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Original Research

Efficacy of a Graftless Salter Osteotomy in Developmental Dysplasia of the Hip

Andrew G. Kim, BA; Carter E. Hall, BS; Sulagna Sarkar, MS; Christopher J. DeFrancesco, MD; Wudbhav N. Sankar, MD*

Children's Hospital of Philadelphia, Division of Orthopaedics, Philadelphia, PA, USA

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ABSTRACT

Background: Salter's innominate osteotomy is one of the most popular pediatric hip procedures for developmental dysplasia of the hip (DDH). Traditionally, Salter osteotomies require harvesting of autograft from the iliac crest, which can result in iliac wing deformities, pelvic asymmetry, and abductor dysfunction. A graftless variation of this procedure has been described in which the iliac osteotomy is fixed with threaded pins without an intervening graft, but literature surrounding this technique is sparse. The purpose of this study was to evaluate the efficacy of a graftless Salter osteotomy and compare the degree of correction to the traditional method.

Methods: A retrospective review was performed of all Salter osteotomies performed at a single tertiary care children's hospital from 2009 to 2024. Demographic and clinical variables were extracted from electronic medical records. Acetabular indices (AIs) on preoperative and 3-month postoperative AP pelvic radiographs were compared to assess the degree of acetabular correction. Traditional and graftless procedures were propensity score matched 1:2 based on age, gender, and preoperative AI. Acetabular correction was compared between the two cohorts using the Wilcoxon Mann-Whitney test.

Results: Forty-seven hips were identified (14 traditional, 33 graftless). Seventy-two percent of patients were female; the mean age at surgery was 29.9 months (range: 15–70). Thirty-eight hips (81%) underwent concomitant open reduction. Propensity score matched analysis demonstrated no significant difference in the degree of acetabular correction between the cohorts (traditional vs graftless: 11.9° ± 5.4 vs 12.7° ± 5.7, $P = .69$). All osteotomies healed by 3 months, and there were no cases of lost fixation with either technique.

Conclusions: The graftless variation of Salter's osteotomy yields a comparable degree of acetabular correction to the traditional technique. There were no complications in either cohort from the osteotomy. The graftless Salter osteotomy is a safe and effective alternative to the traditional Salter osteotomy without the risk of iliac wing deformities and potential abductor dysfunction.

Key Concepts:

(1) Graftless Salter osteotomy provides similar degrees of correction to the traditional technique.
(2) No complications related to the osteotomy were observed in both the graftless and traditional cohort.
(3) All Salter osteotomies demonstrated healing at the 3-month postoperative timepoint.

Level of Evidence: IV

Introduction

The Salter innominate osteotomy is one of the most widely performed surgical interventions to correct acetabular dysplasia and subluxation in children with developmental dysplasia of the hip (DDH) [1]. It is a well-established operation that has demonstrated favorable long-term results and appropriate acetabular correction [1–6]. However, the Salter osteotomy traditionally requires the harvesting of autologous bone graft from the brim of the iliac crest to bridge the iliac osteotomy. Removal of this section of the ilium, however, raises potential concerns for later iliac wing deformity, pelvic asymmetry, and abductor dysfunction from a decreased footprint of muscle origin [7–9]. Additionally, though some degree of pelvic lengthening occurs in any opening-wedge osteotomy of the ilium regardless of whether a bone graft is used or not, a

* Corresponding author: Children's Hospital of Philadelphia, Division of Orthopaedics, Perelman School of Medicine at the University of Pennsylvania, 3500 Civic Center Blvd, Philadelphia, PA 19104, USA.
E-mail address: sankarw@chop.edu (W.N. Sankar).

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larger autograft can acutely increase the pelvic length to a greater extent and lead to potential limb-length discrepancy [7,10,11].

As a result, various modifications to the traditional Salter technique have been made to address these potential concerns [9,11,12]. Notably, a novel technique that avoids the use of an autograft was first described in 2019 [9]. Similar to the Kalamchi modification of the Salter osteotomy, the technique reported in that study uses an angulated cut. With this method, the iliac osteotomy is then fixed with pins without an intervening graft. This is theoretically a less invasive variation of the traditional Salter osteotomy that preserves the anterior superior iliac spine (ASIS), minimizing the subsequent risk of iliac deformity and pelvic asymmetry [8,9].

