Effect of Pelvic Osteotomy in the Skeletally Immature on Acetabular Coverage

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Abstract *Background:* Although pelvic osteotomy in children has been effective in re-establishing containment of the hip joint, its impact on hip joint development with respect to acetabular coverage is ill defined. *Purpose:* The purpose of this study is to determine the prevalence of acetabular overcoverage in patients who had pelvic osteotomy during childhood and its impact on patient function. *Patients and Methods:* Between 1980 and 2008, all patients who had a pelvic osteotomy done at our institution for non-neuropathic hip dysplasia (DDH) or secondary to Legg–Calvé–Perthes disease (LCP) prior to skeletal maturity were reviewed. A clinical assessment and the WOMAC, UCLA Activity Score, Marx activity score, and SF-36 quality-of-life questionnaires were completed. A standardized AP pelvic X-ray was performed to determine the acetabular coverage, signs of retroversion, and degenerative changes. *Results:* Twenty-eight patients (32 hips) were identified, of which 14 (9 DDH, 5 LCP) agreed to participate. Impingement sign was positive in eight patients (six DDH, two LCP). Crossover and ischial spine signs were each present in ten hips. Tonnis grades were: 0 in 1 hip, 1 in 10 hips, 2 in 2 hips, and 3 in 1 hip. The mean Tonnis angle was $11.6 \pm 8.6^\circ$. The mean CE angle was $24.0 \pm 15.9^\circ$ with six hips having a CE angle $< 20^\circ$ and one hip with a CE angle $> 40^\circ$. There was no correlation between crossover sign or ischial sign and Tonnis grade ($p=0.739$), hip pain ($p=0.520$), or impingement sign ($p=1.00$). *Conclusions:* Acetabular overcoverage is common in patients who underwent pelvic osteotomy during childhood.

No correlation was identified between retroversion and hip pain in our patient cohort.

Keywords pelvic osteotomy · acetabular coverage · retroversion · pediatric

Introduction

Undercoverage of the femoral head by the acetabulum in childhood can present itself at varying degrees of severity ranging from instability, subluxation, and/or dislocation [32]. Over the years various pelvic osteotomies have been described and used to correct the undercoverage which can not only occur with dysplasia but also with other childhood hip disorders such as Legg–Calvé–Perthes (LCP) and different teratological disorders [11, 19, 28, 31, 35, 36]. One of the most common osteotomy is Salter's pelvic osteotomy which was meant to redirect the entire acetabulum anterolaterally by cutting the innominate bone across the sciatic notch and hinging the correction on the symphysis pubis [6, 12–14, 37]. Although the long-term results have been excellent in regards to avoiding arthritis and/or total hip replacement [6], some patients who have had a pelvic osteotomy as a child have to undergo repeat hip surgery because of persistent hip pain either because of insufficient coverage/dysplasia or acetabular retroversion [24]. More importantly, residual dysplasia puts the hip at risk of degenerative changes [25] in the long term. Similarly, acetabular retroversion has been proposed as a cause of hip pain and possibly arthritis [10, 17, 29]. Overcoverage can either be localized (acetabular retroversion: where the most proximal anterior acetabular rim appears lateral to the posterior rim, creating a figure eight) or global (center–edge angle $> 39^\circ$), both of which can either be congenital [27, 29, 33] or postsurgical in etiology [24, 26]. Myers reported on five cases following periacetabular osteotomy that had acetabular retroversion that lead to secondary femoroacetabular impingement causing hip pain and decreased hip function [26]. Similarly, Reynolds et al. [29] noted that patients

Level of Evidence Prognostic study, level IV (case series). See the guidelines for authors for a complete description of levels of evidence.

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Table 1 Demographics of sample

	DDH	LCP	Total
Total	19(67.9%)	9(32.1%)	28
Sex			
• Males	5	7	12
• Females	14	2	16
Unilateral			24
• Right	4	3	7
• Left	15	6	17
Bilateral	4	0	4

suffering from intra-articular hip pathology (i.e., labral tear) had an associated crossover sign on the anteroposterior radiograph. This isolated overcoverage has also been included within the concept of femoroacetabular impingement (FAI) [20] and defined as pincer where excessive anterior coverage of the acetabulum leads to labral tears due to premature contact with the anterior femoral neck [3]. The purpose of this study is to determine: (a) presence or absence of acetabular overcoverage in skeletally mature patients who underwent a pelvic osteotomy during childhood and (b) its impact on patient function and presence of arthritic changes.

