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ORIGINAL ARTICLE

Long-term outcomes of shelf acetabuloplasty for developmental dysplasia of the hip in adults: a minimum 20-year follow-up study

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Abstract
Background Shelf acetabuloplasty has been applied to secondary osteoarthritis of the hip due to congenital dislocation or acetabular dysplasia; however, there are few reports on the long-term outcomes of this operation. Here, we aimed to investigate the long-term effects of our shelf acetabuloplasty for developmental dysplasia of the hip in adults.
Methods Outcomes for 28 hips (7 with pre-arthrosis, 21 with initial stage of arthrosis) were retrospectively reviewed clinically and radiologically at a minimum of 20 years after operation. Mean age of the patients at operation was 34 years (range 17–54 years), and the mean follow-up period was 25 years (range 20–32 years).
Results Mean Japanese Orthopaedic Association hip score improved from 76 points preoperatively to 82 points, and mean pain score improved from 24 points preoperatively to 33 points at 20 years. Mean Sharp angle improved from 51° preoperatively to 37° immediately after the operation. Similarly, the mean center-edge angle improved from −4° to 38°, and the mean acetabulum head index improved from 52 to 99%. More than 50% of the hips showed no change in joint space width at 20 years. Survival rates were 100% at 10 years, 93% at 20 years and 71% at 32 years, with conversion to total hip replacement as the endpoint.
Conclusion Long-term outcomes of our shelf acetabuloplasty were comparable to other reports, and the clinical outcomes and survivorship revealed positive long-term effects of our procedure over approximately 20 years.

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Introduction

Various types of shelf acetabuloplasty were originally carried out mainly for the treatment of dysplasia and dislocation of the hip in children and adolescents [1, 2]. In Japan, secondary osteoarthritis of the hip due to congenital dislocation or acetabular dysplasia is more common than primary osteoarthritis. Nakamura et al. [3] reported that 88% of osteoarthritis cases in adults were secondary to congenital hip dislocation or dysplasia. Shelf acetabuloplasty was subsequently applied to a number of adults. However, there are few reports on the long-term outcomes of such cases [4–7]. The purpose of this study was to investigate the long-term effects of our shelf acetabuloplasty for developmental dysplasia of the hip (DDH) in adults.

Patients and methods

Between August 1977 and June 1990, 57 shelf acetabuloplasties were performed for DDH with pre-arthrosis or at the initial stage of arthrosis in adults. The procedures were performed by multiple surgeons. Radiographic staging was done according to the Japan Orthopaedic Association's (JOA) staging criteria for coxarthrosis [8]. Of the cases, 28 hips in 26 female patients comprising 7 hips with pre-arthrosis and 21 hips with initial-stage were retrospectively reviewed clinically and radiologically to determine the outcomes, which could be directly evaluated after a minimum period of 20 years. The mean age of the patients at operation was

34.3 years (range 17–54 years), and the mean follow-up period was 24.6 years (range 20–32 years). Twenty-nine patients were lost to follow-up.

Operative technique

Shelf acetabuloplasty was done using the Smith-Peterson approach. Our procedure was classified as a slotted acetabular augmentation [2], a modified tectoplasty as devised by Mizuno [9] and a modified shelf operation with combined muscle transfers as reported by Ito et al. [10]. Briefly, the rectangular flap of the pedicle of the outer cortex was hinged outwards on its proximal base. The bone flap was 3 cm long and 3 cm wide from the anterior margin. The bone plate and cancellous bone chips were taken from the outer table of the ilium. The free bone plate, measuring 3 × 3 cm, was inserted into the slot between the split outer cortex and the capsule to augment the acetabular roof (Fig. 1a). Bone chips were packed into the triangular space of the ilium, the bone plate, and the bone flap (Fig. 1b). The straight head of the rectus femoris muscle was transferred to the anterolateral aspect of the capsule in all cases, and the distal tendon of the iliopsoas muscle was transferred to the anterolateral aspect of the capsule in several cases. Ito et al. [10] described that the muscle power that forced the femoral head up was markedly reduced by these muscle transfers; six hips were combined with intertrochanteric femoral osteotomy (valgus, 3 hips; derotation, 2 hips; varus and derotation, 1 hip).

