Slotted Acetabular Augmentation in the Treatment of Painful Residual Dysplastic Hips in Adolescents and Young Adults

Yu-Ping Su,1 Matthew N.H. Wang,2* Wei-Ning Chang3

Background/Purpose: This study retrospectively evaluated the benefits and prognostic factors of slotted acetabular augmentation (SAA) used for treating painful residual or neglected dysplastic hips in adolescents and young adults.

Methods: Sixteen hips in 15 patients underwent SAA at an average age of 14.4 years. The radiologic and functional outcomes were reviewed after an average follow-up of 6.6 years.

Results: All the patients obtained marked alleviation of pain (p < 0.05). Harris hip score (HHS) was improved from 74.7 to 92.7 on average (p < 0.05). Postoperative center-edge angle, Sharp’s angle, c/b ratio and femoral head coverage showed significant improvement (p < 0.01). Among the radiographic parameters, only the postoperative measurement of the femoral head coverage was significantly correlated with improvement of HHS (p < 0.05). Detectable progression of osteoarthritis, from grade III to IV, was found in one patient 12 years after surgery. None of the hips required conversion to joint replacement. There were no surgical complications. Three-dimensional computed tomography showed that the grafts remained intact and provided congruent coverage at the latest follow-up, and none of them required arthroplasty.

Conclusion: The major benefit of SAA was to alleviate hip pain by increasing load-bearing area. This benefit was not sensitive to preoperative radiographic parameters. There were no postoperative complications. Compared with other complex reconstructive acetabuloplasty procedures, SAA is a simple, safe and effective pain-reducing procedure for symptomatic dysplastic hips in adolescents and young adults. [J Formos Med Assoc 2008;107(9):720–727]

Key Words: acetabulum, adolescent, hip dysplasia, hip joint, slotted acetabular augmentation

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or even sparing the necessity for hip replacement. Various types of osteotomy have been advocated for different indications; all with the aim of increasing joint containment. Millis et al have classified these various types of osteotomy into either reconstructive or salvage procedures, according to the properties of the joint surface they can provide. Reconstructive osteotomy, which provides the femoral head with more hyaline cartilage coverage, is more favored for joint preservation, in theory, than salvage osteotomy, while, salvage osteotomy is generally indicated in more dysplastic, incongruent, unstable or degenerated hips. The choice between these two types of procedures, however, has been inconclusive with regard to the relief of symptoms and the eventual conversion to total hip replacement, because of the wide range of patient ages, severity of dysplasia, and incomparable surgical indications and techniques.

Slotted acetabular augmentation (SAA) is one of the salvage procedures. It was developed to provide a relatively simple method to create congruent coverage of the femoral head. Staheli has pointed out that hips with aspheric congruity or extreme acetabular deficiency are the primary indications for SAA. The purposes of this study were to retrospectively review the results of SAA for painful hip dysplasia in adolescents and young adults, to document the benefits of treatment and analyze the prognostic factors of the final outcome.

**Methods**

Patients who underwent SAA in their second or third decade of life at the authors’ institute were included. Patients who were diagnosed with concomitant neuromuscular disease, such as cerebral palsy or poliomyelitis, were excluded because of their different natural course. Patients who were lost to follow-up were also excluded. Between 1995 and 2006, 15 consecutive patients (12 female, 3 male) who underwent SAA at an average age of 14.4 years (range, 10–25 years) for residual or neglected hip dysplasia were enrolled (Table 1). All patients were followed-up at the clinic. One of them received bilateral SAA sequentially (case 6). The indications for SAA were hip pain and a limp for >6 months, in spite of conservative treatment. The average body mass index (BMI) was 21.2

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<th>BMI</th>
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<th>Pre-op HHS</th>
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VDRO = varus derotation osteotomy.
(range, 14.8–27.5). Ten patients had prior management for their hip problems, including three with closed reduction, two with open reduction, one with femur varus derotation osteotomy, one with Pemberton’s osteotomy and five with Salter’s osteotomy.

The surgical technique of SAA used in this study was similar to those reported previously. A standard iliofemoral approach was employed to expose the hip joint. The reflected head of the rectus femoris (RHRF) was detached anteriorly and tagged with a stay suture. When the RHRF was absent, the capsule was filleted to create an anterior- and a posterior-based capsular flap for stabilizing the graft later. A slot with a depth of 1 cm was created exactly at the acetabular margin, which was identified by intraoperative fluoroscopy. The floor of the slot should be a thin layer of bone and very close to the articular cartilage. Strips of cortical and cancellous bone graft were harvested from the outer table of the ilium. The graft was cut into an adequate length to achieve a 35° center-edge (CE) angle, with 1 cm in the slot. The first layer of graft was extended from the slot to cover the head congruently. The second layer was perpendicular to the first layer and then secured by suturing the RHRF or the capsular flaps back to their original position. The remaining graft was packed above the shelf and held in place with the hip abductor muscles. The operated hip was maintained in a hip spica for 6 weeks, and the patient was allowed to walk with partial weight bearing after removal of the cast. It is not easy for young adults to tolerate the spica unless comprehensive home-care education and close supervision are given. However, all the patients completed the treatment and achieved full weight bearing 3 months after surgery.

