The modified Spitzy shelf acetabuloplasty for the dysplastic hip

A retrospective study of 144 hips

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Correspondence should be sent to K. Oe oeken@hirakata.kmu.ac.jp

K. Oe,[1] H. Iida,[1] Y. Otsuki,[1] F. Kobayashi,[1] S. Sogawa,[1] T. Nakamura,[1] T. Saito[1]

Department of Orthopaedic Surgery, Kansai Medical University, Hirakata, Japan

Aims

Although there are various pelvic osteotomies for acetabular dysplasia of the hip, shelf operations offer effective and minimally invasive osteotomy. Our study aimed to assess outcomes following modified Spitzy shelf acetabuloplasty.

Methods

Between November 2000 and December 2016, we retrospectively evaluated 144 consecutive hip procedures in 122 patients a minimum of five years after undergoing modified Spitzy shelf acetabuloplasty for acetabular dysplasia including osteoarthritis (OA). Our follow-up rate was 92%. The mean age at time of surgery was 37 years (13 to 58), with a mean follow-up of 11 years (5 to 21). Advanced OA (Tönnis grade ≥ 2) was present preoperatively in 16 hips (11%). The preoperative lateral centre-edge angle ranged from -28° to 25°. Survival was determined by Kaplan-Meier analysis, using conversions to total hip arthroplasty as the endpoint. Risk factors for joint space narrowing less than 2 mm were analyzed using a Cox proportional hazards model.

Results

The mean Merle d'Aubigné clinical score improved from 11.6 points (6 to 17) preoperatively to 15.9 points (12 to 18) at the last follow-up. The survival rates were 95% (95% confidence interval (CI) 91 to 99) and 86% (95% CI 50 to 97) at ten and 15 years. Multivariate Cox regression identified three factors associated with radiological OA progression: age (hazard ratio (HR) 2.85, 95% CI 1.05 to 7.76; p = 0.0398), preoperative joint space (HR 2.41, 95% CI 1.35 to 4.29; p = 0.0029), and preoperative OA (HR 8.34, 95% CI 0.94 to 73.77; p = 0.0466).

Conclusion

Modified Spitzy shelf acetabuloplasty is an effective joint-preserving surgery with a wide range of potential indications.

Take home message

- Modified Spitzy shelf acetabuloplasty is an effective joint-preserving surgery with a wide range of potential indications.
- Risk factors of radiological osteoarthritis (OA) progression after modified Spitzy shelf acetabuloplasty were age, preoperative joint space, and preoperative OA.

Introduction

Acetabular dysplasia of the hip is a common cause of osteoarthritis (OA).[1,2] In younger patients with acetabular dysplasia, joint-preserving hip surgery can change the mechanical environment and prevent or at least retard the development of secondary OA, which may prevent the future need for total hip arthroplasty (THA). Rotational acetabular osteotomy (RAO) and periacetabular osteotomy (PAO), which can reorient the dysplastic acetabulum, improve hip stability, relieve pain, and reduce the load on the acetabular rim including the labrum and articular cartilage,

Table I. Patient demographic and radiological data.

Variable	Data
Hips, patients (n)	144 (122)
Mean age at surgery, yrs (range)	37 (13 to 58)
Male:female, n	18:104
Right:left, n	73:71
Previous surgery in childhood (hips), n	
Open reduction	2
Salter osteotomy	4
Unknown osteotomy	4
Mean follow-up, yrs (range)	11 (5 to 21)
Mean lateral centre-edge angle, degrees (range)	10 (-28 to 25)
Preoperative modified Tönnis grade (hips), n	
0	64
1	64
2	13
3	3
Preoperative morphology according to Stulberg (hips), n	
Class I and II: sphericity of femoral head	132
Class III, IV, and V: asphericity of femoral head	12
Mean operation time, mins (range)	
Only shelf operation	106 (74 to 176)
Combined with osteotomy	178 (135 to 245)
Combined with arthroscopy	205 (159 to 259)
Mean blood loss, ml (range)	
Only shelf operation	135 (30 to 592)
Combined with osteotomy	277 (35 to 629)
Combined with arthroscopy	146 (58 to 321)
Combined operation (hips), n	
Varus intertrochanteric osteotomy	9
Valgus intertrochanteric osteotomy	4
Arthroscopic debridement	7

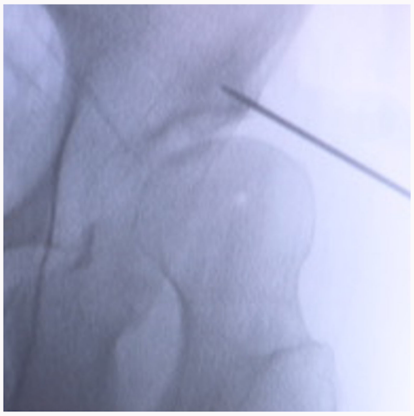

Fig. 1
Intraoperative anteroposterior radiograph using a fluoroscope. During the surgery, two 2.0 mm Kirschner (K-) wires were temporarily inserted, one each from the anterior and posterior ends of the bone slot, and were pointed in the direction of the planned shelf. The height and orientation of the shelf were determined under fluoroscopy, based on findings from these two K-wires.