Despite promising preliminary outcomes in patients who have undergone the graftless variation of the Salter osteotomy [8,9], literature on this topic is quite limited. To the best of our knowledge, there is currently no formal comparison between the graftless and traditional Salter osteotomy techniques in the U.S., representing a gap in the literature that may elucidate further benefits and drawbacks of each surgical approach. The purpose of this study was to evaluate the efficacy of the graftless Salter osteotomy and compare the degree of acetabular correction to the traditional technique using propensity matched analysis.

Methods

A retrospective cohort study was conducted following institutional review board approval. All Salter osteotomies performed from 2009 to 2024 at a single urban tertiary care children's hospital were identified. Patients with a minimum 3-month follow-up were included as the goal of the study was to compare the degree of correction and perioperative complications not long-term outcomes. Salter osteotomy cases performed for indications other than DDH (e.g., bladder exstrophy) were excluded. Patients were segregated and compared by surgical approach. Surgeon choice determined the technique used for the Salter osteotomy. The vast majority of the procedures were performed by the senior author who transitioned from standard to a graftless technique early in his career. Demographics (age, sex, race, and body mass index [BMI]), comorbidities, and treatment information were extracted from electronic medical records.

Acetabular indices (AIs) on preoperative and 3-month postoperative anteroposterior (AP) pelvic radiographs were assessed to determine the degree of acetabular correction, which was the primary radiographic outcome. AI was measured as the angle between Hilgenreiner's line and a tangential line from the superolateral margin of the triradiate cartilage to the superolateral margin of the acetabular sourcil [13]. This well-established metric has been shown to have good inter-rater and intrarater reliability [14,15]. The 3-month radiograph was chosen for assessing postoperative correction as the acetabular sourcil is visible without the overlying casting material, but the pelvis has not remodeled significantly (Fig. 1). Radiographic healing was defined as the presence of bridging bone across the osteotomy site.

Surgical technique

Our modified Salter iliac osteotomy is performed through a standard Smith-Peterson anterior approach often in conjunction with an open hip reduction. Either way, after elevating the external oblique fascia off the ilium, the apophysis is split sharply along its midpoint. Both the outer and inner tables are exposed subperiosteally, and the sciatic notch is identified using a Crego elevator. Rang retractors are subsequently placed, and a right-angle clamp is used to shuttle a Gigli saw through the sciatic notch. The straight unangled osteotomy is performed to a point just distal to the ASIS. Both fragments are grasped using a penetrating towel clamp. The distal fragment is pulled anteriorly and extended such that the medial point of the distal fragment can dock along the proximal ilium. Care is taken not to retrovert the distal fragment. Two to three threaded K-wires are then inserted from proximal to distal, transfixing both fragments (Fig. 2). Pin position, depth, and overall correction are confirmed on both the AP and false-profile views using the image intensifier. The apophysis is closed around the pins, which are then cut a few millimeters above the apophysis to facilitate later removal.

Statistical analysis

Descriptive statistics are expressed as mean ± standard deviation (SD) for continuous variables and *N* (%) for categorical variables. Traditional and graftless cohorts were propensity score matched 1:2 using the nearest neighbor method, based on age, gender, and preoperative AI. The degree of acetabular correction was compared between the two cohorts using the Wilcoxon Mann-Whitney test. All statistical analyses were conducted in RStudio, version 2022.07.1 (RStudio Inc). A P value <0.05 was deemed significant.

Results

We identified 47 hips which met the inclusion criteria with a mean age of 29.9 ± 13.3 months at surgery. Fourteen hips were included in the traditional cohort and 33 in the graftless cohort. (Table 1). Five of the 14 hips (36%) in the traditional group had DDH in the setting of an underlying syndrome or condition**;** 9 (64%) underwent concomitant open reduction. Eleven of the 33 hips (33%) in the graftless cohort had DDH in the setting of an underlying condition. Twenty-nine of the graftless hips (88%) underwent concomitant open reduction. The most frequently used number of pins was two pins (n = 28) followed by three pins (n = 18); 5/64 inches (n = 65) was the most commonly utilized pin size followed by 3/32 (n = 28), 1/16 (n = 13), and 7/64 (n = 4) inches.

