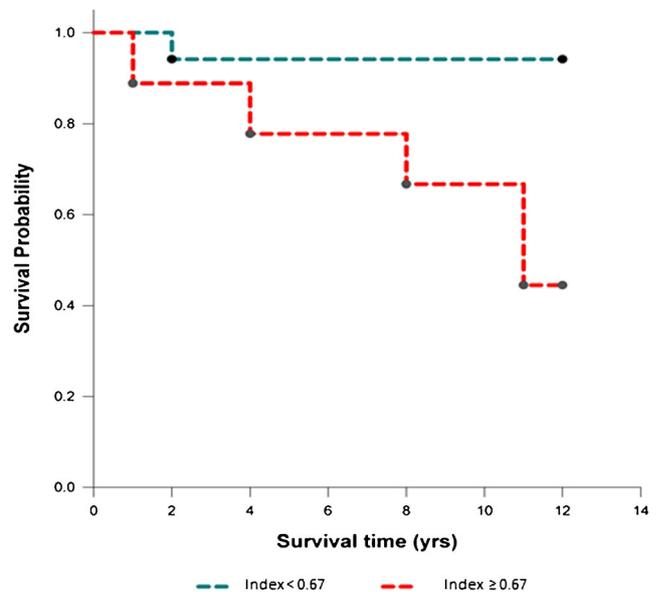


Fig. 5 Survival curve of clinical failure by necrotic index

radiographic progression, 10 hips were still preserved at the last follow-up with acceptable daily function (HHS  $\geq 70$ ) and without conversion to THA.

### Discussion

Non-vascularized bone grafting techniques for the treatment of ONFH were popularized in the 1960s and 1970s [3, 7]. Currently, there are three distinct surgical techniques to deposit non-vascularized bone graft into the necrotic lesion within femoral head: (1) through one or two core decompression tracks (the Phemister procedure); (2) a window in the femoral head-neck junction (the “light-bulb” procedure); or (3) a trap-door made in the articular cartilage of the femoral head [7, 23].

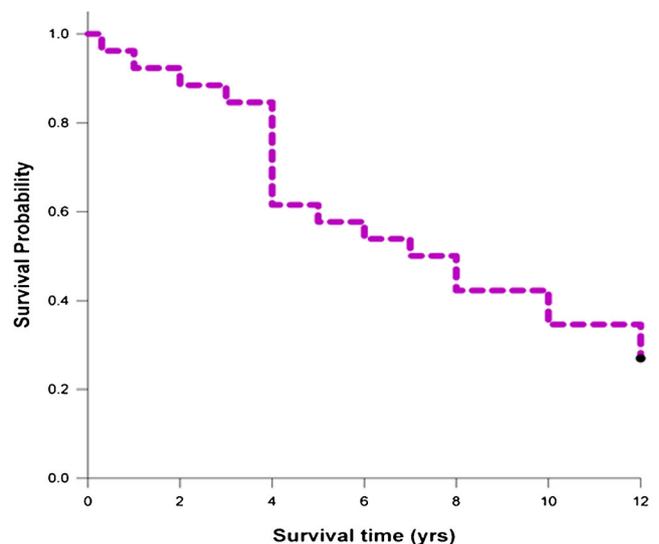


Fig. 6 Survival curve of radiographic failure

**Table 3** The results of Cox proportional hazards model for hips conversion to THA

Risk factors to clinical failure	Hazard ratio (95% CI)	P value
Male vs. female	0.032 (0.004–0.278)	<b>&lt; 0.01</b>
Age, < 40 vs. ≥ 40 years	0.95 (0.19–4.69)	0.95
BMI, ≥ 25 vs. < 25	0.32 (0.04–2.77)	0.3
Etiology		0.83
Idiopathic vs. alcohol	0.71 (0.06–7.78)	0.78
Corticosteroids vs. alcohol	1.39 (0.23–8.35)	0.72
ARCO stage		
Stage III vs. II	8.02 (1.42–45.36)	<b>0.02</b>
Kerboul angle		
Large vs. (small + medium)	3.72 (0.68–20.35)	0.13
Necrotic index	11.33 (1.32–97.21)	<b>0.03</b>
Lesion location (lateral vs. central)		0.99

The significance of data are presented in bold text

The advantages of Phemister procedure, in contrast to the other two approaches, are that it is technically straightforward, extra-articular, and reproducible. We have used this technique to treat patients with early stage ONFH for the past 20 years. Because of varied results reported following non-vascularized bone grafting, this retrospective study is aimed to answer the following questions: (1) what are the long-term clinical and radiographic outcomes of the Phemister procedure, (2) whether the procedure effectively defers the timing of THA, and (3) whether there are any clinical or radiographic factors that may portend successful or unsuccessful surgical outcomes.

Our study has some limitations, including small number of patients and no control group (ex. non-operative treatment or other bone grafting techniques). However, our patient selection and surgical indications are well-defined, and the time of follow-up is considerably long. In addition, the clinical and radiographic data were recorded in detail and completely. This renders our results exceptionally representative of the long-term outcomes of the Phemister procedure in the treatment of early stage ONFH.