are commonly performed for acetabular dysplasia worldwide.[3,4] However, factors such as advanced OA and joint incongruity can negatively affect the prognosis for these realignment pelvic osteotomies and have generally been considered contraindications.[5-7]

Shelf operation, which is considered an extra-articular pelvic procedure, was first described by König[8] in 1891, and many modifications, such as those by Albee,[9] Spitzy,[10] and Lance,[11] have been reported. Shelf operations are reasonable and minimally invasive compared to realignment pelvic osteotomies. Since 2000, our institution (Kansai Medical University, Hirakata, Japan) has performed over 200 Spitzy shelf operations combined with a vertical flap osteotomy of the outer cortex of the ilium, a procedure called "tectoplasty" for acetabular dysplasia, including patients with OA if necessary.[12–16] However, although several studies have proven the efficacy of shelf operations,[13-22] the indications for these procedures and the risk factors for poor outcomes remain unclear.

The primary aim of this study was to assess the mid-term durability of our modified Spitzy shelf acetabuloplasty. We also planned to identify the subsequent risk factors for radiological OA progression. We hypothesized that this modified procedure would be safe and effective in the management of acetabular dysplasia.

Methods

Study design and patients

Between November 2000 and December 2016, we treated 157 consecutive hips (134 patients) with modified Spitzy shelf acetabuloplasty for acetabular dysplasia at our institution. In the current study, 144 hips (122 patients) in 104 females and 18 males were retrospectively evaluated for a minimum of five years, with 13 hips lost to follow-up (follow-up rate 92%). The main reason that hips were lost to follow-up was that those patients moved away; we did not identify any specific demographic characteristics among that group. The indication for this procedure was symptomatic hip dysplasia with hip pain in all patients, including even those in middle age and those with OA. We chose this approach to provide the patient with more time before THA became necessary. No other surgical treatments in adults were performed for acetabular dysplasia by our institution during this study period. Mean age at time of surgery was 37 years (13 to 58), with mean follow-up of 11 years (5 to 21). OA stage was assessed based on the Tönnis classification.[23] However, under that system, hips that had lost femoral head sphericity were immediately classified as grade 3 or higher, so we used a modified Tönnis classification that did not consider sphericity. The preoperative stage was modified Tönnis grade 0 in 64 hips, grade 1 in 64 hips, grade 2 in 13 hips, and grade 3 in three hips. Asphericity of the femoral head, class III or above based on the Stulberg classification,[24] was noted preoperatively in 12

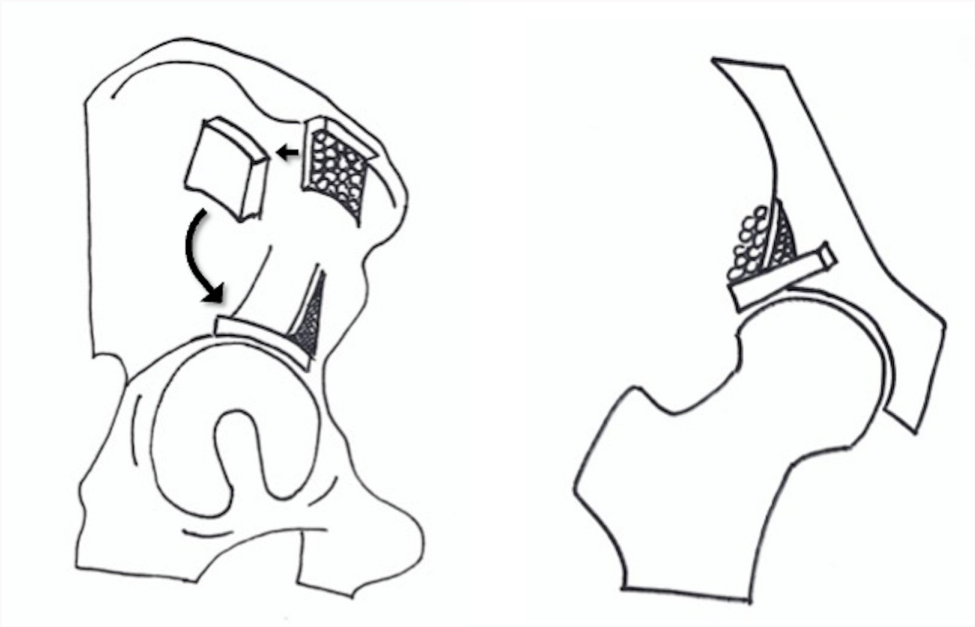

Fig. 2
Schema of modified Spitzy shelf acetabuloplasty in the right hip. The free cortex graft was inserted into the slot. At the same time, a proximally-based vertical flap of the outer iliac cortex was raised proximal to the inlet of the slot (tectoplasty). Finally, cancellous bone chips were packed into the triangular space made by the new shelf and the raised vertical flap.

hips (8%). The preoperative lateral centre-edge angle (LCEA) ranged from -28° to 25°.[25] Previous surgery in childhood had been performed in ten hips (7%), consisting of open reduction for congenital dislocation in two hips, a Salter osteotomy in four hips, and unknown osteotomy in four hips (Table I).

Our institutional review board approved this retrospective cohort study, and each patient gave informed consent for patient data to be included in the published findings.