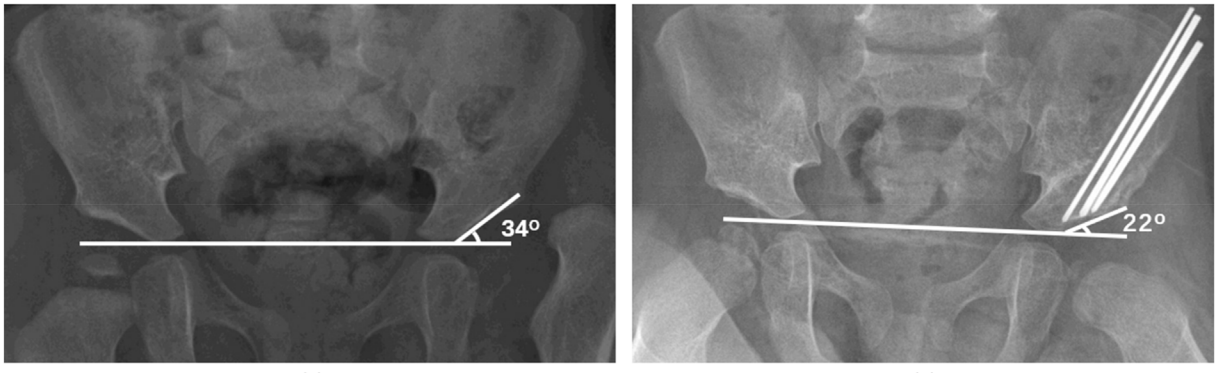

Figure 1. Acetabular index on (a) preoperative and (b) 3-month postoperative anteroposterior radiographs was measured by determining the angle between Hilgenreiner's line and a tangential line from the superolateral margin of the triradiate cartilage to the superolateral margin of the acetabular sourcil.

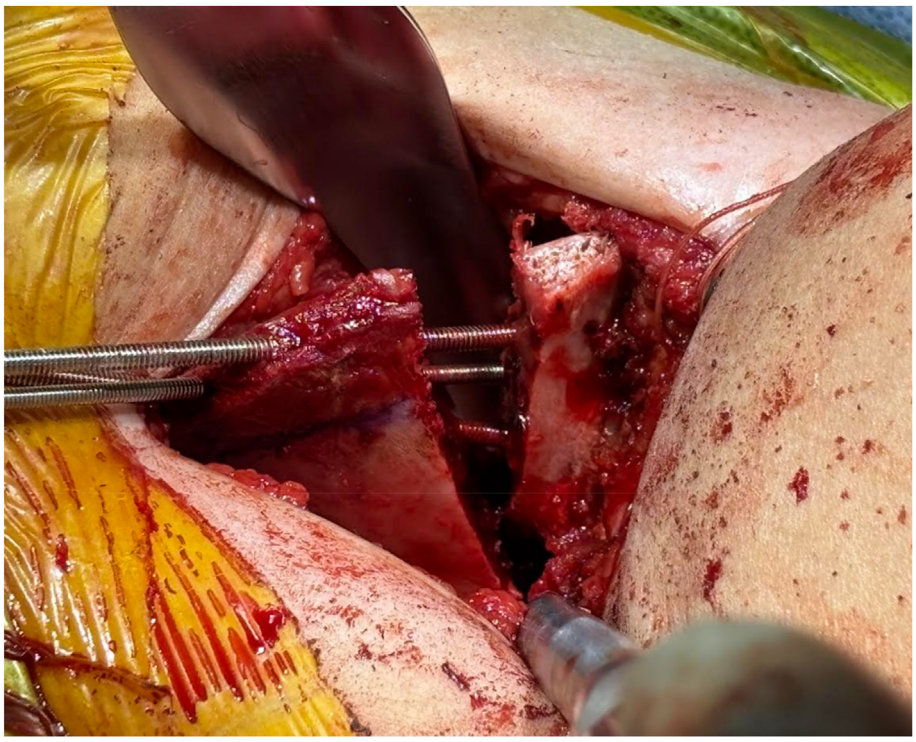

Figure 2. Intraoperative photo of the right ilium of a two-year old patient demonstrating fixation of the Salter osteotomy with three threaded K-wires without an intervening bone.