Patients and Methods

Prior to patient enrollment, ethical approval was obtained from our institutional research ethics board. The study population was defined as patients who have had a pelvic osteotomy at our children's hospital between 1980 and 2008 using the medical records through the following word search: pelvic and/or hip osteotomy. Patients younger than 15 years at the time of the study, patients with teratological hip diseases, and females who may be pregnant were excluded. Twenty-eight patients (32 hips) who met our inclusion criteria were identified. Charts were retrospectively reviewed. There were 16 (57%) females [14 in the developmental dysplasia of the hip (DDH) group and 2 in the LCP disease group] and 12 (43%) males (5 in the DDH group and 7 in the LCP disease group; Table 1). Twenty-four had unilateral and 4 bilateral pelvic osteotomies of which 25 Salter, 3 Steel, 3 Dega, and 1 Pemberton pelvic osteotomies were performed. The average age at the time of surgery was 6.5 ± 5.2 years. Eleven hips had a varus

derotation osteotomy performed as an additional procedure at the time of the index surgery.

Only 14 patients (50% follow-up rate) agreed to be interviewed for clinical assessment and a follow-up pelvic X-ray. The mean age of patients at the time of the study was 17.5 years with nine DDH patients (64.3%) and five LCP patients (35.7%). During this follow-up visit, patients were examined where the range of motion was recorded, the presence or absence of the impingement sign [18], and presence of leg length discrepancy was confirmed if a 1-cm block under the affected leg was required to level the pelvis. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [4], UCLA Activity Score [2], the Marx activity score [22], and the Short-Form 36-item Health Survey (SF-36) [41] questionnaires were completed by patients. In the case of the WOMAC, each total raw score was normalized into a 0-to-100 scale, with 0 representing the worst quality of life and 100 representing the best quality of life [5]. A standardized AP pelvic X-ray was taken for each patient [29, 34] and was reviewed for the presence of acetabular retroversion based on either the presence of a crossover [15] or ischial spine sign [16]. Hip joint degeneration was identified and graded according to Tonnis grading system of hip osteoarthritis [39]. Both Tonnis angle [38] and center-edge angle [42] were calculated for the operated hip.

Chi-square analyses were performed to examine the relationship between the crossover or ischial spine sign to Tonnis grading and/or hip pain. Student's *t* tests were performed to examine potential outcome differences between the DDH and LCP groups. Statistical significance was set at $\alpha=0.05$

Results

No significant differences in outcome scores (WOMAC, SF-36, UCLA, Marx Score) were detected between the DDH and LCP patient groups ($p>0.05$ in all cases; Table 2). However a trend for better scores was observed among the LCP group in all domains of the WOMAC, as well as on the UCLA and Marx scores (Table 2). Despite having undergone surgical correction, our cohort's WOMAC scores at follow-up continue to be below those of a normative population. Impingement sign was positive in eight (57.2%) patients [six in the DDH group (66.7%) and two in the LCP group (40%)] (Table 3). Leg length discrepancy was evident in four patients (28.6%;

Table 2 Outcome scores [mean (SD)]

Outcome	Total patients (<i>n</i> =14)	DDH group (<i>n</i> =9)	LCP (<i>n</i> =5)	<i>p</i>
WOMAC				
Pain	68.46 (27.19)	59.38 (28.32)	83.00 (28.20)	0.13
Stiffness	65.38 (31.11)	60.94 (26.25)	72.50 (39.92)	0.54
Function	69.57 (24.03)	61.40 (19.12)	82.65 (27.30)	0.13
Total	68.99 (24.34)	60.94 (18.97)	81.88 (28.46)	0.14
SF-12				
Physical	36.03 (12.52)	34.32 (11.86)	39.44 (15.78)	0.60
Mental	54.95 (7.19)	55.27 (7.81)	54.31 (7.29)	0.86
UCLA	6.42 (2.64)	5.88 (2.47)	7.50 (3.00)	0.34
Marx	5.25 (5.93)	4.38 (4.84)	7.00 (8.25)	0.50