Surgical procedure

We used a Smith-Petersen approach in the lateral position in all patients.[26] To avoid postoperative pain from irritation, we avoided placing an incision directly above the iliac crest, but instead used a short oblique transverse incision (about 12 cm) distal to the original approach. We used a chisel to remove a thin strip of bone from the iliac crest and attach that bone fragment to the tensor fascia latae muscle to encourage reattachment. The outer cortex of the ilium was exposed subperiosteally down to the joint capsule, and the reflected head of the rectus femoris muscle was detached from the acetabular rim. We used fluoroscopy in the anteroposterior (AP) plane, angled approximately 20° cephalad, with two 2.0 mm Kirschner (K-) wires temporarily inserted, once each from the anterior and posterior ends of the bone slot, and pointed in the direction of the planned new shelf (Figure 1). A broad osteotome was introduced along the joint capsule into the acetabular rim at the exact level of the location connecting the entry points for the two K-wires. Osteotomes and small curettes were used to create a slot on the new shelf 1 cm in depth and an inlet of 3 × 0.3 cm, and the K-wires were removed. We then used osteotomes to collect a free bone graft of 3 × 3 cm and cancellous bone chips from the outer portion of the ilium (not all layers). A proximally-based vertical flap of the outer iliac cortex of 2 × 4 cm was created proximal to the inlet of the slot using a curved osteotome and elevatorium (tectoplasty). The free bone graft was then inserted into the slot to encourage the concave side of the cortex cover to fit snugly into the joint capsule, and the vertical flap was carefully raised to cover the new shelf, with the curved osteotomes remaining in position on the sides of the flap. In middle age, tectoplasty must be performed with meticulous care because of the increased age-related stiffness of the cortical bone. After removing the curved osteotomes, cancellous bone chips were packed into the triangular space made by the new shelf and the raised vertical flap (Figures 2 and 3). Autografts were used for all shelf operations. A drain was placed in the outer iliac region, after which approximately five holes were made at 1.0 cm intervals in the iliac crest using a 2.0 mm K-wire, and the detached tensor fascia latae muscle and thin strip of bone fragment were sutured with No. 2 non-absorbable polyester sutures (TEVDEK; Akiyama-Seisakusho, Japan).

The modified Spitzy shelf acetabuloplasty was combined with a varus (nine hips) or valgus (four hips) intertrochanteric osteotomy or with arthroscopic debridement (seven hips). Intertrochanteric osteotomy was indicated if there was obvious improvement in congruency on dynamic radiography (i.e., in the position of hip abduction or adduction), while arthroscopic debridement was indicated for severe pain with labral tear and synovitis.

Follow-up protocol

In the postoperative rehabilitation protocol, the patients were encouraged to move in bed while wearing compression stockings for three days after surgery.

On postoperative day four, gait training and muscle exercise were started with physiotherapy. Partial weightbearing and walking with double crutches were

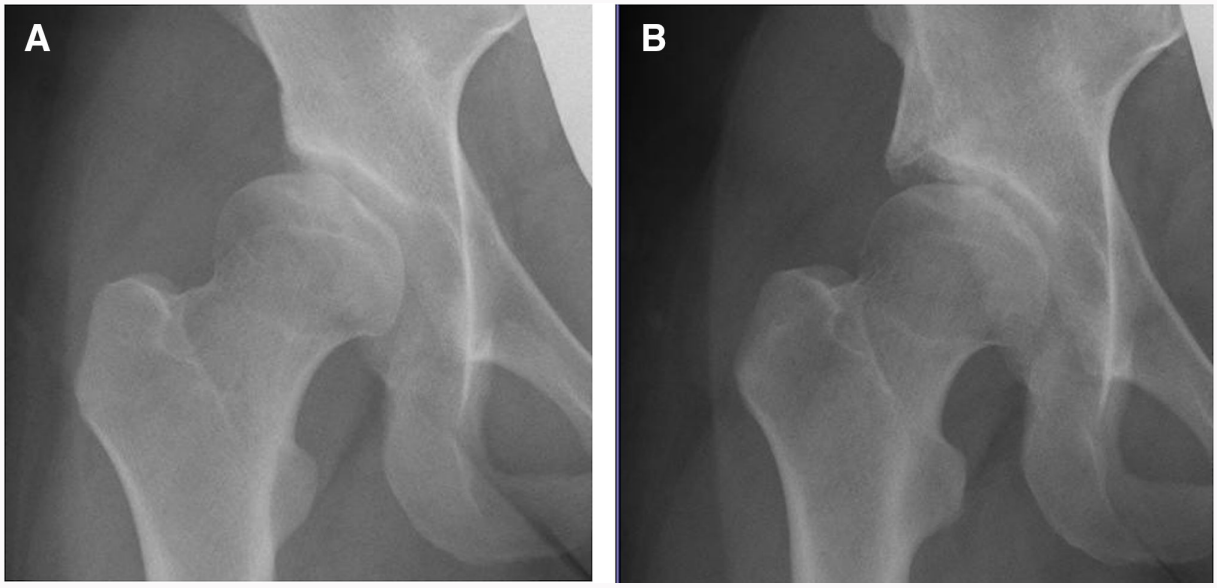

Fig. 3
Radiographs of a 23-year-old female who had undergone a modified Spitzy shelf acetabuloplasty on the right hip: a) preoperatively, osteoarthritis Tönnis grade 0, a lateral centre-edge angle of 9° (Merle d'Aubigné clinical score, 14 points), and b) at ten years postoperatively, no osteoarthritis changes, a lateral centre-edge angle of 37° (Merle d'Aubigné clinical score, 18 points).