In this study, we have shown acceptable long-term results without serious complications in the use of the Phemister procedure over a follow-up of 14 years, especially for lesions with earlier stage and smaller necrotic index. Reviewing of the literature, there was a considerably wide range of successful rates (36 to 90%), with long-term results being less than satisfactory [3, 7, 9–12, 14–17]. This was mostly because of varied period of follow-up, high variability in patient populations, inconsistent disease stages at surgery, and variation in grafting technique (Table 4). Buckley et al. reviewed 19 patients ( $n = 20$  hips) in Ficat stage I and II of ONFH treated with tibia autogenous graft or fibular allograft. At a mean follow-up of eight years, only two hips (10%) require THA [16]. Keizer et al. also evaluated the results of 78 hips undergoing non-vascularized bone grafting following core decompression. However, they found a mean five year clinical survivorship of 59% and decreased to 44% at ten years [9]. In addition, 44% of hips required subsequent hip arthroplasty at a mean of four years. The results might to some extent influenced by the mixed inclusion of Ficat stages 1 to 4 ONFH in their cohort. As Nelson and Clark have concluded in their study that the Phemister procedure was not recommended once excessive femoral head collapse was present [17]. Strict patient selection and a well-defined surgical indication limited to patients with pre-collapsed or early collapsed stage might be an important factor to obtain favourable long-term outcomes. Our results showed 88.5% of five year survival rate and 76.9% of 12-year survival rate using conversion to THA as the end point. For those hips requiring THA, the averaged time-to-event was about ten years, with 60% of THA occurred 10 years after the index procedure. The results suggested the Phemister procedure being safe and effective in deferring THA in selected patients.

Surgical technique might be another important factor influencing the surgical outcomes. First, the guided pins should disperse slightly away from each other at the tip near the subchondral cortex to maximize as much support on weight-bearing area as possible. Second, different from most of the studies using only single strut fibular graft [3, 5, 9, 10, 15, 24], two fibular allografts were tapped into femoral head

**Table 4** Studies on the outcomes of Phemister procedure since 2000 with a mean follow-up more than 5 years

Author (year)	Surgical technique	No. of hips	Stage of ONFH	Mean follow-up (months)	Clinical success (%)	Mean time to THA (months)
Yu et al. [18]	Phemister (synthetic bone graft substitute)	19	ARCO IIC to IIIA	60	42	8.5 (4 to 30)
Wang et al. [19]	Phemister (fibular allografts)	28	ARCO I to III	104 (95 to 108)	36	NR
Keizer et al. [14]	Phemister (fibular allograft or tibia autograft)	78	Ficat I to IV	84 (36 to 204)	56	48 (12 to 180)
Israelite et al. [15]	Phemister (cancellous autograft)	276	Steinberg I to IV	NR (24 to 145)	62	29 (1 to 155)
Plakseychuk et al. [20]	Phemister (fibular autograft)	50	Pittsburgh I to III	60 (36 to 96)	36	NR
Steinberg et al. [6]	Phemister (cancellous autograft)	312	Steinberg I to IV	63 (23 to 146)	64	29 (3 to 155)
Our study	Phemister (fibular allografts)	29	ARCO II to IIIA	156 (12 to 240)	65.5	120 (12 to 216)

deep to the subchondral bone along with morsellized fibular head allografts filling the excavated cavities in our series. We were not aware of any biomechanical study demonstrating the most optimal graft number and position for structural support. However, the use of two fibular allografts in theory might provide more mechanical strength than single strut bone graft and without increasing the risk of proximal femur fracture.

There was a higher incidence of radiographic progression in the current study.

Though a proportion of patients witnessed slight radiographic progression, their Harris hip score had significant improvement. Radiographic progression was seen in 53% of hips that did not require hip replacement. The result was very similar to that reported by Keizer et al., in which hips showing a progression in their radiological stage did not have a higher chance of subsequent clinical failure [9]. While slight progression of necrotic region was often observed in the first few years after core decompression, further bone collapse was halted by the support of allograft, which built a strut of non-resorbable bone at the reactive zone around the collapsed region as the bone remodeling and healing occurred [6, 25]. The pain resulted from microfracture of the trabeculae was therefore mitigated.

Advanced ARCO stage and larger necrotic index were found to portend unsuccessful clinical results in our analysis. It was compatible with those reported in other literature, corroborating that core decompression was most efficacious in patients with small to medium-sized and pre-collapsed lesions [3, 7, 23, 26, 27]. The location of lesions was often considered as an important factor affecting the treatment results, with the lateral lesions predictive of poor prognosis [22, 23, 26–28]. In our study, eight of 15 patients with a lateral lesion underwent THA, whereas only two of 14 patients with a central lesion failed. Because the two failed patients in the central lesion group received THA at 14 and 17 years after the Phemister procedure, respectively, the 12-year survival rate of central lesion was 100% (as shown in Table 2). As a result, the hazard ratio of lesion location could not be calculated using cox proportional hazards model, and the *P* value was 0.99. However, it seemed that patients with central lesions did have lower clinical failure rate and longer period of time to THA than those with lateral lesions. More patients are needed to further prove the location of lesion a statistically significant factor to predict surgical outcomes after Phemister procedure.

## Conclusions

In this study, Phemister procedure using two strut allografts achieved a 65.5% of overall clinical success rate at a mean follow-up of 14 years in early stage ONFH. As a technically straightforward head-preserving surgery, we suggested this procedure could be recommended to those young active patients with early ONFH to postpone the need for THA.

## Compliance with ethical standards

**Conflict of interest** There is no conflict of interest throughout the whole study.

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