The postoperative protocol used skin traction for 2 weeks followed by non-weight-bearing walking with crutches for 4 weeks. Partial weight-bearing walking was allowed at 6–8 weeks for a further 4 weeks and was eventually followed by full weight-bearing walking.

Clinical evaluation

The function of the hip joint was assessed using the JOA hip score (total 100 points) based on pain (40 points), range of motion (20 points), ability to walk (20 points), and activities of daily living (20 points) [11, 12].

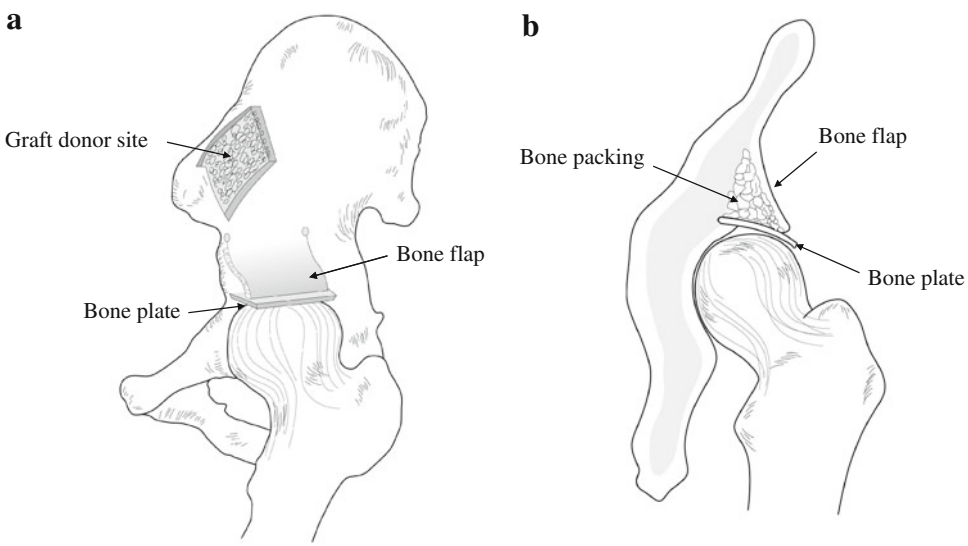
Radiological evaluation

The Sharp angle [13], center-edge (CE) angle [14], and acetabulum head index (AHI) [15] were measured from the anteroposterior view. The joint space width was assessed using the JOA staging criteria and its modified criteria [8] as follows: stage 1, no narrowing; stage 2, partial narrowing (joint space width maintained at 2 mm); stage 3, localized contact of the subchondral bones (joint space width <2 mm at the thinnest point, or contact width of subchondral bones <15 mm); and stage 4, extensive disappearance of the joint space (contact width ≥ 15 mm) (Fig. 2). All radiological measurements were carried out by a single observer (SH). All evaluations of the radiological staging were assessed and reconfirmed by three authors (SH, HO, TM) to obtain the objectivity.

Patients were divided into two groups on the basis of a good or poor radiological result of the joint space width at 20 years after shelf acetabuloplasty. A good result meant no change compared to the preoperative stage, while a poor result meant deterioration or conversion to total hip replacement (THR). Risk factors were analyzed by logistic regression analysis of the two groups using parameters such as preoperative age, radiological stage, pre- and postoperative Sharp angle, CE angle, and AHI.