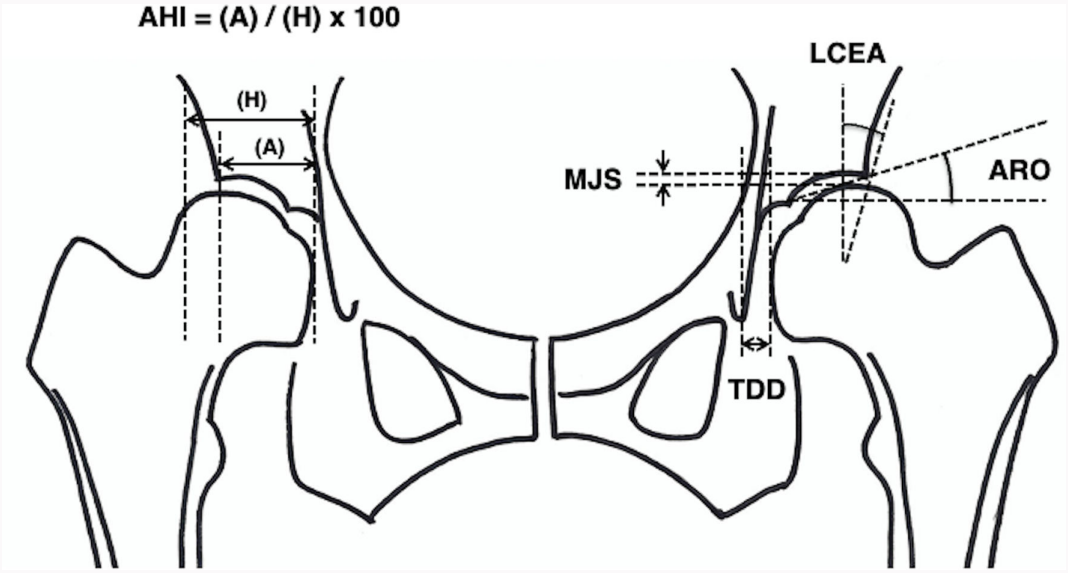

Fig. 4
Radiographical parameters for evaluation: a) minimum joint space (MJS), b) lateral centre-edge angle (LCEA), c) acetabular head index (AHI), d) acetabular roof obliquity (ARO), and e) tear drop distance (TDD).

allowed three weeks after surgery, and full weightbearing and active hip flexion were recommended at eight weeks after surgery.

Prophylaxis of heterotopic ossification was not performed. All patients had weekly follow-up for two months, then follow-up at three, six, and nine months, and biannually thereafter.

Retrospective analysis was performed by two blinded orthopaedic surgeons (KO, YO). Patients' records were used to identify surgical operation time, loss of blood volume, intraoperative and postoperative complications, and additional operations.

Clinical and radiological evaluation

For clinical assessment, the Merle d'Aubigné and Postel[27] grading system was used preoperatively and at the last follow-up. For radiological assessment, AP radiographs of the pelvis in the supine position were evaluated using a ruler (Carestream Health Japan, Japan). Shelf height, defined as the vertical distance between the lower surface of the grafted bone and the outer acetabular edge, was measured.[15] Measured parameters included the LCEA,[25] acetabular head index (AHI),[28] acetabular roof obliquity (ARO),[29] and tear drop distance (TDD)[30] (Figure 4). Minimum joint space (MJS) was also measured at

Table II. Preoperative and last follow-up radiological parameters.

Variable	Preoperative	Last follow-up	p-value*
Mean shelf height, mm (range)	N/A	2.3 (0 to 8)	
Mean lateral centre-edge angle, degrees (range)	10.3 (-28 to 25)	37.8 (11 to 66)	< 0.001
Mean acetabular head index (range)	61.3 (28 to 86)	89.8 (58 to 110)	< 0.001
Mean acetabular roof obliquity, degree (range)	21.1 (3 to 43)	8.3 (-9 to 38)	< 0.001
Mean tear drop distance, mm (range)	11.8 (1 to 26)	12.4 (5 to 22)	0.007
Mean minimum joint space, mm (range)	3.9 (0.5 to 8.2)	3.1 (0 to 6.8)	< 0.001
Mean resorption of grafted bone, % (range)	N/A	82 (68 to 96)	
Modified Tönnis grade (hips), n			
0	64	49	
1	64	71 (3)	
2	13	17 (4)	
3	3	7 (5)	

Numbers in parentheses indicate the number of conversions to total hip arthroplasty.
*Wilcoxon's signed-rank test.
N/A, not applicable.

the apical transection of the weightbearing surface by a vertical line through the centre of the femoral head.[31] Resorption of grafted bone was defined as the ratio between immediately after surgery and final follow-up, in the horizontal distance from the lateral edge of the graft to the outer acetabular edge. OA was evaluated by modified Tönnis classification, [23] with radiological OA progression defined as joint space narrowing to less than 2 mm. Each observer measured each hip three times at one week intervals, and the values were averaged. Kappa values were used to analyze the data for intraobserver and interobserver agreement,[32] with those values interpreted as poor below 0.20, fair from 0.21 to 0.40, moderate from 0.41 to 0.60, good from 0.61 to 0.80, and very good from 0.81 to 1.0.[32] The intraobserver variability of shelf height (mean kappa value 0.90), LCEA (0.87), AHI (0.82), ARO (0.85), TDD (0.89), and MJS (0.88) was very good, as was the interobserver variability of those same kappa values (0.88, 0.90, 0.85, 0.83, 0.90, and 0.89, respectively).