Radiographic evaluation was performed preoperatively, 3 and 6 months postoperatively, and then yearly until the latest follow-up. Clinical functions were evaluated with the Harris hip score (HHS) at the latest follow-up. The HHS rated the pain, gait, activity, range of motion and deformity on a 100-point scale. Figure 1 illustrates the radiologic parameters measured on the anteroposterior radiograph of the hip joint, including the CE angle of Wiberg, classic Sharp’s angle, c/b ratio and the percentage of femoral head coverage. The CE angle and Sharp’s angle are mainly used to measure the inclination of the acetabulum, while the c/b ratio and the percentage of femoral head coverage are used to measure the extent of the lateral migration of the femoral head and the coverage by the acetabulum. Hilgenreiner’s line is a line through bilateral triradiate cartilage. It can be replaced by the line that connects bilateral tear-drops of the acetabulum when the triradiate cartilages are fused. Perkin’s line, drawn at the lateral margin of the acetabulum, is perpendicular to Hilgenreiner’s line. The CE angle of Wiberg, formed at the juncture of Perkin’s line and a line that connects the lateral margin of the acetabulum to the center of the femoral head, represents the degree of lateral coverage of the femoral head. Sharp’s angle forms between a line drawn along the margin of the acetabulum and Hilgenreiner’s line. It represents the inclination of the acetabulum. For the measurement of c/b ratio, a center line is drawn vertically through the sacrum and symphysis pubis; ‘c’ is the distance from the center line to the medial-most portion of the proximal femoral metaphysis, and ‘b’ is the distance of the center line to Perkin’s line. The percentage of femoral head coverage is the percentage of ossified femoral head medial to Perkin’s line (Figure 1). The severity of osteoarthritis upon radiography was classified according
to the classification of Tonnis:²³ stage I, no osteoarthritic changes; stage II, subchondral sclerosis and slight narrowing of the articular space; stage III, marked narrowing sclerosis of the articular space, subchondral cysts and marginal spurs; and stage IV, total obliteration of the articular space. Three-dimensional computed tomography (3D CT) was performed in four cases (cases 7–10) with a 64 multi-slice scanner (Toshiba Aquilion TSX-101A, Tokyo, Japan). It gave qualitative evaluations about the conformity of the interface and a 3D perception of graft distribution.

Nonparametric tests, which included Wilcoxon signed rank test and Mann-Whitney test were performed for comparison of the pre- and postoperative measurements of radiologic parameters and HHS. Correlation testing (Pearson’s and Spearman’s ρ tests) was performed to analyze the relationship between improvement of HHS and radiologic parameters. Differences were considered significant at \( p < 0.05 \).

This study followed all the principles outlined in the Declaration of Helsinki. Oral or written informed consent was obtained from all participating patients or their parents.

### Results

All 15 patients were followed up for an average of 6.6 years (range, 1–12.3 years). Their mean BMI was 21.2 (range, 14.8–27.5) at the time of surgery.

The preoperative and final assessment of the radiologic parameters, severity of osteoarthritis and functional scores are shown in Table 2. The average preoperative CE angle was 0.6° (range, −8° to 16°) with 10 out of 16 hips having negative values. These measurements reflected the fact that most of our cases had marked dysplasia. Sharp’s angle, normally ranging from 33° to 42°, decreased from 53.8° to 40.3° on average after surgery. The CE angle, normally no less than 20°, improved from 0.61° to 36.3° on average after surgery. The c/b ratio, normally 0.6–0.85, changed from 0.95 to 0.78 on average after surgery. The coverage of femoral head was 58% before and 90% after surgery. All of these four parameters showed significant improvement (\( p < 0.01 \)).

Twelve patients had no or mild osteoarthritis (grade I and II), while the other three had moderate osteoarthritis before surgery. Among them,
only one (case 3) had worse osteoarthritis, from late grade III to early grade IV at the latest follow-up. The change was not substantial, but detectable. The other patients remained unchanged. All the femoral heads retained their original shape at the latest follow-up.

HHS improved from 74.7 to 92.7 on average ($p < 0.05$). The pain score in HHS improved from 27.8 to 40.3 ($p < 0.05$) and became the major contributor to the overall functional improvements. The other components of HHS, which included gait, activity and deformity, had no significant change.