Survival analysis was performed by the Kaplan-Meier method. The endpoint was defined as the time when the

Fig. 1 Operative technique



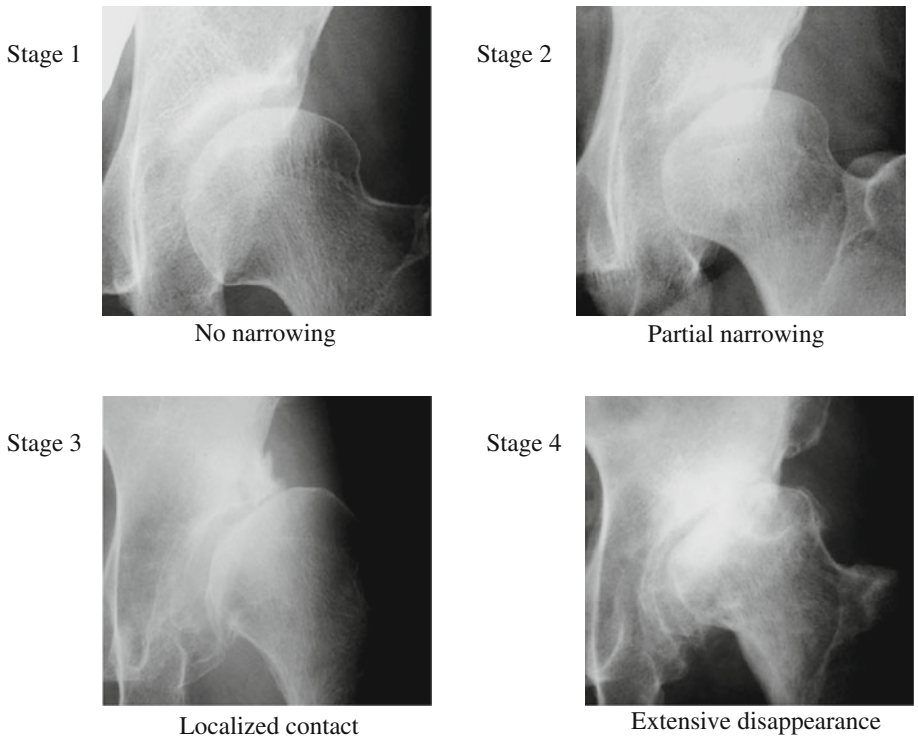


Fig. 2 Japan Orthopaedic Association (*JOA*) staging criterion: joint space

joint space width deteriorated to stage 3 or when the pain score dropped to 20 points or less, or when the hip joint was converted to THR. SPSS (version 15.0J) was used for logistic regression and survival analysis. Statistical significance was set at $P < 0.05$.

This study design was approved by the institutional review board of Aichi Medical University. The patients or their family were informed that data from the cases would be submitted for publication and gave their consent.

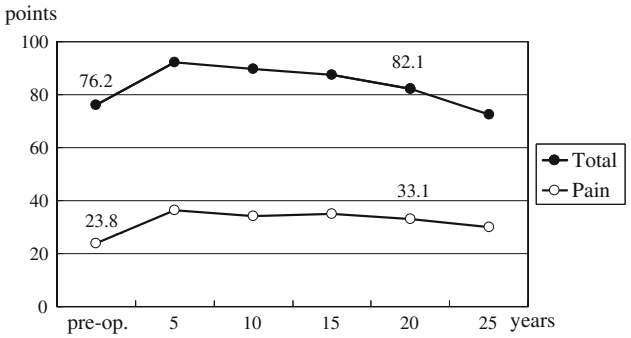


Fig. 3 Alteration of mean JOA hip score

Results

Clinical evaluation

The mean total score improved from 76.2 points preoperatively to 92.2 points at 5 years. Although the mean total score decreased gradually, it maintained >80 points over 20 years. The mean pain score improved from 23.8 points preoperatively to 36.2 points at 5 years and stayed >30 points over 20 years (Fig. 3).

Radiological evaluation

The mean Sharp angle improved from 50.8° preoperatively to 36.7° immediately after surgery. Similarly, the mean CE angle improved from −4.4° to 37.6°, and the mean AHI improved from 52.0 to 99.3% (Table 1). For hips, 80.8% showed no change in the joint space width at 5 years. Although the percentage of no change decreased gradually, 52.0% of hips showed no change at 20 years (Fig. 4). Logistic regression analysis did not demonstrate any risk factor in the good or poor result group at 20 years (Table 2).