Table 3). Overall range of motion was reduced compared to that normally expected (Table 3). The mean Tonnis angle was 11.6° (SD=8.55) and a mean CE angle of 24.0° (SD=15.9). Six of the 14 (43%) patients had a center–edge angle $<20^\circ$, and only 1 patient had a CE angle $>40^\circ$. Crossover sign was present in ten hips (71.4%) as well as ischial spine sign, six of which were also dysplastic. Only one patient had a normal hip joint (Tonnis grade 0). Ten patients (71.4%) had Tonnis grade 1; two patients (14.3%) were grade 2, and one patient (7.1%) was grade 3. There was no correlation between the presence of the crossover sign and the Tonnis grade of hip osteoarthritis ($p=0.74$). In regards to functional scores, there was no significant difference in functional scores between patients with and without signs of acetabular retroversion (ischial spine and/or crossover signs; Table 4). Although not statistically significant, a trend for better outcomes was observed among patients with an absent ischial spine or crossover sign, particularly on the WOMAC, UCLA, and Marx scores. No correlation was found between the presence of the crossover or ischial sign and impingement sign ($p=1.00$) as well as presence of hip dysplasia and hip pain.

Discussion

Pelvic osteotomies in skeletally immature patients have been performed to correct femoral head undercoverage not only to facilitate normal function but also to favor normal hip development by improving containment of the femoral head by the acetabulum. Although long-term follow-up has noted good results in the majority of patients, some authors [24] have also noted that patients who had a pelvic osteotomy as a child can present later on in adulthood with hip pain secondary to persistent dysplasia as well as excessive anterior overcoverage [24]. In our series, we noted that 6 of the 14 had persistent dysplasia (CE angle $<20^\circ$), all of which had a crossover sign (Fig. 1) as well as an additional four with acetabular retroversion (crossover/ischial sign). Overall, patients who had underwent pelvic osteotomy as a child had good functional scores with a mean of 68.9 but inferior to the normative population [40]. Because of the small number of cases, we were unable to

Table 3 Clinical data

	DDH	LCP	Total
Impingement sign			
• Present	6	2	8
• Absent	3	3	6
Average ROM			
• IR	25.88 (20.00)	25.25 (13.30)	25.67 (17.40)
• ER	22.00 (8.21)	34.00 (24.39)	26.00 (15.49)
• FLX	97.63 (15.59)	114.50 (24.57)	103.25 (19.71)
• EXT	12.63 (11.10)	10.50 (22.23)	11.92 (14.64)
• ADD	19.57 (11.30)	24.75 (5.74)	21.45 (9.66)
• ABD	25.29 (6.24)	21.50 (21.49)	23.91 (12.86)
LLD			
• Present	2	2	4
• Absent	7	3	10

IR internal rotation, ER external rotation, FLX flexion, EXT extension, ADD adduction, ABD abduction

Table 4 Outcome scores as mean (SD)

Outcome	Present (n=10)	Absent (n=4)	p
By ischial spine sign			
WOMAC			
Pain	62.00 (28.00)	76.25 (27.50)	0.41
Stiffness	57.50 (28.99)	81.25 (29.76)	0.19
Function	62.50 (25.09)	77.94 (24.99)	0.32
Total	61.98 (24.84)	77.87 (25.48)	0.30
SF-36			
Physical	44.98 (11.24)	29.67 (11.47)	0.09
Mental	56.82 (6.92)	53.87 (9.88)	0.59
UCLA	5.40 (2.24)	8.25 (2.36)	0.07
Marx	3.00 (4.64)	9.00 (6.83)	0.09
By crossover sign			
WOMAC			
Pain	62.00 (28.00)	76.25 (27.50)	0.41
Stiffness	57.50 (28.99)	81.25 (29.76)	0.19
Function	62.35 (24.84)	78.31 (25.40)	0.30
Total	61.88 (24.66)	78.13 (25.77)	0.29
SF-36			
Physical	32.98 (14.15)	39.40 (8.08)	0.57
Mental	56.86 (6.41)	52.25 (13.39)	0.47
UCLA	5.90 (2.56)	7.67 (2.52)	0.32
Marx	3.90 (5.22)	8.00 (8.00)	0.31

attain statistical significance but there was a trend between presence of hip pain and acetabular retroversion with two of four patients with no hip pain having a crossover sign whereas eight of ten patients with hip pain having a crossover sign. In addition, patients without an ischial sign had higher activity score which almost reach statistical significance.