When investigating the prognostic factors for SAA, in the correlation test, none of the preoperative radiographic parameters were correlated with functional improvement (data not shown). Furthermore, among all the postoperative radiographic parameters, only the final femoral head coverage was significantly correlated with improvement (Table 3).

3D CT in cases 7–10 showed that all the shelves contoured well on weight bearing surface of femoral heads and provided wide coverage from anterior to posterior (Figure 2). Slight bone graft resorption was observed in one patient (case 2), which ceased 1 year after surgery (Figure 3). The patient’s last HHS was 90. None of the hips in this series required a conversion to arthroplasty at the latest follow-up.

**Discussion**

Hip dysplasia is a developmental abnormality. Therefore, early diagnosis and intervention is the best strategy for its management. The number of undiagnosed cases has decreased with the
increasing popularity of neonatal screening. However, there are still patients who present in their 20s and 30s with painful hip dysplasia because of neglect or residual deformity from previous attempts at management. To treat this population, the ability of connective tissue to adapt to mechanical loading is used to enlarge the weight-bearing interface. Shelf procedures, including SAA, provide a new interface with the joint capsule instead of cartilage. It is widely known that the interposed capsule will become fibrocartilage through metaplasia, under the influence of the mechanical load. This theory is supported by the morphological and histochemical examinations of interposed tissue retrieved from patients or animals, while the call for more evidence in biochemistry and molecular biology does exist. Various clinical results have been reported. Love et al reported that almost 80% of the hips treated with a shelf procedure remained relatively free of symptoms at a mean 11 years after operation. Furthermore, with conversion to total hip arthroplasty as the end point, Migaud et al reported that the 18-year survival rate for shelf procedures was 83%. In contrast to these good results, Fong et al reported 16 cases of SAA in which only 50% of patients achieved a good result. The causes of failure included graft resorption, hip impingement, hip ankylosis and re-subluxation. Here, all the patients showed marked clinical improvement, especially for pain relief, and all the operated hips remained free from the need of further surgery, such as hip replacement. This success could be attributed to several factors. The skill of the surgeon in positioning the bone graft correctly was critical. Care should be taken not to place the graft higher than adjacent subchondral bone, which could reduce the risk of graft resorption. Moreover, SAA allowed for easy distribution of bone grafts smoothly along the joint capsule, which created a congruent interface. 3D CT reconstruction revealed that the grafts fitted flush with the femoral head from anterior to posterior. Another factor for clinical success could be body weight. Premature weight bearing should be guarded against, so as to avoid early graft failure. BMI, which normally ranges from 18.5 to 23, was a mean of 21.2 in our patients. This also benefits the long-term maintenance of hip joints.

The clinical results of SAA had been shown to be sensitive to preoperative osteoarthritis. Patients who present with more severe osteoarthritis before surgery tend to have worse results.
However, this trend was not observed in our study. Pompe and Antolic have reported promising early results after a median of 4 years of follow-up in 14 hips of adult women treated with SAA for the prevention of hip arthrosis.29 All the patients experienced marked pain relief, as did our own. No further progression of arthrosis has been observed in these cases. In the study of Pompe and Antolic, mathematical calculation was used to confirm the reduction in peak stress on the weight-bearing area. It was decided that SAA could be used to postpone the development of osteoarthritis in adults with hip dysplasia. In our study, the good early results were comparable to those of Pompe and Antolic; however, detectable progression of hip arthrosis was observed in one of the 16 hips. This patient still felt satisfactory and did not require hip replacement at the latest follow-up. Our study did not have a control group with a long natural history; therefore, it was not possible to establish whether SAA actually altered the progression of osteoarthritis or just temporarily reduced hip pain.

All the radiographic parameters, including Sharp’s angle, CE angle, c/b ratio and femoral head coverage, were improved after surgery. There was no significant correlation between functional improvement and preoperative measurements. In the other words, the surgical benefit of SAA is not limited by, or at least is not sensitive to, preoperative conditions. Among the postoperative measurements, only femoral head coverage achieved a significant correlation with functional improvement. This may be because SAA derives its effect from good coverage of the femoral head. The failure of the other three parameters to achieve a significant correlation with functional improvement reflects the controversy surrounding their measuring methods and application.20–22,30 It is not unusual that after surgery, the anatomic landmarks become too indistinct to identify consistently. Here, only one investigator was assigned for measurement in order to decrease the interobserver bias.

Based on the fact that the symptoms and radiographic measurements improved after surgery and that there were no postoperative complications, we believe that SAA is a simple, safe and effective procedure for adolescents and young adults with painful hip dysplasia.

References