As of the latest follow-up, 19 hips had deteriorated to stage 3 of joint space width, and the survival rate with stage 3 of joint space width as an endpoint was 78.6 ± 7.8% at 10 years, 53.6 ± 9.4% at 20 years and 20.7 ± 9.6% at 32 years (Fig. 5). Similarly, nine hips had decreased to 20 points with moderate pain, and the survival rate with 20 points of pain score as an endpoint was 100% at 10 years, 85.7 ± 6.6% at 20 years and 50.5 ± 13.6% at 32 years (Fig. 6). Five hips had been converted to THR, and the survival rate with conversion to THR as an endpoint was 100% at 10 years, 92.9 ± 4.2% at 20 years and 71.3 ± 12.3% at 32 years (Fig. 7).

Table 1 Pre- and postoperative radiological values

	Preoperation	Postoperation
Sharp angle (°)	51 (43 to 57)	37 (24 to 45)
CE angle (°)	−4 (−27 to 20)	38 (13 to 60)
AHI (%)	52 (28 to 77)	99 (75 to 130)

Values are represented as mean (range)

CE angle center-edge angle, *AHI* acetabulum head index

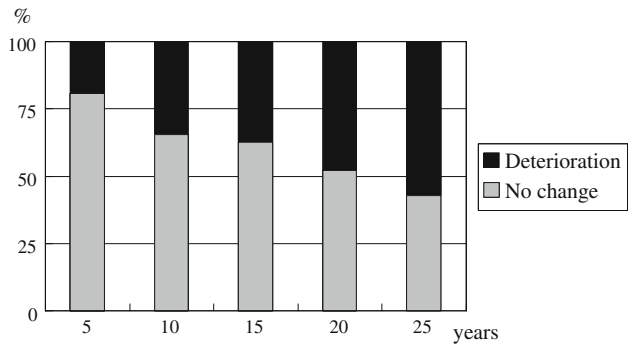


Fig. 4 Alteration of joint space width

Table 2 Radiological risk factor analysis

Factors	*P* values
Preoperative	
Age	0.318
Stage	0.718
Sharp angle	0.935
CE angle	0.131
AHI	0.147
Postoperative	
Sharp angle	0.440
CE angle	0.676
AHI	0.817

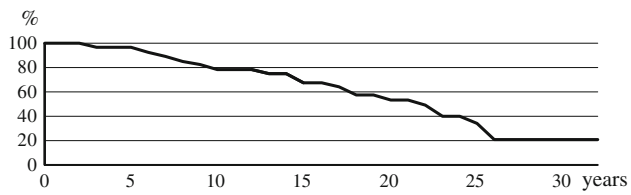


Fig. 5 Survival rate with joint space width at stage 3 as an endpoint

Figure 8 shows a representative case of a 17-year-old woman who underwent shelf acetabuloplasty of the right hip. The joint space width was maintained as stage 1 after 23 years. Figure 9 shows longest follow-up case of a 24-year-old woman who underwent shelf acetabuloplasty

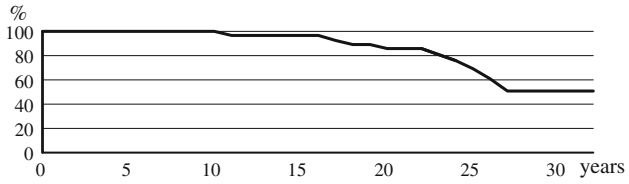


Fig. 6 Survival rate with a pain score of 20 points as an endpoint

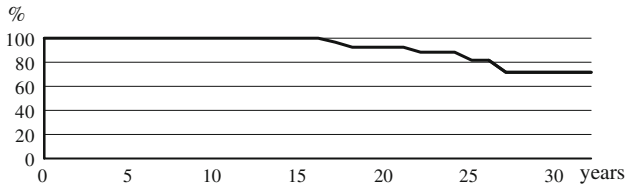


Fig. 7 Survival rate with conversion to total hip replacement as an endpoint

of the left hip. Although the joint space showed alteration from stage 1 to stage 2, the left hip was preserved without the need for THR after 32 years.