Statistical analysis

For differences between means, we used the Wilcoxon's signed-rank test. Survival was determined from Kaplan-Meier analysis with 95% CIs, with conversion to THA as the endpoint. We created univariate Cox's proportional hazards models to assess risk factors for radiological OA progression and applied multivariate Cox analysis to all independently related variables. Cross-tables and the chi-squared test were also used to analyze risk factors. All data were analyzed using one-way analysis of variance with SAS version 9.2 (SAS Institute, USA); p-values < 0.05 were considered significant.

Results

The mean Merle d'Aubigné clinical score was 11.6 points (6 to 17) preoperatively and improved to 15.9 points (12 to 18 points) at the last follow-up ($p < 0.0001$, Wilcoxon's signed-rank test). In 16 hips, that score worsened during follow-up, and 12 hips were converted to THA. The mean score immediately prior to conversion to THA was 6.9 points (4 to 8). We noted temporary lateral femoral cutaneous nerve palsy in two hips (1%). No other complications, such as femoral head necrosis, deep vein thrombosis, or wound issues, were encountered, and no patients required blood transfusion.

Preoperative and last follow-up radiological parameters are shown in Table II. There were no graft displacements or graft fractures. Mean shelf height was 2.3 mm (0 to 8). We found equivalent improvements in LCEA and AHI in all patients. Mean MJS decreased significantly, from 3.9 to 3.1 ($p < 0.001$, Wilcoxon's signed-rank test), and radiological OA progression was seen in 30/144 (21%).

Based on a modified Tönnis classification, improvement in OA stage was noted in 14/144 (10%), and progression of OA stage in 50/144 (35%). A total of 12 THAs were performed at a mean of nine years (3 to 17) after the modified Spitzy shelf acetabuloplasty (Table III).

Under Kaplan-Meier survivorship analysis, with conversions to THA as the endpoint, survival rates of 95% (95% CI 91 to 99) and 86% (95% CI 78 to 95) were predicted at ten and 15 years (Figure 5). We used multivariate analysis to identify three risk factors associated with radiological OA progression after modified Spitzy shelf acetabuloplasty: age at time of surgery (hazard ratio (HR) 2.85; 95% CI 1.05 to 7.76; $p = 0.0398$, Cox's proportional hazards model), preoperative joint space (HR 2.41; 95% CI 1.35 to 4.29; $p = 0.0029$, Cox's proportional hazards model), and preoperative OA (HR 8.34; 95% CI 0.94 to 73.77; $p = 0.0466$,

Cox's proportional hazards model) (Table IV). There were no significant differences in the cross-tables between radiological OA progression and the following risk factors: age at time of surgery, preoperative OA, asphericity of femoral head, and LCEA (Table V).

Table III. Total hip arthroplasty after modified Spitzy shelf acetabuloplasty in 12 patients.

Age, yrs/sex	Modified Tönnis grade	Stulberg class	Combined operation	Duration from shelf operation, yrs	Preoperative minimum joint space, mm	Preoperative LCEA, degrees	Shelf height, mm
44/F	1	I	N/A	9	3	16	4
45/F	1	II	N/A	9	3	15	3
45/F	1	I	N/A	17	2	13	6
54/F	1	I	N/A	11	3	5	3
38/M	1	I	N/A	8	3	10	4
29/F	0	I	N/A	10	8	9	1
13/F	0	III	N/A	14	3	11	3
48/M	0	I	N/A	13	6	15	2
40/F	1	I	N/A	11	2	17	5
46/F	1	I	N/A	5	4	11	0
51/F	1	I	Arthroscopy	3	3	10	2
44/F	1	II	N/A	5	4	12	5

LCEA, lateral centre-edge angle; N/A, not applicable.