The main study limitation of our study is the relatively small number of patients making definitive statements difficult. Only 28 patients that fit the inclusion criteria were identified. Out of those, 14 (follow-up rate=50%) agreed to come for a further clinical assessment and radiological imaging. Having said that, our findings are similar to other papers in regards to

Fig. 1 Anteroposterior radiograph of a 20-year-old female post-Salter osteotomy showing residual dysplasia and acetabular retroversion. Patient has left hip pain

other studies looking at retroversion after pelvic osteotomy in childhood [9]. In addition, although we attempted to locate these individuals because of their young age at the time of surgery, locating patients can be quite difficult [37]. Another limitation is the determination of acetabular retroversion based on two-dimensional radiographic signs where 4 out of the 14 patients had only the ischial sign or crossover signs. At this time it is still unclear if one of those signs is more representative of retroversion with future studies looking at three-dimensional quantification are needed. Finally, our study included two different patient groups Legg–Calvé–Perthes and dysplasia, and although both groups demonstrated signs of retroversion, it maybe that acetabular development may differ between the two patients groups, making it difficult to determine the real impact of the pelvic osteotomy. Having said that, because patients with dysplasia also have abnormal proximal femoral morphology [7], the effect of the pelvic osteotomy in both groups on acetabular development is most likely comparable.

The coexistence of retroversion and dysplasia in the native hip joint has been reported to be in one in six [21] and as high as one in three [23]. The significance of acetabular retroversion in regards to hip pain as well as the development of arthritis is still being debated [1, 8]. In a recent paper, Jamali et al. [15] were able to validate the accuracy and validity of the crossover sign in defining acetabular retroversion. Based on their cadaveric study, just over one third of cadavers were found to have acetabular retroversion which was limited to the cranial portion of the acetabulum. More recently, the ischial spine sign was described as a method of diagnosing acetabular retroversion [16] and defined as the ischial spine projection into the pelvis on an AP film. Although acetabular retroversion has been identified as an etiological factor for the development of hip osteoarthritis [10] as well as FAI [29], our study as that of others [9, 30, 43] has failed to show any correlation between acetabular retroversion and the presence of hip pain. When looking at signs of retroversion and its correlation with hip pain in patients with FAI, Allen et al. [1] did not find an association, concluding that the severity of the CAM lesion was the main driver in regards to development of hip pain. Cobb et al. [8] using three-dimensional computer tomography also questioned the significance of acetabular retroversion in regards to the development of hip pain. Although it is clear that some degree of retroversion will affect hip range of motion leading to intra-articular cartilage damage, it is unclear in what individuals this will occur due to the variability in the functional pelvic position [18] as well as severity of the retroversion. Future research is needed to better quantify severity acetabular retroversion in the native hip joint and its relationship to hip function.

When performing pelvic osteotomies such as the Salter [32] and Pemberton [28] in the skeletally immature, one is trying to improve containment not only to stabilize the hip joint but also to favor normal development [28, 37]. Although long-term follow-up has shown very good results with Salter's osteotomy [37], because an effort is made to correct deficient anterior coverage, this can lead to excessive anterior coverage of the acetabulum (i.e., acetabular retroversion). The results of this study show the high prevalence of acetabular retroversion among this patient population (71.4%) as well as persistent dysplasia being common at 43%. Similarly, other studies have

shown that acetabular retroversion can be a common finding after pelvic osteotomy either in childhood [9] or adulthood [43], but it remains unclear as the true clinical significance of this finding both at the short and long term. Having said that, striving to achieve proper acetabular version should always be the main goal when performing a pelvic osteotomy, and in that regards, the triple innominate osteotomy [40] maybe more effective as the placement of the osteotomized acetabular fragment is not restricted by a hinging fragment.

Persistent dysplasia and retroversion are highly prevalent in patients who underwent pelvic osteotomy for childhood hip diseases, likely as a result of the tendency for over-correction anteriorly at the time of the hip osteotomy. Signs of impingement are also highly prevalent (57.2) in the same population, however no correlation between hip pain and retroversion was noted in this patient population.

Disclosures The authors declare that they have no conflict of interest. Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a significant conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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