Discussion

With regard to the name of the procedure undertaken, Salter [16] described the term shelf operation as referring to an operation in which the acetabular roof was extended by turning down the outer cortex of the ilium on the capsule or by inserting an extra-capsular bone graft. The term acetabuloplasty referred to an operation in which the acetabular roof was mobilized with an incomplete osteotomy. On the other hand, Migaud et al. [7] used the term 'shelf arthroplasty,' while Fawzy et al. [17] used the term 'shelf acetabuloplasty' in recent reports. In this report, we have adopted the term 'shelf acetabuloplasty.'

There have been few studies in the English literature on long-term outcomes of shelf acetabuloplasty in adults [6, 7]. Nishimatsu et al. [6] reported that 87% of such patients had good clinical results in dysplastic hips with prearthrosis and initial stage arthrosis at a mean follow-up of 24 years. Furthermore, shelf operation was indicated for early osteoarthritic change in patients younger than 25 years of age. Migaud et al. [7] reported that the survival rate, using hip replacement as the endpoint, was 83% at 18 years in hips with arthritic change without joint space narrowing. Moreover, shelf arthroplasty was reported to be the best indication for moderate dysplasia (CE angle >0°) without severe arthrosis. In this study, the long-term outcomes of our shelf acetabuloplasty procedure were comparable to those of the above-mentioned reports, and clinical outcomes and survivorship showed the positive long-term effect of the procedure over a period of

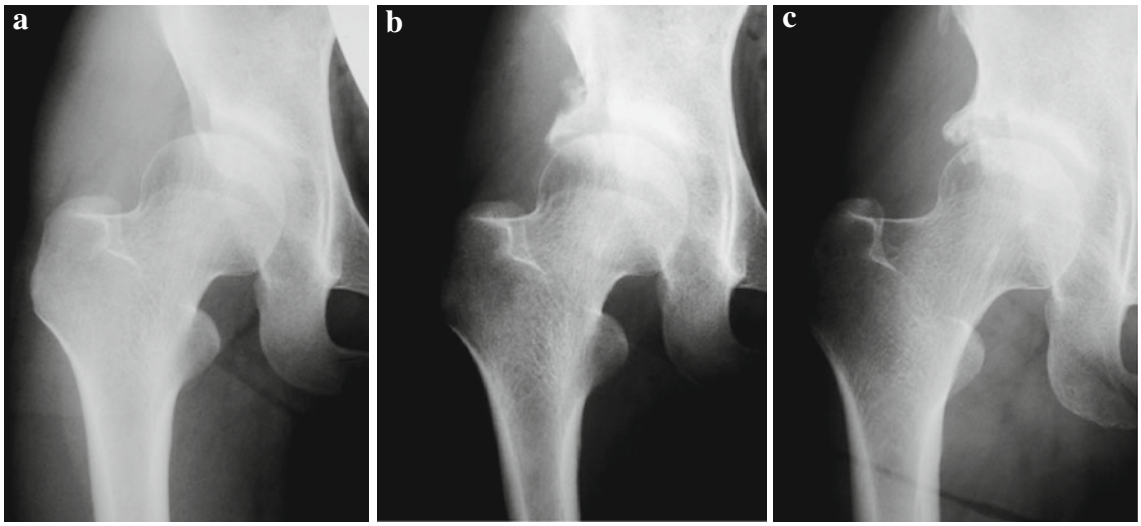


Fig. 8 A 17-year-old woman, pre-arthrosis. **a** Preoperative: Sharp angle, 57°; center-edge (CE) angle, 0°; acetabulum-head index (AHI), 54%; joint space, stage 1. **b** Postoperative: Sharp angle, 36°; CE angle, 44°; AHI, 100%. **c** At 23 years after operation. Joint space, stage 1; JOA hip score, 95 points

