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ORIGINAL ARTICLE

Trochanteric Advancement in Patients with Legg-Calvé-Perthes Disease Does Not Improve Pain or Limp

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Abstract Premature closure of the proximal epiphysis in patients with Legg-Calvé-Perthes disease can cause overgrowth of the greater trochanter. We asked whether distal transfer of the greater trochanter relieved pain and improved limp and whether the operation changed frontal plane kinematic and kinetic parameters of the hip and pelvis in the gait analysis. We reviewed 15 patients (15 hips) with an average age of 16.9 years (range, 13–26 years) who had the operation and were followed for a minimum of 28 months (average, 42 months; range, 28–54 months). The Iowa hip score increased from 85.0 (range, 75.5–87.0) before surgery to 89.1 (range, 83.0–97.0) at the final followup. Only three patients had no pain and Trendelenburg sign postoperatively. Pelvic obliquity angle of affected and contralateral normal hips in ipsilateral stance and contralateral swing phases remained unchanged after surgery. Hip adduction angle and abductor moment during single stance phase of affected and contralateral normal hips were not changed. We concluded trochanteric advancement does little to relieve pain and improve limp in patients with relative overgrowth of the greater trochanter and Legg-Calvé-Perthes disease.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has 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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Introduction

Premature closure of the proximal femoral physis often occurs after treatment of developmental dislocation of the hip (DDH), Legg-Calvé-Perthes disease, slipped capital femoral epiphysis, or septic arthritis. Retardation or arrest of longitudinal growth of the femoral neck, along with continuing growth of the greater trochanter, induces relative overgrowth of the greater trochanter (ROGT). Subsequently, the resting length and lever arm of the hip abductor muscles become shortened, ostensibly leading to functional abductor weakness and increased hip reaction force [11, 23, 25]. Clinically, ROGT presents as a positive Trendelenburg sign, gluteus medius lurch, and fatigue pain on walking.

Several operative methods for a high-standing greater trochanter have been suggested, and they all share the same goal of improving altered biomechanics of the hip. If the deformity is in its early phase of development, epiphysiodesis of the greater trochanter can stabilize the relationship between the greater trochanter and the femoral head and neck regions [23, 25]. Conversely, when there is relatively little or no growth remaining, trochanteric advancement has been advocated to correct biomechanical consequences of ROGT by distally moving the greater trochanter and its attached muscles [6, 11, 29].

This procedure usually is performed when there is a markedly positive Trendelenburg sign and the value of distance from top of the femoral head to that of the greater trochanter, measured along the axis of the femoral shaft (articulotrochanteric distance), is negative, ie, when the trochanter is taller.

Earlier studies indicate trochanteric advancement is an effective treatment for ROGT, which resulted from many children's hip diseases [4, 5, 11, 15, 20, 23]. However, these studies included patients with different etiologies and severities of diseases and report results as an outcome from one or multiple operative techniques. Furthermore, some studies report on patients with DDH; only 10% of patients (41 patients totally) reported in the English literature who were treated by trochanteric transfer were in fact afflicted with Perthes disease [3–5, 14, 15, 27]. To the best of our knowledge, there has been no study to date that reports the results of trochanteric advancement performed exclusively in patients with Perthes disease. However, it has been assumed ROGT resulting from Perthes disease has a better outcome than that resulting from a complication of treatment for hip dysplasia.

We therefore asked whether distal transfer of the greater trochanter relieved pain and improved limp in patients with ROGT and Perthes disease and whether the operation changed frontal plane kinematic and kinetic parameters of the hip and pelvis in the instrumented gait analysis.