Table 1.
Patient and treatment characteristics of the traditional vs graftless cohorts.

	Traditional N = 14 n (%) or mean ± SD	Graftless N = 33 n (%) or mean ± SD
Age at surgery (months)	35.5 ± 13.1	27.5 ± 12.9
Sex		
Female	9 (64%)	25 (76%)
Body mass index (kg/m^2)	16.6 ± 1.6	14.2 ± 2.0
Number of pins		
0	1 (7%)	0 (0%)
1	0 (0%)	0 (0%)
2	11 (79%)	17 (52%)
3	2 (14%)	16 (48%)
Pin size (inches)		
1/16	3 (11%)	10 (12%)
5/64	12 (43%)	53 (65%)
3/32	11 (39%)	17 (21%)
7/64	2 (7%)	2 (2%)
Concomitant open reduction		
Yes	9 (64%)	29 (88%)

Percentages are based on column totals.
SD, standard deviation.

Propensity score matched analysis

Forty-two hips (14 traditional and 28 graftless) were included in the propensity score matched analysis. The mean preoperative AI was 40.0° ± 9.3 in the traditional cohort and 37.4° ± 6.4 in the graftless cohort. This decreased to 28.1° ± 6.4 and 24.7° ± 5.1, respectively at the 3-month postoperative timepoint. There was no significant difference in the degree of acetabular correction between the traditional and graftless cohorts (11.9° ± 5.4 vs 12.7° ± 5.7, $P = .69$). All osteotomies demonstrated healing (i.e., consolidation and bridging callus) at the three-month visit. There were no cases of lost fixation or complications related to the osteotomy in either cohort.

Discussion

Although the traditional Salter osteotomy is a well-established procedure for DDH that has demonstrated reliable outcomes, there remain concerns about the procedure, particularly regarding the use of hardware and the harvesting of iliac autograft [7–9]. Verifying the efficacy of a modified Salter osteotomy that avoids the use of a bone graft could reinforce an alternative method to achieve adequate acetabular correction while minimizing the risk of pelvic deformities. The present analysis is the first to evaluate in parallel the acute postoperative outcomes and acetabular correction between patients who underwent graftless and traditional Salter osteotomies in the U.S. The most important finding of our study was that the graftless Salter osteotomy yields a comparable degree of correction to that of the traditional technique. No complications related to the osteotomy were observed in either cohort. Of note, the current study elected to only report AI and radiographic healing because other outcomes, such as return to activity, can be challenging to reliably evaluate in the presence of concomitant procedures such as open hip reduction.

In the traditional Salter osteotomy, the iliac apophysis is split, the osteotomy is performed, and autograft is harvested from the brim of the pelvis including the ASIS (Fig. 3). This shortens the ilium which decreases the footprint of the abductor origin and significantly alters the contour of the pelvis. As a result of this harvest, cases of growth disturbance and pelvic deformities have been reported [16]. These changes may have functional effects as abductor muscle function can be compromised. In addition, cosmetic concerns have been raised by the largely female population as they enter adolescent and young adult years.