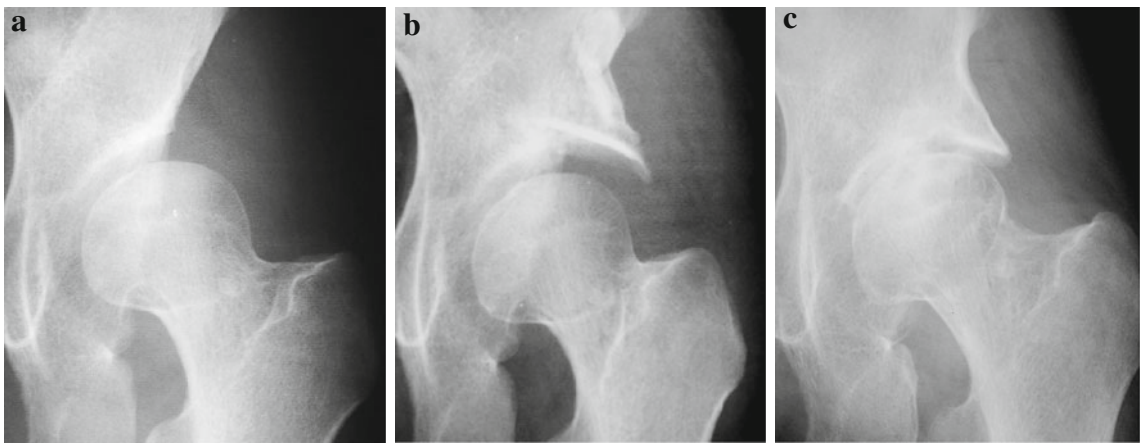


Fig. 9 A 24-year-old woman: pre-arthrosis. **a** Preoperative: Sharp angle, 53°; CE angle, 0°; AHI, 50%; joint space, stage 1. **b** Postoperative: Sharp angle, 36°; CE angle, 47°; AHI, 105%. **c** At 32 years after operation: joint space, stage 2; JOA hip score, 80 points

approximately 20 years. Although several authors [6, 7, 17, 18] have suggested that preoperative age, degree of dysplasia, and arthritic change are related to outcome, there was no significant relationship between the alteration of joint space width and any other parameters in our series.

There were several limitations to this study. The follow-up rate was low as 29 patients were lost to follow-up. Of these patients, 27 could not be evaluated because medical records and x-ray films had been lost. Another two hips of two patients with initial stage were assessed at 13 years and 15 years after surgery; both hips were maintained at the preoperative stage, and the mean JOA hip score showed 90 points at the final follow-up. In regard to risk factor analysis, we admit that our study population was too small for worthwhile statistical analysis.

An extra-capsular procedure is important in a shelf acetabuloplasty, which is similar to Chiari's pelvic osteotomy. Chiari [19] hypothesized that the interposed capsular tissue could transform into fibrocartilage after his osteotomy procedure. Furthermore, Hiranuma et al. [20] reported that the interposed capsule underwent metaplastic change to fibrocartilaginous tissue with some hyaline-like cartilage present near the joint surface in rabbits after Chiari osteotomy. Similarly, Zlatić et al. [21] also found hyaline-like cartilage in the capsule of a patient when THR was performed 11 years after a Chiari procedure. We

believe that the same metaplastic change can occur in the interposed capsule and plays an important role in the formation of a new joint after shelf acetabuloplasty. Consequently, we are trying to expand the indications for this procedure to advanced arthrosis by combining it with a valgus femoral osteotomy to improve joint congruity. We consider that shelf acetabuloplasty is one of the options that can delay the need for THR in adults with coxarthrosis secondary to DDH.

Conflict of interest No benefits or funds were received in support of this study.

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