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Clinical outcomes following total hip arthroplasty for bony ankylosed hips: a propensity score-matched analysis

Sakumo Kii[1], Ryo Takamatsu[2], Motoki Sonohata[3*], Masaya Ueno[1], Toshihiro Nonaka[1], Masaru Kitajima[4] and Masaaki Mawatari[1]

Abstract

Background Total hip arthroplasty (THA) is one of the most effective treatments for hip arthritis. However, postoperative outcomes of THA in patients with bony ankylosed hips remain inconclusive. We aimed to examine the postoperative results of THAs for bony ankylosed hips using propensity score matching.

Methods A propensity score was calculated using logistic regression analysis for a bony-ankylosed group (40 hips, 38 patients) and a non-ankylosed (control) group (829 hips, 729 patients). Patients were followed up for more than 10 years after primary THA. The propensity score used five covariates: age, sex, height, weight, and body mass index. Propensity matching was performed, with each bony ankylosed hip being matched to a non-ankylosed control hip. The clinical outcomes of the Japanese Orthopaedic Association (JOA) hip scores and complications were investigated.

Results The propensity-matched population consisted of 40 bony ankylosed hips (38 patients) and 40 hips (40 patients) of matched controls. In both groups, the postoperative JOA hip scores at the last follow-up significantly improved compared to the preoperative scores. The JOA hip scores at the last follow-up for all components in the bony-ankylosed group were significantly lower than those in the control group. The number of hips with postoperative complications was significantly higher in the bony-ankylosed group than that in the control group.

Conclusions THA for patients with bony ankylosed hips achieved positive results, including improved JOA hip scores; however, these scores were inferior to those observed in patients with non-ankylosed hips. This should be preoperatively communicated to patients with bony ankylosed hips who undergo THA.

Keywords Bony ankylosed hip, Clinical outcome, Non-ankylosed hip, Propensity score matching, Total hip arthroplasty

*Correspondence:
Motoki Sonohata
epc9719@yahoo.co.jp
Full list of author information is available at the end of the article

Background

Patients with spontaneous ankylosis due to hip arthritis or those who have undergone arthrodesis in adolescence for hip disease often achieve pain relief but experience difficulty with activities of daily living and disability of adjacent joints, such as the lumbar spine and knee [1–3]. Therefore, pain due to adjacent joint disorders caused by ankylosed hips is an indication for total hip arthroplasty (THA) for ankylosed hips [4, 5]. THA is known to be one of the most useful treatment procedures for hip arthritis [6]. However, the postoperative outcomes of THA in patients with bony ankylosed hips are nonconclusive.

To our knowledge, no studies have compared clinical outcomes following THA in patients with bony ankylosed and non-ankylosed hips using propensity scores. In this study, we examined the postoperative results of THA for bony ankylosed hips using propensity score matching.

Methods

This retrospective cohort study used data obtained from the THA database of our institution. Data obtained included the Japanese Orthopaedic Association (JOA) hip score, laboratory data, postoperative complications, and computed tomography (CT) images. The study protocol was in accordance with the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the Ethics Committee of Saga University Hospital (Reference number: 2020–06-R07). All patients provided written informed consent prior to participation.

Patients

Data were extracted for 3338 hips (2863 patients) that underwent primary unilateral THA at our institution between January 1999 and December 2011 (Fig. 1). Cases with follow-up periods of less than 10 years and those with missing data were excluded. The hips included in the study were then temporarily divided into two groups: a bony-ankylosed group (40 hips, 38 patients) and a non-ankylosed (control) group (829 hips, 729 patients). Bony ankylosed hips were defined as cases with joint ossification on simple radiography and no range of motion (Fig. 2A). The remaining cases were defined as non-ankylosed hips.

Propensity score matching

To minimise confounding factors, propensity score matching was used to match bony ankylosed to non-ankylosed hips. Using logistic regression, propensity scores were calculated using the five variables of age, sex, height, weight, and body mass index, which were selected based on previous studies [7–11].

Propensity score matching was then performed using nearest neighbour matching without replacement, with each bony ankylosed hip matched to a control hip [12]. We used a calipre width of 0.2, which is the standard deviation of the logit of the propensity score [13]. To check the balance of the matches, a standardised mean difference threshold of 0.1 was set to determine the residual imbalances [14, 15].

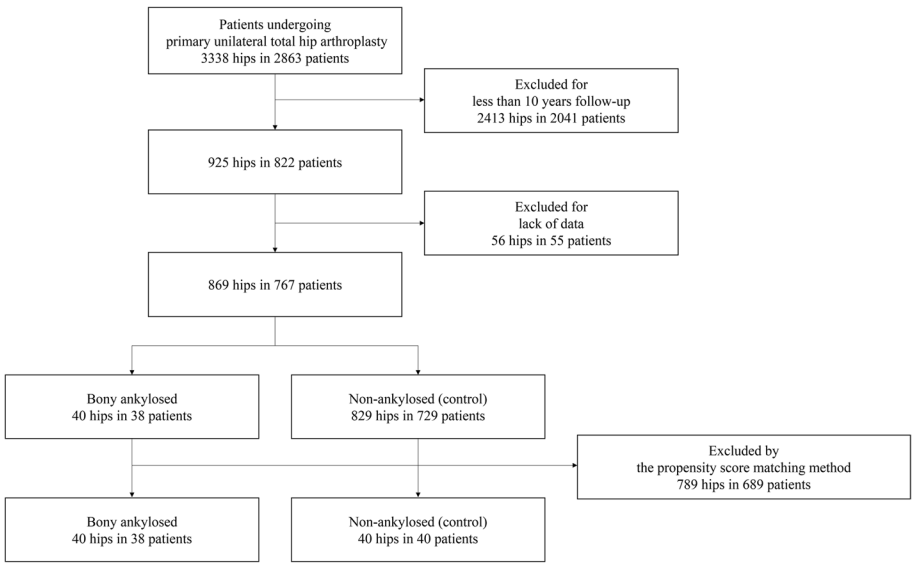

Fig. 1 Flow chart depicting the selection process and number of hips among patients with bony ankylosed hips and patients with non-ankylosed hips undergoing primary unilateral total hip arthroplasty