In response to these concerns, modifications to the traditional technique have been made to avoid autograft harvest. Kamegaya et al. replaced the use of a bone graft with a hydroxyapatite block, which demonstrated

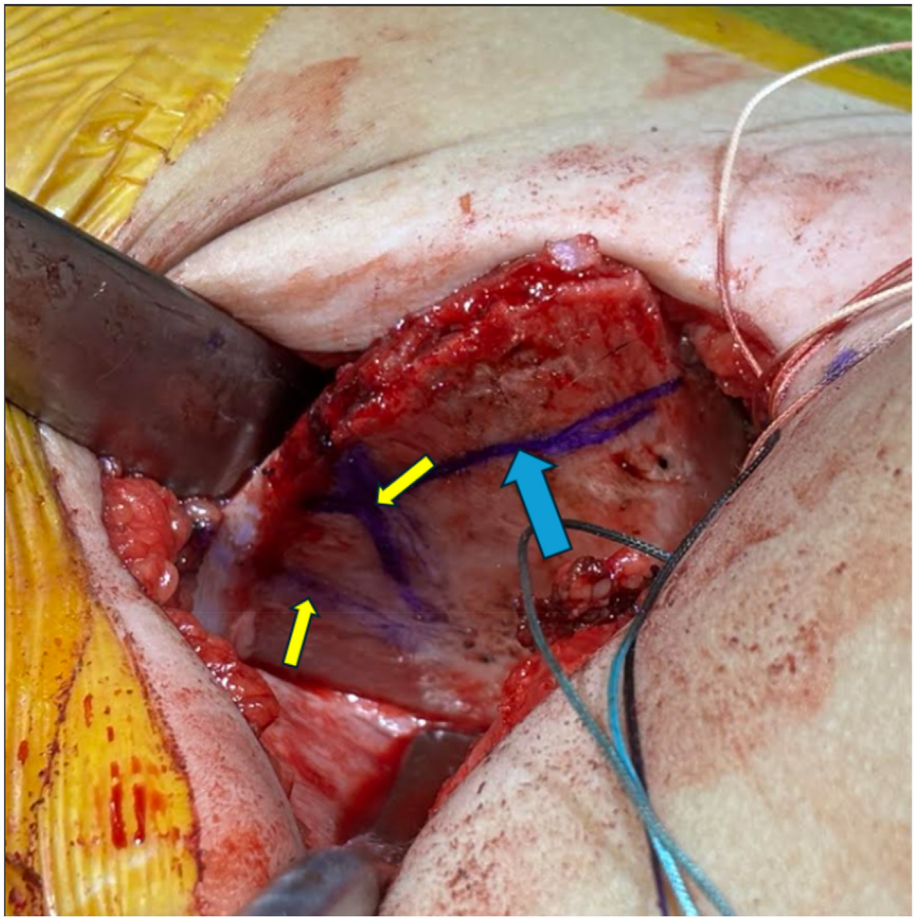

Figure 3. Intraoperative photo of the right ilium displaying typical options for autogenous bone graft. The traditional bone graft for the Salter osteotomy is harvested from the brim of the pelvis including the ASIS (blue arrow). An alternative technique harvests a triangle of bone graft from the proximal ilium which better preserves the contour of the pelvis (yellow arrows). *ASIS, anterior superior iliac spine*.

appropriate correction with less iliac deformities, blood loss, and operative time [17]. However, there were challenges with fixing the hydroxyapatite block with K-wires. Wada et al. similarly proposed the use of a beta-tricalcium phosphate graft substitute. Mixed results were observed, with the modified technique demonstrating a superior improvement in center-edge angle and comparable improvement in AI to the traditional technique. However, greater lateral displacement of the distal osteotomy fragment was observed in the immediate postoperative period for the modified group [7]. More recently, a variation of the Salter osteotomy that eliminates the need for an intervening graft or graft-substitute was formally described [8,9]. In this method, the proximal and distal osteotomy components are fixed directly with 3 to 4 threaded K-wires in a way that ensures two points of contact between the proximal and distal fragments.