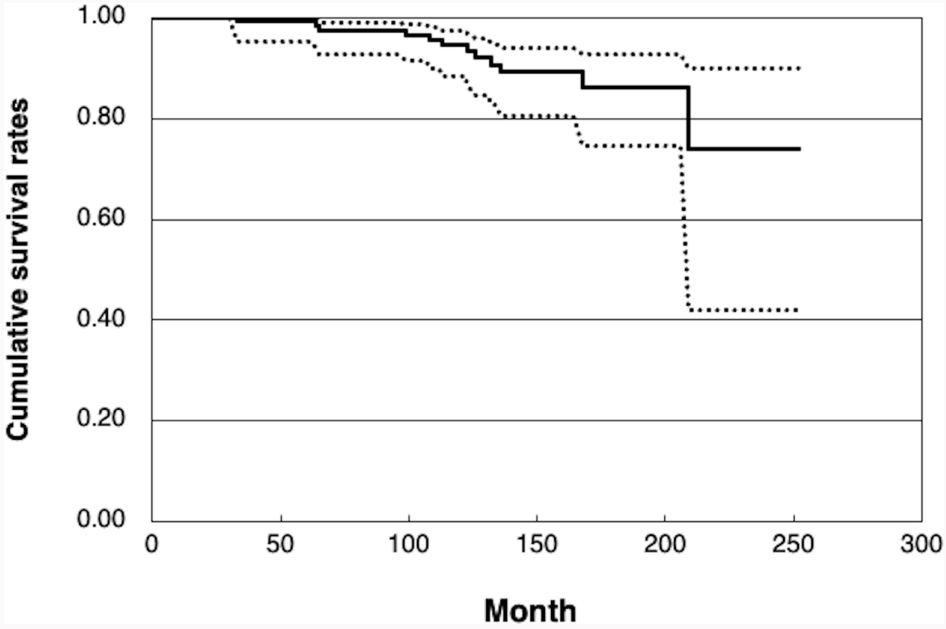

Fig. 5
Kaplan-Meier survivorship analysis with conversion to total hip arthroplasty as the endpoint. Values were expressed as cumulative survivorship with 95% confidence intervals. The survival rates for modified Spitzy shelf acetabuloplasty were 95% and 86% at ten and 15 years, respectively.

Discussion

When determining the course of treatment for a patient with hip dysplasia, two factors should always be included in consideration. First, although most untreated dysplastic hips deteriorate gradually over time, some do not. Some unoperated dysplastic hips that have not undergone surgical intervention and are presenting with pain may also experience reduced pain and improved function after a period of rest and physical therapy. Second, surgery to repair the dysplastic hip is not risk-free, and in some cases could be associated with the acceleration of OA in the hip joint.[33] It is thus important, insofar as possible, to avoid or minimize invasive procedures in hips that do not need such treatment. Realignment pelvic osteotomies such as PAO are associated with a significant risk of major complications, ranging from 5% to 37%, and sometimes lead to acetabular defects.[34-36] In contrast, a shelf operation does not affect the shape of the pelvic ring and only rarely interferes with future THA, if needed.[22,37,38] However, shelf operations are unable to improve the coverage of the femoral head with true acetabular articular cartilage, and they

Table IV. Risk factors associated with radiological OA progression after the modified Spitzy shelf acetabuloplasty .

Variable, mean (range)	HR (95% CI)	p-value*
Univariate analysis		
Age (increments of 10 yrs)	2.31 (0.92 to 5.79)	0.0734
Sex, female vs male	1.29 (0.26 to 6.43)	0.7551
Shelf height, mm	0.87 (0.56 to 1.36)	0.5495
LCEA, degrees	1.01 (0.93 to 1.09)	0.8732
Acetabular head index	1.04 (0.96 to 1.13)	0.3447
Acetabular roof obliquity	1.06 (0.97 to 1.16)	0.1715
Tear drop distance, mm	1.21 (0.96 to 1.36)	0.5495
Minimum joint space, mm	1.31 (0.82 to 2.11)	0.2571
Modified Tönnis classification, grade 0 vs 1 to 3	3.86 (0.77 to 19.26)	0.0993
Asphericity of femoral head	2.05 (0.82 to 1.51)	0.0951
Multivariate analysis		
Age (increments of 10 yrs)	2.85 (1.05 to 7.76)	0.0398
Minimum joint space, mm	2.41 (1.35 to 4.29)	0.0029
Modified Tönnis classification, grade 0 vs 1 to 3	8.34 (0.94 to 73.77)	0.0466

OA progression was defined as joint space narrowing of less than 2 mm.
*Cox regression analysis.
CI, confidence interval; HR, hazard ratio; LCEA, lateral centre-edge angle; OA, osteoarthritis.

Table V. Risk factors associated with radiological OA progression after the modified Spitzy shelf acetabuloplasty.

Variable	OA progression, positive	OA progression, negative	p-value*
Age, yrs			
< 30	6	27	0.6692
≥ 30	24	87	
Modified Tönnis grade			
0 to 1	27	101	0.8277
2 to 3	3	13	
Stulberg classification			
I and II	25	107	0.0634
III and IV	5	7	
LCEA, degrees			
< 10	10	40	0.8574
≥ 10	20	74	

OA progression was defined as joint space narrowing of < 2 mm.
*Chi-squared test.
LCEA, lateral centre-edge angle; OA, osteoarthritis.

are limited in their ability to correct the mechanical environment of the hip. We assessed the mid-term durability of our modified Spitzy shelf acetabuloplasty and analyzed the risk factors for radiological OA progression.