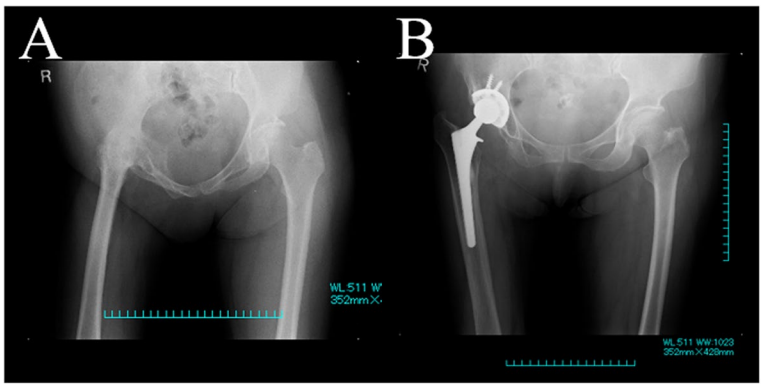

Fig. 2 Representative simple radiographs of the bony-ankylosed group. **A** A preoperative frontal radiograph of a 65-year-old woman with a bony ankylosed right hip resulting from treatment of developmental acetabular dysplasia at age 10 years with cast immobilisation.**B** A frontal radiograph of the patient undergoing total hip arthroplasty on the right hip at 10 years postoperatively. The preoperative Japanese Orthopedic Association hip score was 73 points; however, this improved to 89 points at the time of the last follow-up

Surgical procedure

THA was performed using the posterolateral approach under spinal anaesthesia with identical cementless implants. In the bony-ankylosed group, 33 of the 40 hips underwent an additional approach from the anterior edge of the gluteus medius.

Surgical indication

The main surgical indication for the bony-ankylosed group was pain due to adjacent joint disorders caused by the ankylosed hips and for the control group it was a decline in activities of daily living due to pain and limited range of motion in the hip joints. Walking training within the allowable pain range was initiated without weight-bearing limitations after drain removal on day-2 postoperatively.

Types of implants

In both groups, proximal hydroxyapatite-coated cementless femoral components with a proximal porous coating consisting of pure titanium (PerFix-HA femoral component; Kyocera, Kyoto, Japan) and hydroxyapatite-coated cementless hemispherical acetabular shells with a porous coating consisting of pure titanium (AMS-hydroxyapatite acetabular shell; Kyocera, Kyoto, Japan) were implanted. An alumina or zirconia ball and ABS (alumina ceramic inlay mechanically fixed to a polyethylene liner) or AMS (polyethylene liner) liner were used for the bearing surface (Fig. 2B).

Outcomes

The outcomes of this study were the JOA hip score and use of walking aids, preoperatively and at the last postoperative follow-up; length of hospital stay; follow-up period; operating time; intraoperative blood loss; postoperative blood loss calculated from a drain tube; allogeneic blood transfusion; number of hips with allogeneic blood transfusions; number of hips with postoperative complications; number of hips that underwent revision surgery; laboratory data obtained preoperatively and at postoperative days 1 and 7. Postoperative haemoglobin included data for patients who received allogeneic blood transfusions.

The JOA hip score consists of four subcategories and is calculated on a 100-point scale: pain, 40 points; range of motion, 20 points; gait ability, 20 points; and activities of daily living, 20 points. Laboratory data, including platelet count and creatine phosphokinase levels, were evaluated using routine blood tests.

Additionally, data were missing after propensity score matching; however, postoperative CT images were used to evaluate the gluteus medius on the surgical side in the transverse section, and the image information unification system ShadeQuest/ViewR (version 1.26.10; Yokogawa, Tokyo, Japan) was used to take measurements. A complete-case analysis was used for the evaluation. The midpoint of the line connecting the superior anterior iliac spine and the apex of the greater trochanter was defined in the frontal simple radiograph image of the pelvis for positioning when the CT image was captured. The cross-sectional area (CSA) and CT value of the gluteus medius were measured at the midpoint level (Fig. 3A and B) [16].

Statistical analyses

Statistical analyses were performed using JMP Pro software (version 15.2.0, SAS Institute Inc., Cary, NC, USA). Categorical variables were expressed as absolute and percentage values, and continuous variables were expressed as mean ± standard deviation. The Shapiro–Wilk test was conducted to evaluate the normality of the distribution