Given the senior author's experience with triple and Bernese-type periacetabular osteotomies which often have large bone voids, particularly following greater degrees of correction, our center moved to a graftless modification of the Salter over a decade ago prior to its formal description in the literature. Our experience and the findings of the current study reinforce what has been previously reported of a graftless technique. The 2019 study by Morita et al. found no significant difference in the latest postoperative AI between the graftless and traditional groups ($16.4^\circ \pm 4.9$ vs $15.8^\circ \pm 3.0$). Although the study did not directly compare the degree of acetabular correction, the mean preoperative AI was $30.0^\circ \pm 4.9$ and $31.0^\circ \pm 0.7$ in the graftless and traditional groups, respectively [9]. Hence, the modified graftless and traditional cohorts achieved similar corrections of about 14 and 15 degrees, respectively. In line with these findings, our study observed comparable changes in AI between the graftless and traditional cohorts. The mean AI decreased by 11.9 and 12.7 degrees in the traditional and graftless groups, respectively. No postoperative complications related to the osteotomy were observed in either study. Morita et al. additionally reported significantly reduced operative duration and blood loss in the graftless Salter osteotomy [9]. Our study did not report these data points as the intention of this study is to provide a pure comparison of osteotomy techniques. Surgical variables, such as operative time and blood loss, can be confounded by concomitant procedures at the time of Salter osteotomy, such as open reduction and/or femoral osteotomy. Therefore, our study focuses primarily on data pertinent specifically to the osteotomy technique itself. A separate reliability analysis was not performed for this study as several other publications, including multiple ones from our own center, have well established the reliability of the AI measurement [14,15].

One of the proposed reasons by Dr. Salter himself for taking the bone graft from the iliac crest was to mitigate the risk of avascular necrosis (AVN). With the Salter osteotomy, there is an opening-wedge anteriorly, which can lead to stretching of the abductors and theoretically an increased risk for AVN of the femoral head. Harvesting the ilium shortens the iliac crest and may reduce the risk of AVN. While this would be an interesting outcome to investigate, we could not reliably evaluate this within the scope of our study, given the shorter follow-up period. Additionally, the risk of AVN can be influenced by factors unrelated to the osteotomy itself, such as concurrent open reductions and femoral osteotomies [18]. Therefore, we decided to focus this study specifically on degree of correction and acute postoperative complications.

The present study has several limitations. First, the study had somewhat limited numbers. Our center performs many different types of pelvic osteotomies (both redirectional and reshaping) depending on the

clinical circumstances, so the number of Salter-specific osteotomies is somewhat modest. Clearly, additional power could reveal some differences in correction between the two cohorts, although we believe that is unlikely. Second, the current study only looked at short-term follow-up. This was by design as the purpose of this study was to specifically compare the amount of correction and the perioperative complications between the two techniques. There is a wealth of information on acetabular remodeling and long-term outcomes following Salter osteotomies, which we believe is entirely applicable to the graftless technique once bony union has occurred. As such, we chose to focus this study solely on correction, healing, and complications following osteotomy surgery. However, we certainly acknowledge that longer follow-up would provide additional important data about growth and remodeling in standard vs graftless technique. Additionally, we did not measure the opening wedge of the Salter osteotomy intraoperatively and compare to 3-month postoperative imaging to assess for possible graft collapse. While we considered this metric, we found too much variability in the intraoperative positioning and fluoroscopic images to allow reliable measurements. As a result, we chose to focus on the degree of correction, which ultimately is the most important radiographic outcome measure.

Conclusion

Our findings reinforce the graftless Salter osteotomy as a safe and effective alternative to the traditional Salter osteotomy. Importantly, the graftless variation of Salter osteotomy yields a comparable degree of acetabular correction to the traditional technique without the risk of iliac wing deformities and potential abductor dysfunction.

Consent for publication

The author(s) declare that no patient consent was necessary as no images or identifying information are included in the article. There are no identifiable images in the paper. Per Elsevier's consent policy “formal consents are not required for the use of entirely anonymized images from which the individual cannot be identified.”

Author contributions

Andrew G. Kim: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Carter E. Hall:** Writing – review & editing, Writing – original draft, Project administration, Data curation. **Sulagna Sarkar:** Writing – original draft, Methodology, Formal analysis. **Christopher J. DeFrancesco:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Wudbhav N. Sankar:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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Declaration of competing of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Wudbhav N Sankar reports a relationship with the Pediatric Orthopaedic Society of North America that includes board membership. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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