Several studies have proven the efficacy of shelf operations (Table VI).[13-21] Indications for the procedure are not limited by patient age, OA stage, or LCEA. Long-term success, in particular, is strongly affected by the two factors of shelf operation technique and preoperative OA stage. The techniques of shelf operation involve numerous variations, and incorporation of tectoplasty can be associated with favourable outcomes.[15,16] For realignment pelvic osteotomies, advanced OA and joint incongruity were generally considered to be contraindications, and the risk factors for failure were increased age, BMI, OA, and severe acetabular dysplasia.[5-7,39] Regarding the risk factor for OA progression after a shelf operation, Fawzy et al[18] reported that significantly lower survival was associated with narrower preoperative joint space. Furthermore, Nishimatsu et al[15] reported that the shelf height was significantly lower in radiologically favourable outcomes (mean height 0.6 mm) than in radiologically unfavourable outcomes (mean height 5 mm). Tanaka et al[21] also showed a significant association between shelf height and OA progression using multivariate analysis (odds ratio 3.37, 95% CI 1.6 to 13.1; p = 0.001). Conversely, Hirose et al[16] showed no significant relationship between the alteration of joint space width and any other parameters. In the current study, we used a Cox proportional hazards model to assess the risk factors for joint space narrowing of less than 2 mm. Our findings were similar to those from previous reports,[18,21] except that we found shelf height not to be a risk factor for reoperation. We attribute these findings to meticulous shelf operation procedures supported by intraoperative fluoroscopy, leading to relatively few instances of high shelf height. Determining the optimal height can be challenging, but in general the shelf should be placed as low as possible. In addition, during ten to 18 years of follow-up, no reoperations were performed in the 16 patients who had advanced OA before surgery, although some patients of middle age required THA after the shelf operation (Figure 6).

The diagnosis of acetabular dysplasia utilizes multiple radiograph assessments but has no definitive indicators, and there are also no definitive indications for joint-preserving surgery. In Japan, > 80% of patients with OA have secondary osteoarthritis due to dysplasia, and a number of authors have discussed the natural course of acetabular dysplasia of the hip in that context.[2,40-42] According to those studies, OA will develop in 67% of hips with an LCEA of < 10° and in 100% of hips with an LCEA of < 0°. Therefore, we tend to actively recommend modified Spitzy shelf acetabuloplasty to our patients who are in pain and have an LCEA of < 10°. For all other patients, we do not actively recommend this procedure out of concern that the surgery might worsen the condition of hips that would not require treatment in their natural clinical course. We are, however, willing to perform a modified Spitzy shelf acetabuloplasty in patients who have progressive OA and are clear that they do not want THA. Consequently, our survival rates in this study were 95% and 86% at ten and 15 years, respectively, with radiological OA progression seen in 21%.

There are some limitations to this study. First, we retrospectively evaluated the patients without a control

Table VI. Published studies reporting on relatively large series of shelf operation.

Author, yr	Hips, n	Mean age, yrs (range)	Preoperative advanced OA, n (%)	Mean preoperative LCEA, degrees (range)	Technique	Mean follow-up, yrs (range)	Survival rate*
Saito et al, 1986[13]	27	25 (11 to 55)	6 (22)	22	Modified Spitzy	12 (5 to 19)	N/D
Hamanishi et al, 1992[14]	124	10 (5 to 25)	N/D	5 (-40 to 15)	Modified Spitzy	10 (5 to 25)	N/D
Nishimatsu et al, 2002[15]	119	25 (1 to 56)	58 (49)	N/D	Modified Spitzy	24 (15 to 41)	108 (91%)
Miguad et al, 2004[17]	56	32 (17 to 56)	32 (57)	5 (-32 to 19)	N/D	17 (15 to 30)	37% at 20 yrs
Fawzy et al, 2005[18]	76	33 (17 to 60)	32 (42)	11 (-20 to 17)	Spitzy (no tectoplasty)	11 (6 to 14)	46% at 10 yrs
Berton et al, 2010[19]	18	34 (20 to 49)	4 (14)	10 (2 to 19)	Roy-Camille	16 (16 to 18)	41% at 18 yrs
Hirose et al, 2011[16]	28	34 (17 to 54)	0	4 (-27 to 20)	Modified Spitzy	25 (20 to 32)	93% at 20 yrs
Bartoníček et al, 2012[20]	25	31 (16 to 52)	2 (8)	16 (-15 to 20)	Bosworth	15 (10 to 23)	21 (84%)
Tanaka et al, 2018[21]	35	31 (19 to 49)	2 (6)	9	Spitzy (no tectoplasty)	26 (16 to 36)	70% at 30 yrs
Current study, 2022	144	37 (13 to 58)	16 (11)	10 (-28 to 25)	Modified Spitzy	11 (5 to 21)	86% at 15 yrs

*End point: Conversion to total hip arthroplasty (THA). If survival rate was not available, the number of hips that did not undergo conversion to THA during follow-up was used.
LCEA, lateral centre-edge angle; N/D, not described; OA, osteoarthritis.