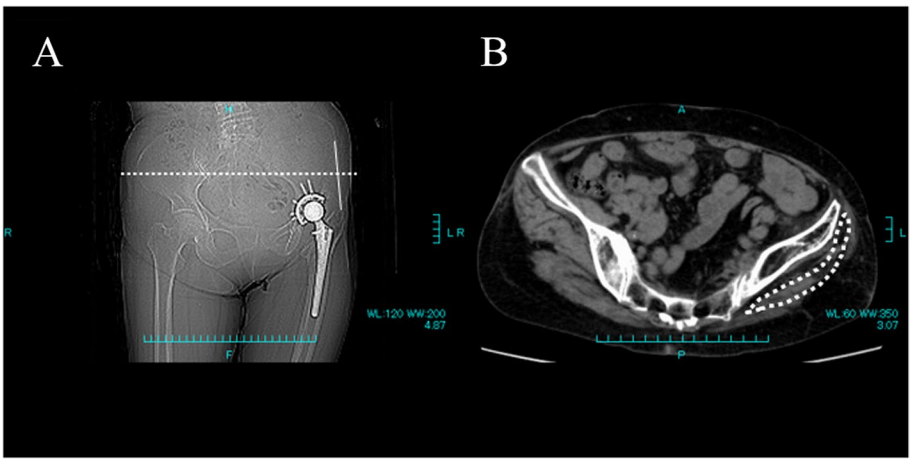

Fig. 3 Computed tomography (CT) image of a patient with a bony ankylosed left hip after total hip arthroplasty. **A** The midpoint of the line connecting the superior anterior iliac spine and apex of the greater trochanter was defined in the frontal simple radiograph image of the pelvis for positioning when CT was performed. **B** At that midpoint level, the cross-sectional area and CT value of the gluteus medius, which is shown by an enclosed dotted line, were measured using the transverse section image on CT

of the continuous variables. A two-tailed F-test was used to evaluate variance. The Wilcoxon signed-rank test was used to compare the postoperative JOA hip score at the last follow-up and post-propensity score matching with the preoperative and pre-matching values, respectively, in the same group.

Comparisons between the bony-ankylosed and control groups were performed as follows: a two-tailed Student's t-test was used to compare the post-propensity score-matched height, weight, preoperative total JOA score, haemoglobin level, and alkaline phosphatase on the day prior to surgery and postoperative day 1. A two-tailed Welch's t-test was used to compare the pre-propensity score-matched height, body mass index, postoperative blood loss, and creatine phosphokinase level on postoperative day 1. The Mann–Whitney U test was used to compare the preoperative JOA hip score, except for the total score, postoperative JOA hip score at the last follow-up, preoperative and postoperative use of walking aids, length of hospital stay, follow-up period, operating time, intraoperative blood loss, allogeneic blood transfusion, laboratory data except for the haemoglobin level, alkaline phosphatase on preoperative day and postoperative day 1, and creatine phosphokinase level on postoperative day 1, and postoperative CSA of the gluteus medius and CT values at that site. Post-hoc analyses were performed for the postoperative total JOA hip score at the last follow-up (effect size d = 1.13, two-sided alpha = 0.05, sample size = 40 and 40), CSA of the gluteus medius (effect size d = 1.88, two-sided alpha = 0.05, sample size = 11 and 8), and the CT value of the gluteus medius (effect size d = 1.39, two-sided alpha = 0.05, sample size = 11 and 8), resulting in calculated power values of 0.99, 0.96, and 0.79, respectively. Regarding CT imaging studies, intra-rater reliability was assessed by two measurements recorded by one orthopaedic surgeon 1 week apart, and inter-rater reliability was assessed by measurements recorded by two orthopaedic surgeons. The intra-rater intraclass correlation coefficient (ICC) and inter-rater ICC values were 0.9448 and 0.8133 for the postoperative CSA of gluteus medius and 0.9446 and 0.8512 for the postoperative CT values of gluteus medius at CSA, respectively, all of which were sufficiently reproducible to be classified in the first class by Wheeler's Evaluating the Measurement Process method [17]. Following Cochran's rule, Fisher's test was used for the number of hips that underwent revision surgery and time of postoperative CT imaging, where more than 20% of the squares had an expected number less than five [18].

The chi-square test was used for to analyse sex, preoperative and postoperative use of walking aids, number of hips with allogeneic blood transfusions, number of hips with postoperative complications, where no squares had an expected number less than five [18]. Survival analysis was performed using Kaplan–Meier and log-rank tests for the acetabular side, femoral side, and both sides of the prosthesis, with total hip arthroplasty revision as the endpoint. The relationship between intraoperative blood loss and other variables, including the type of ankylosis, was evaluated using Spearman's correlation coefficient in the bony-ankylosed group. For all analyses, statistical significance was set at a p-value < 0.05.

Results

Propensity score matching

The propensity score-matched population consisted of 40 bony ankylosed (38 patients) and 40 non-ankylosed (40 patients) hips as matched controls. The area under the receiver operating characteristic curve for fitting the propensity score was 0.68. This value is an appropriate value for calculating the propensity score as it ranges from 0.6–0.9 and is not extremely close to 0.5 or 1.0, which are considered inappropriate [19, 20]. The standardised mean differences in baseline demographics for the matched study population are shown in Table 1 and Fig. 4: all variables achieved an appropriate balance (standardised mean difference < 0.1). In the bony-ankylosed group, the mean duration of ankylosis, as assessed by preoperative interviews with patients, was 36.1 ± 19.0 years, with 22 cases of spontaneous ankylosis and 18 of arthrodesis.

Clinical results

Intragroup comparison

In both groups, the postoperative JOA hip scores at the last follow-up had significantly improved compared to the preoperative scores for all components of "total", "pain", "range of motion", "gait ability", and "activities of daily living" (bony-ankylosed group: $p < 0.0001$, $p < 0.0001$, $p < 0.0001$, $p = 0.0038$, and $p = 0.0001$, respectively; control group: $p < 0.0001$, $p < 0.0001$, $p < 0.0001$, $p < 0.0001$, and $p < 0.0001$, respectively; Table 2).

Comparison between the bony-ankylosed and control groups

Preoperatively, the JOA hip scores for "total" and "pain" in the bony-ankylosed group were significantly higher than those in the control group ($p < 0.0001$ and $p < 0.0001$, respectively), whereas the scores for "range of motion" and "percentage of use of walking aids" were significantly lower ($p < 0.0001$ and $p = 0.0368$, respectively). No

Table 1 Baseline demographics for the propensity score-matched study population

Factors	Pre-match				Post-match			
1:1	Bony-ankylosed (*N* = 40)	Non-ankylosed (*N* = 829)	*p*-value	SMD	Bony-ankylosed (*N* = 40)	Non-ankylosed (*N* = 40)	*p*-value	SMD
Propensity score	0.08 ± 0.07	0.05 ± 0.04	< 0.0001*	0.678	0.08 ± 0.07	0.08 ± 0.07	1.000	0.002
Age (years)	60.2 ± 7.8	59.3 ± 9.2	0.251	0.097	60.2 ± 7.8	61.0 ± 9.3	0.958	0.099
Sex (Female)	24 (60.0%)	736 (88.8%)	< 0.0001*	0.698	24 (60.0%)	24 (60.0%)	1.000	0.000
Height (cm)	156.8 ± 9.1	152.4 ± 6.8	0.005*	0.540	156.8 ± 9.1	156.4 ± 8.6	0.856	0.041
Weight (kg)	57.7 ± 8.8	55.5 ± 9.4	0.143	0.244	57.7 ± 8.8	57.1 ± 8.9	0.745	0.073
BMI (kg/m^2)	23.4 ± 2.5	23.9 ± 3.7	0.279	0.146	23.4 ± 2.5	23.3 ± 2.6	0.796	0.058

* Significant differences ($p < 0.05$)

SMD Standardised mean difference, *BMI* Body mass index

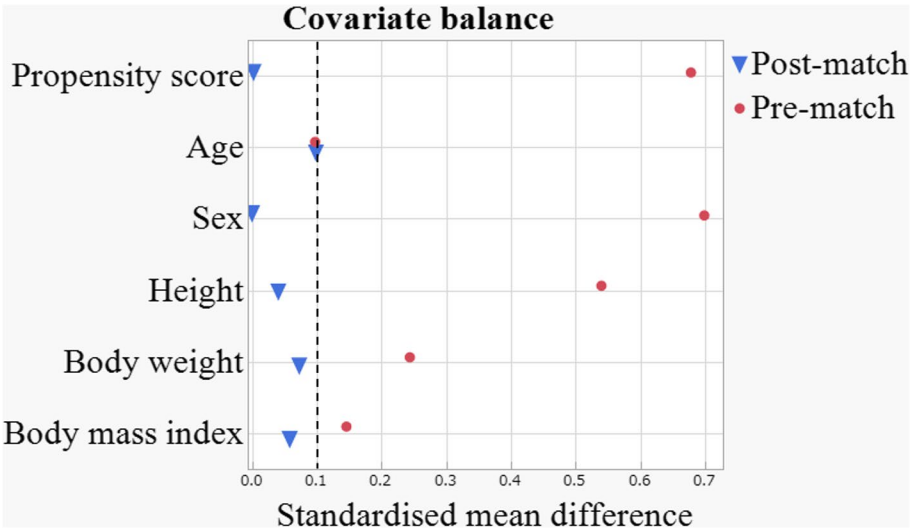

Fig. 4 Covariate balance in the comparative study. Dot chart showing changes in the standardised mean difference before (circle) and after (inverted triangle) matching

Table 2 Intragroup comparison of the Japanese Orthopaedic Association hip score

Group	Factors	Before surgery	Last follow-up	*p*-value
Bony ankylosed	JOA hip score			
	Total	60.0 ± 9.8	76.4 ± 13.3	< 0.0001*
	Pain	40.0 ± 0.0	37.6 ± 3.0	< 0.0001*
	ROM	0.0 ± 0.0	13.1 ± 3.8	< 0.0001*
	Gait ability	9.7 ± 5.6	12.4 ± 6.0	0.0038*
	ADL	10.3 ± 4.9	13.9 ± 5.2	0.0001*
Control	JOA hip score			
	Total	46.6 ± 12.4	90.0 ± 10.6	< 0.0001*
	Pain	14.3 ± 7.5	38.6 ± 3.6	< 0.0001*
	ROM	11.2 ± 3.5	16.8 ± 2.8	< 0.0001*
	Gait ability	9.3 ± 3.5	17.8 ± 3.7	< 0.0001*
	ADL	12.0 ± 2.5	16.8 ± 3.6	< 0.0001*

* Significant differences ($p < 0.05$)

Continuous variables are expressed as mean ± standard deviation

JOA Japanese Orthopaedic Association, *ROM* Range of motion, *ADL* Activities of daily living

significant differences were observed between the two groups with regards the JOA hip scores for "gait ability" and "activities of daily living" ($p = 0.5654$ and $p = 0.0563$, respectively). Regarding the postoperative values, the JOA hip scores at the last follow-up for all components of "total", "pain", "range of motion", "gait ability", and "activities of daily living" were significantly lower in the bony-ankylosed group than in the control group ($p < 0.0001$, $p = 0.0382$, $p < 0.0001$, $p < 0.0001$, and $p = 0.0083$, respectively).

The percentage of patients who used walking aids postoperatively, length of hospital stay, operating time, intraoperative and postoperative blood loss, allogeneic blood transfusion, number of hips with allogeneic blood transfusions, and number of hips with postoperative complications were significantly higher in the bony-ankylosed group than in the control group ($p < 0.0001$, $p < 0.0001$, $p < 0.0001$, $p < 0.0001$, $p = 0.0003$, $p < 0.0001$, $p = 0.0015$, and $p = 0.0021$, respectively; Table 3).