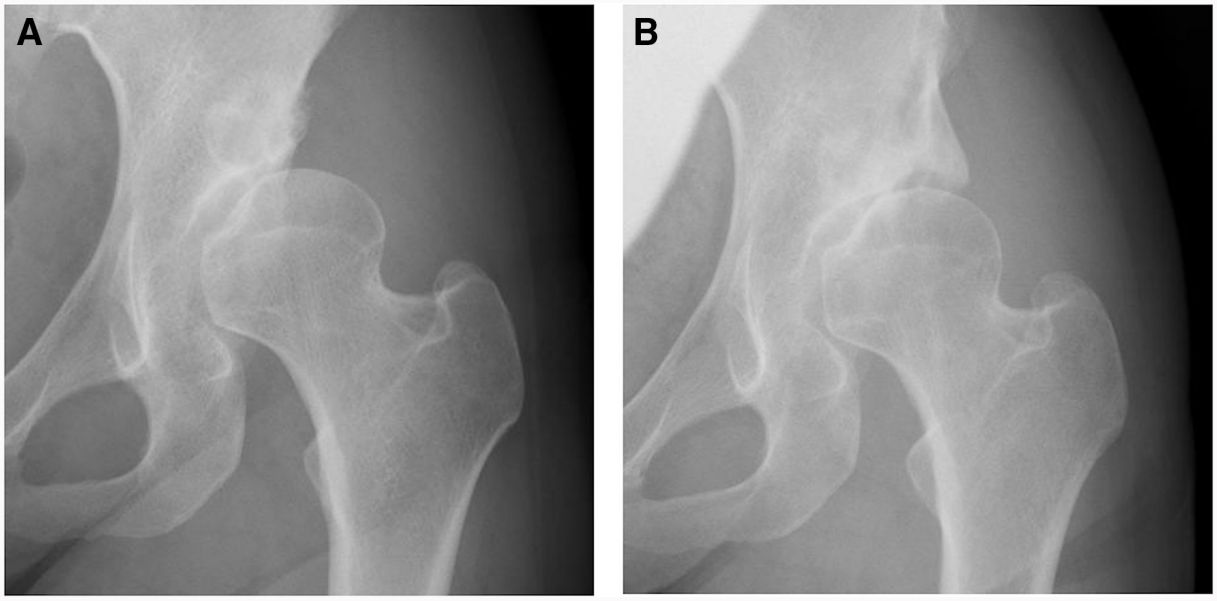

Fig. 6
Radiographs ofa 44-year-old female who had undergone a modified Spitzy shelf acetabuloplasty on the left hip: a) preoperatively, osteoarthritis Tönnis grade 2 with bone cyst, a lateral centre-edge angle of 0° (Merle d'Aubigné clinical score, 8 points), and b) at 12 years postoperatively, osteoarthritis Tönnis grade 2, a lateral centre-edge angle of 35° (Merle d'Aubigné clinical score, 16 points).

group, assessed a relatively small number of patients, and limited our follow-up to a minimum of five years. We selected a minimum follow-up period of only five years because a large number of cases was needed to assess the risk factor for joint narrowing. However, continued follow-up will be required to establish the long-term outcomes of this procedure. Second, different observers assessed the clinical parameters at each follow-up. Patient-reported outcomes were not included, and we could not determine clinically important differences in clinical outcome measures at the individual patient level. Third, only AP radiographs of the pelvis were evaluated for the diagnosis of acetabular dysplasia. Anterior coverage of the acetabulum was intraoperatively measured using a false radiograph profile view and 3D CT, but we did not evaluate that anterior coverage in the current study. In addition, we did not routinely assess joint congruency. RAO is not indicated when joint congruency is not improved or when preoperative AP radiographs of the hip in abduction show no widening of the joint space.[7] To comprehensively evaluate the broad indications of our procedure, further investigation is required, including long-term follow-up and examination of risk factors, such as joint congruency. Our cohort also contained a wide variety of patient morphologies, including some hips with MJS < 1 mm. A much longer follow-up period is needed in order to accurately assess survival until THA. Fourth, there are no definitive benchmarks for the diagnosis of

acetabular dysplasia and the indication of joint-preserving hip surgery. In some cases, the Merle d'Aubigné and Postel score had been maintained despite the progression of OA stage by Tönnis grade, and clinical results did not always correlate with OA progression. The decision to convert to THA was also affected by each individual patient's tolerance for pain and functional limitations, and by individual variations in patient preference for THA.

In conclusion, the survival rates for modified Spitzy shelf acetabuloplasty were 95% and 86% at ten and 15 years, respectively. Risk factors were age, preoperative joint space, and preoperative OA, based on multivariate Cox regression analysis. We found that this procedure is widely indicated and reduces the severity of clinical symptoms.

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Author information
K. Oe, MD, PhD, Hip Surgeon, Associate Professor
H. Iida, MD, PhD, Hip Surgeon, Professor
Y. Otsuki, MD, Hip Surgeon
F. Kobayashi, MD, Hip Surgeon, Assistant Professor
S. Sogawa, MD, Hip Surgeon, Assistant Professor
T. Nakamura, MD, PhD, Hip Surgeon, Lecturer
T. Saito, MD, PhD, Orthopaedic Surgeon, Professor
Department of Orthopaedic Surgery, Kansai Medical University, Hirakata, Japan.

Author contributions
K. Oe: Project administration, Investigation, Writing – original draft.
H. Iida: Conceptualization, Investigation, Supervision, Writing – review & editing.
Y. Otsuki: Investigation, Data curation, Validation, Writing – review & editing.
F. Kobayashi: Investigation, Data curation, Validation, Writing – review & editing.
S. Sogawa: Investigation, Data curation, Validation, Writing – review & editing.
T. Nakamura: Operation, Methodology, Investigation, Writing – review & editing.
T. Saito: Supervision, Writing – review & editing.

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