Complications in the bony-ankylosed group included eight cases of heterotopic ossification (HO), with four grade 1, three grade 2 and one grade 3 in Brooker's HO

Table 3 Comparison of outcomes between bony-ankylosed and control groups

Factors	Bony-ankylosed	Control	*p*-value	Odds ratio	95% confidence interval
Preoperative JOA hip score					
Total	60.0 ± 9.8	46.6 ± 12.4	< 0.0001*		
Pain	40.0 ± 0.0	14.3 ± 7.5	< 0.0001*		
ROM	0.0 ± 0.0	11.2 ± 3.5	< 0.0001*		
Gait ability	9.7 ± 5.6	9.3 ± 3.5	0.5654		
ADL	10.3 ± 4.9	12.0 ± 2.5	0.0563		
Preoperative use of walking aids	26 (65.0%)	34 (85.0%)	0.0368*	0.3	0.11–0.97
Postoperative JOA hip score at last follow-up					
Total	76.4 ± 13.3	90.0 ± 10.6	< 0.0001*		
Pain	37.6 ± 3.0	38.6 ± 3.6	0.0382*		
ROM	13.1 ± 3.8	16.8 ± 2.8	< 0.0001*		
Gait ability	12.4 ± 6.0	17.8 ± 3.7	< 0.0001*		
ADL	13.9 ± 5.2	16.8 ± 3.6	0.0083*		
Postoperative use of walking aids	21 (52.5%)	5 (12.5%)	< 0.0001*	7.7	2.51–23.8
Length of hospital stay (days)	29.3 ± 12.4	19.4 ± 9.2	< 0.0001*		
Follow-up period (years)	12.7 ± 2.7	11.6 ± 1.5	0.1619		
Operating time (minutes)	68.8 ± 19.9	34.8 ± 9.5	< 0.0001*		
Intraoperative blood loss (g)	328.5 ± 246.4	175.6 ± 136.3	< 0.0001*		
Postoperative blood loss (g)	834.1 ± 462.7	504.9 ± 284.5	0.0003*		
Allogeneic blood transfusion (unit)	2.4 ± 1.9	0.8 ± 1.2	< 0.0001*		
Complications	12 (30.0%)	2 (5.0%)	0.0021*	8.1	1.69–39.32
Revision surgery	3 (7.5%)	1 (2.5%)	0.6153	2.1	0.18–23.59

* Significant differences ($p < 0.05$)

Continuous variables are expressed as mean ± standard deviation. Categorical variables are expressed as absolute and percent values

JOA Japanese Orthopaedic Association, *ROM* Range of motion, *ADL* Activities of daily living

grade [21]; and loosening of the acetabular side prosthesis; destruction of the femoral side prosthesis; periprosthetic joint infection; and dislocation in one case each. Complications in the control group included periprosthetic joint infection and dislocation in one case each.

Laboratory results

In the bony-ankylosed group on postoperative day 1, the platelet and creatinine phosphokinase levels were significantly lower and higher, respectively, than those in the control group ($p < 0.0209$ and $p < 0.0034$, respectively; Table 4). A positive correlation was found between operative time and intraoperative blood loss; a negative correlation was found between age at primary THA and intraoperative blood loss, and between the duration of ankylosis before primary THA and intraoperative blood loss ($p = 0.0001$, $p < 0.0080$, and $p < 0.0289$, respectively; Table 5).

Radiographic results

To study the additional outcomes, CT was performed in 11 and eight patients in the bony-ankylosed and control groups, respectively (19 cases). The mean postoperative CSA of the gluteus medius in the bony-ankylosed group was 1363.3.9 ± 495.1 mm^2, which was significantly lower than that in the control group (2377.5 ± 580.2 mm^2; $p = 0.0030$).

The mean postoperative CT values of the gluteus medius at the CSA in the bony-ankylosed group was −4.4 ± 28.6 Hounsfield unit, which was significantly lower than that in the control group (31.8 ± 23.0 mm^2; $p = 0.0039$). The mean time of postoperative CT imaging in the bony-ankylosed and control groups were 7.6 ± 3.5 and 10.1 ± 2.6 years, respectively, which were not significantly different ($p = 0.2437$).

Survival of acetabular and femoral components

The cumulative survival rates of the cup, stem, and overall, with revision as the endpoint, were not significantly different between the bony-ankylosed and control groups ($p = 0.5620$, $p = 0.1753$, and $p = 0.3378$, respectively; Fig. 5A–C).

Table 4 Comparison of laboratory data between bony-ankylosed and control groups

Laboratory data	Bony ankylosed	Control	*p*-value
Hb (g/dL)			
Preoperative	12.8 ± 1.7	13.4 ± 1.7	0.0706
POD 1	10.1 ± 1.4	10.5 ± 1.6	0.2715
POD 7	9.8 ± 1.5	10.3 ± 1.6	0.1342
Plt ($\times 10^9$/L)			
Preoperative	229.6 ± 75.6	248.9 ± 70.6	0.1358
POD 1	150.1 ± 42.4	178.4 ± 57.0	0.0209*
POD 7	248.1 ± 6.6	277.3 ± 78.8	0.0898
AST (U/L)			
Preoperative	22.1 ± 7.4	22.4 ± 9.6	0.8756
POD 1	24.5 ± 10.5	21.3 ± 7.1	0.1291
POD 7	25.7 ± 9.4	23.3 ± 11.6	0.1501
ALT (U/L)			
Preoperative	19.1 ± 10.1	21.2 ± 19.3	0.5080
POD 1	15.5 ± 7.1	15.8 ± 12.5	0.6637
POD 7	27.0 ± 19.6	26.6 ± 31.8	0.4384
CK (mg/dL)			
Preoperative	104.3 ± 38.2	97.5 ± 48.3	0.3100
POD 1	616.0 ± 402.4	318.2 ± 91.5	0.0034*
POD 7	134.2 ± 83.4	140.2 ± 53.1	0.4784
ALP (IU/L)			
Preoperative	265.7 ± 93.4	268.8 ± 83.5	0.8871
POD 1	186.8 ± 58.0	188.7 ± 66.2	0.9003
POD 7	243.3 ± 94.3	266.2 ± 144.5	0.4355
CRP (mg/dL)			
Preoperative	0.2 ± 0.2	0.3 ± 0.4	0.1676
POD 1	3.1 ± 1.6	3.2 ± 1.9	0.9873
POD 7	2.0 ± 1.8	2.1 ± 1.8	0.3490

* Significant differences ($p < 0.05$)

Continuous variables are expressed as mean ± standard deviation

POD Postoperative day, *Hb* Haemoglobin, *Plt* Platelet, *AST* Aspartate transaminase, *ALT* Alanine aminotransferase, *CK* Creatine phosphokinase, *ALP* Alkaline phosphatase, *CRP* C-reactive protein

Discussion

This study revealed two important clinical findings. First, except for pain, patients with bony ankylosed hips had improved JOA hip scores after THA; however, the pain scores were worse. Furthermore, the postoperative JOA hip scores in all subcategories and the rate at which the use of walking aids was not required in the bony-ankylosed group were significantly lower than those in the control group. Second, the number of hips with postoperative complications was significantly higher in the bony-ankylosed group than in the control group.

The results of the current study showed that although the total JOA hip score of the bony-ankylosed group improved, the pain score worsened: this disadvantage indicated some discomfort and fatigue in the hip that was originally pain-free. Compared to the control group, JOA hip scores were lower in the bony-ankylosed group in all categories. More than half the patients (52.5%, 21/40) with bony ankylosed hips used a walking aid postoperatively (odds ratio, 7.7) compared to 12.5% (5/40) of those in the control group. These results suggest that THA for patients with bony

Table 5 Correlation between intraoperative blood loss and other variables in the bony-ankylosed group

Factors	Spearman's correlation coefficient (ρ)	*p*-value
Continuous variables		
Age at primary THA	−0.4135	0.0080*
Height	−0.00135	0.9341
Weight	−0.1454	0.3706
BMI	−0.2529	0.1153
Duration of ankylosis before primary THA	−0.3595	0.0289*
Length of hospital stay	0.0000	1.0000
Operative time	0.5703	0.0001*
Postoperative blood loss	0.2821	0.0778
Allogeneic blood transfusion	−0.0104	0.9494
Preoperative total JOA hip score	−0.2836	0.0761
Postoperative total JOA hip score at last follow-up	−0.2920	0.0752
Preoperative laboratory data		
Hb	0.0157	0.9232
Plt	0.2275	0.1580
AST	−0.2696	0.1172
ALT	−0.2555	0.1385
CK	−0.1807	0.3223
ALP	0.3299	0.0530
CRP	0.2505	0.1190
Categorical variables		
Sex		0.8541
Ankylosis type		0.8519
Complications		0.1301

* Significant differences ($p < 0.05$)

THA Total hip arthroplasty, *BMI* Nody mass index, *JOA* Japanese Orthopaedic Association, *Hb* Haemoglobin, *Plt* Platelet, *AST* Aspartate transaminase, *ALT* Alanine aminotransferase, *CK* Creatine phosphokinase, *ALP* Alkaline phosphatase, *CRP* C-reactive protein

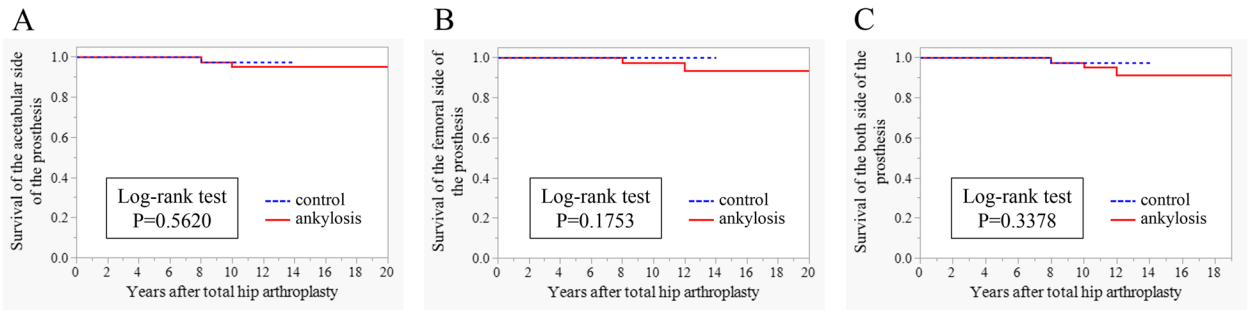

Fig. 5 Cumulative survival rates of the ankylosis group and the control group at 10 years. The cumulative survival rates for the acetabular side of the prosthesis (**A**) for the ankylosis and control groups were 95.0% and 97.5%, respectively. The cumulative survival rates for the femoral side of the prosthesis (**B**) for the ankylosis and control groups were 97.5% and 100%, respectively. The cumulative survival rates of both sides of the prosthesis (**C**) in the ankylosis and control groups were 95% and 97.5%, respectively

ankylosed hips can somewhat improve the JOA hip score, but not to the same extent as THA for patients without ankylosed hips. This should be preoperatively communicated to patients with bony ankylosed hips who undergo THA.

Herein, a greater number of hips in the bony-ankylosed group had postoperative complications than those in the control group and the complications were characterised by HO. HO may be a consequence of the large number of bone fragments produced during osteotomy [22].

Another possible reason is soft tissue damage during surgery. Soft tissue damage due to surgery provides an environment for osteoblasts to develop from mesenchymal cells, causing HO [23, 24]. We observed that blood creatine phosphokinase levels on the first postoperative day in the bony-ankylosed group were higher than those in the control group; creatine phosphokinase levels increase with soft tissue—including skeletal muscle—damage [25, 26]. We hypothesise that damage to the soft tissue during surgery was greater in the bony-ankylosed group than in the control group because of the significant adhesions and anatomical variations around the hip joint, which required a more extensive approach than in normal THA procedures.

THA for an ankylosed hip requires a higher level of surgical skill for osteotomy and soft tissue approach and a longer operative time than normal THA [27]. In the current study, intraoperative blood loss, operative time, and blood transfusion were higher in the bony-ankylosed group than in the control group, and the platelet count on postoperative day 1 was lower. Additionally, intraoperative blood loss and operative time were positively correlated. Age at the time of THA and the duration of ankylosis also showed negative correlations with intraoperative blood loss. Skeletal muscle is a vascular-rich tissue; however, muscle mass and vascularity decrease with age and prolonged lack of use [28]. We believe that this negative correlation occurred because the amount of muscle approached at the time of surgery differed depending on the age and duration of ankylosis. Therefore, adequate blood transfusion preparation should be ensured prior to THA for ankylosed hips, especially in young patients or patients with short duration ankylosis.

The gluteus medius is one of the major muscles of the hip abductor group and an important determinant of hip function: it ensures hip stability and controls pelvic posture during standing and walking [29]. Decreased gluteus medius volume is the main cause of limp gait in patients with hip joint osteoarthritis [30, 31]. A decrease in the CT values of the gluteus medius represents an atrophic change in the nature of the muscle and muscle weakness in patients with gait disturbance [16]. Herein, the bony-ankylosed group had significantly lower CSA and CT values of the gluteus medius than the control group. Thus, gluteus medius atrophy may have contributed to lower JOA hip scores and longer hospital stays in the bony-ankylosed group.

Several studies have reported implant survival rates for THA of ankylosed hips. Hamadouche et al. reported an 8-year survival rate of 96.7% and Joshi et al. reported a 10-year survival rate of 96.1% [32, 33]. Paxton et al. conducted an international comparison of implant survival rates of primary THA for osteoarthritis and reported survival rates of approximately 93–95% [34]. In the current study, the 10-year survival rate of implants in the bony-ankylosed group was 95%, which is comparable with the three aforementioned reports and the current study's control group. In this study, the THAs performed on the patients with bony ankylosed hips had high survival rates. In contrast, Richards and Duncan reported a 10-year survival rate of 74.2% for conversion of hip arthrodesis to THA [35]. They reported lower survival rates than those of our study. Although a statistical examination was not possible, the mean age of the patients in their study (50 years) was lower than that in our study (60.2 years). The relatively older age of our patients at the time of surgery and the different generations of implants may have affected the survival rate of the implants.

This study had four limitations. First, this was a retrospective, single-centre study. However, we used propensity score matching to minimise confounding factors. Second, due to inadequate data recording, we could not assess the outcomes of adjacent joint disorders. Third, only a small number of patients underwent postoperative CT. However, the statistical power of the outcomes was sufficient. Fourth, many patients were excluded due to follow-up periods of less than 10 years. The reason for this is that many patients came to the hospital from far away and the follow-up may have been carried out by the patient's neighbouring doctor, making the follow-up untraceable.

In summary, THA for patients with bony ankylosed hips achieved positive results, such as increased JOA hip scores for all items except pain; however, these scores were inferior to those observed in patients with non-ankylosed hips. The number of hips with postoperative complications was significantly higher in the bony-ankylosed group than in the control group.

Abbreviations

THA	Total hip arthroplasty
JOA	Japanese Orthopaedic Association
CT	Computed tomography
CSA	Cross-sectional area
ICC	Intraclass correlation coefficient
HO	Heterotopic ossification

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Authors' contributions

S. K. initiated the study, analysed the data, wrote the first draft of the manuscript, and contributed significantly to the final draft of the manuscript. R. T. initiated the study, collected data, and assisted with the first draft of the manuscript. M. S. initiated and designed the study, collected data, helped with the first draft of the manuscript, and contributed significantly to the final draft of the manuscript. M. U. and M. K. initiated the study and assisted with the first draft of the manuscript. T. N. collected data and helped with the first draft of the manuscript. M. M. contributed significantly to the final draft of the manuscript and supervised this study. All authors have read and approved the final manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Ethics Committee of Saga University Hospital (Reference number: 2020–06-R07). All patients provided written informed consent prior to participation.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopaedic Surgery, Faculty of Medicine, Saga University, 5-1-1 Nabeshima, Saga City, Saga 849-8501, Japan. [2]Department of Orthopaedic Surgery, Toho University Omori Medical Centre, 6-11-1 Omorinishi, Ota-Ku, Tokyo 143-8541, Japan. [3]Department of Orthopaedic Surgery, Saga Central Hospital, 3-8-1 Hyogominami, Saga City, Saga 849-8522, Japan. [4]Department of Orthopaedic Surgery, Shiroishi Kyoritsu Hospital, 1296 Fukuda, Shiroishi-cho, Kishima-gun, Saga 849-1112, Japan.

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References

1. Callaghan JJ, Brand RA, Pedersen DR. Hip arthrodesis. A long-term follow-up. J Bone Joint Surg Am. 1985;67:1328–35.
2. Sofue M, Kono S, Kawaji W, Homma M. Long term results of arthrodesis for severe osteoarthritis of the hip in young adults. Int Orthop. 1989;13:129–33.
3. Offierski CM, MacNab I. Hip-spine syndrome. Spine (Phila Pa. 1976;1983(8):316–21.
4. Kim YH, Oh SH, Kim JS, Lee SH. Total hip arthroplasty for the treatment of osseous ankylosed hips. Clin Orthop Relat Res. 2003;414:136–48.
5. Fernandez-Fairen M, Murcia-Mazon A, Torres A, Querales V, Murcia A Jr. Is total hip arthroplasty after hip arthrodesis as good as primary arthroplasty? Clin Orthop Relat Res. 2011;469:1971–83.
6. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. Lancet. 2007;370:1508–19.
7. Murphy BPD, Dowsey MM, Spelman T, Choong PFM. What is the impact of advancing age on the outcomes of total hip arthroplasty? J Arthroplasty. 2018;33:1101–7.e1.
8. Inacio MC, Ake CF, Paxton EW, Khatod M, Wang C, Gross TP, et al. Sex and risk of hip implant failure: assessing total hip arthroplasty outcomes in the United States. JAMA Intern Med. 2013;173:435–41.
9. Brunner JH, Foucher KC. Sex specific associations between biomechanical recovery and clinical recovery after total hip arthroplasty. Clin Biomech (Bristol, Avon). 2018;59:167–73.
10. Haynes J, Nam D, Barrack RL. Obesity in total hip arthroplasty: does it make a difference? Bone Joint J. 2017;99-b(1 Supple A):31–6.
11. Hijazi A, Padela MT, Sayeed Z, Hammad A, Devole K, Frush T, et al. Review article: patient characteristics that act as risk factors for intraoperative complications in hip, knee, and shoulder arthroplasties. J Orthop. 2020;17:193–7.
12. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983;70:41–55.
13. Austin PC. Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. Pharm Stat. 2011;10:150–61.
14. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. Stat Med. 2009;28:3083–107.
15. Austin PC. The relative ability of different propensity score methods to balance measured covariates between treated and untreated subjects in observational studies. Med Decis Making. 2009;29:661–77.
16. Momose T, Inaba Y, Choe H, Kobayashi N, Tezuka T, Saito T. CT-based analysis of muscle volume and degeneration of gluteus medius in patients with unilateral hip osteoarthritis. BMC Musculoskelet Disord. 2017;18:457.
17. Wheeler DJ. EMP III using imperfect data. Knoxville, Tennessee: SPC Press; 2006. p. 52–3.
18. Cochran WG. Some methods for strengthening the common χ^2 tests. Biometrics. 1954;10:417–51.
19. Rubin DB. Estimating causal effects from large data sets using propensity scores. Ann Intern Med. 1997;127:757–63.
20. Fu AZ, Li L. Thinking of having a higher predictive power for your first-stage model in propensity score analysis? Think again. Health Serv Outcomes Res Methodol. 2008;8:115–7.
21. Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am. 1973;55:1629–32.
22. Tannous OO, Pellegrini VD. Heterotopic ossification. Philadelphia: Elsevier Inc.; 2013. p. 1277–88.
23. Kaplan FS, Glaser DL, Hebela N, Shore EM. Heterotopic ossification. J Am Acad Orthop Surg. 2004;12:116–25.
24. Ranganathan K, Loder S, Agarwal S, Wong VW, Forsberg J, Davis TA, et al. Heterotopic ossification: basic-science principles and clinical correlates. J Bone Joint Surg Am. 2015;97:1101–11.
25. Kumbhare D, Parkinson W, Dunlop B. Validity of serum creatine kinase as a measure of muscle injury produced by lumbar surgery. J Spinal Disord Tech. 2008;21:49–54.
26. Lott JA, Landesman PW. The enzymology of skeletal muscle disorders. Crit Rev Clin Lab Sci. 1984;20:153–90.
27. Celiktas M, Kose O, Turan A, Guler F, Ors C, Togrul E. Conversion of hip fusion to total hip arthroplasty: clinical, radiological outcomes and complications in 40 hips. Arch Orthop Trauma Surg. 2017;137:119–27.
28. Latroche C, Gitiaux C, Chretien F, Desguerre I, Mounier R, Chazaud B. Skeletal muscle microvasculature: a highly dynamic lifeline. Physiology (Bethesda). 2015;30:417–27.
29. Preininger B, Schmorl K, von Roth P, Winkler T, Schlattmann P, Matziolis G, et al. A formula to predict patients' gluteus medius muscle volume from hip joint geometry. Man Ther. 2011;16:447–51.
30. Arokoski MH, Arokoski JP, Haara M, Kankaanpää M, Vesterinen M, Niemitukia LH, et al. Hip muscle strength and muscle cross sectional area in men with and without hip osteoarthritis. J Rheumatol. 2002;29:2185–95.
31. Rasch A, Byström AH, Dalen N, Berg HE. Reduced muscle radiological density, cross-sectional area, and strength of major hip and knee muscles in 22 patients with hip osteoarthritis. Acta Orthop. 2007;78:505–10.
32. Hamadouche M, Kerboull L, Meunier A, Courpied JP, Kerboull M. Total hip arthroplasty for the treatment of ankylosed hips : a five to twenty-one-year follow-up study. J Bone Joint Surg Am. 2001;83:992–8.
33. Joshi AB, Markovic L, Hardinge K, Murphy JC. Conversion of a fused hip to total hip arthroplasty. J Bone Joint Surg Am. 2002;84:1335–41.
34. Paxton EW, Cafri G, Nemes S, Lorimer M, Kärrholm J, Malchau H, et al. An international comparison of THA patients, implants, techniques, and survivorship in Sweden, Australia, and the United States. Acta Orthop. 2019;90:148–52.
35. Richards CJ, Duncan CP. Conversion of hip arthrodesis to total hip arthroplasty: survivorship and clinical outcome. J Arthroplasty. 2011;26:409–13.

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