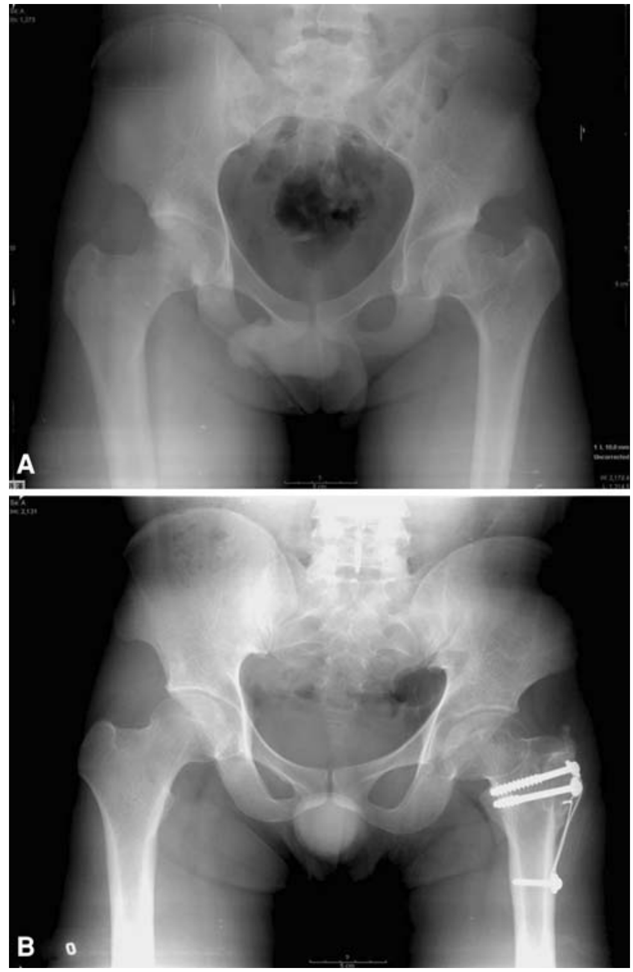

Fig. 1A–B (**A**) A standing anteroposterior radiograph of the hip of a 15-year-old boy shows relative overgrowth of the left greater trochanter. The value of the distance from the top of the femoral head to that of the greater trochanter, measured along the axis of the femoral shaft (articulotrochanteric distance), is negative. (**B**) A postoperative radiograph taken 3 years after surgery shows the greater trochanter advanced distally and laterally.

Materials and Methods

We retrospectively reviewed 15 selected patients (15 hips) with symptomatic ROGT who were treated with distal transfer of the greater trochanter between 2000 and 2004. It was our practice to transfer the greater trochanter when the patient had a positive Trendelenburg sign [23], a negative articulotrochanteric distance (Fig. 1A), and reported localized fatigue pain around the abductor muscles after prolonged activity or walking. We did not perform the surgery in patients who had had previous surgeries on the acetabulum or femur and who had a severely deformed femoral head (Class IV or V of Stulberg et al. [26]). All had reached skeletal maturity before the operation as evidenced by closure of the physis of the femur and tibia and the triradiate cartilage. The average preoperative range of hip abduction was 26° (range, 15°–30°), and preoperative hip abductor strength was Grade 3 in 11 patients and Grade 4 in four patients using a scale of the Medical Research Council [16]. According to classification of Stulberg et al. [26], eight hips belonged to Class II and seven hips to Class III. The average lower limb length discrepancy attributable to shortening of the affected side, measured on an orthoroentgenogram, was 16.2 mm (range, 8.5–23.7 mm). There were 12 males and three females. The mean age of the patients at the time of surgery was 16.9 years (range, 13–26 years), and the minimum followup was 28 months (mean, 42 months; range, 28–54 months). The study was approved by our hospital's Institutional Review Board.

All operations were performed by one surgeon (HWK). To ensure proper placement of the greater trochanter at a distal site, we used fluoroscopic guidance with the hip rotated internally to give negative measured values of the articulotrochanteric distance and greater trochanteric overgrowth. We inserted a guidewire at the level of the abductor tubercle pointing to the trochanteric fossa along a line continuous with the superior cortex of the femoral neck. The greater trochanter was osteotomized following the proximal border of the guidewire. After adequate mobilization of the greater trochanter, the recipient site on the lateral cortex of the proximal femoral shaft was beveled using a curved osteotome, being careful not to remove too much bone. We then transferred the trochanteric fragment distally to lay the tip of the greater trochanter on a horizontal line connecting the center of the femoral heads and to establish an articulotrochanteric distance equal to that in the contralateral normal hip. The trochanteric fragment was fixed with two AO 7.0-mm-diameter cannulated screws. To counteract the pull of the hip abductors, we augmented the internal fixation by a taut tension band of heavy wire suture that extended from a trochanteric screw to a cortical screw, which was inserted approximately 7 cm distally in the femur (Fig. 1B). None of the patients had concomitant surgeries at the time of the index operation.

We did not immobilize or limit patient activities after surgery. Rather, we recommended partial weightbearing with crutches and encouraged active abduction exercise as soon as patients felt comfortable.

Radiographic evaluations on the standing anteroposterior radiographs with the hips in neutral position were performed (Fig. 2). The measured radiographic parameters included radius of the femoral head, lateral displacement of the greater trochanter, greater trochanteric overgrowth, articulotrochanteric distance, and neck-shaft angle [9, 18, 23, 26, 28]. Because the degree of lateral displacement of the greater trochanter could be overestimated because of an enlarged femoral head in the affected hip, we also calculated the ratio of the lateral displacement of the greater trochanter over the radius of the femoral head. The center-edge angle of Wiberg and the ACM angle of Idelberger and Frank [9] were measured to evaluate the head-acetabular relationship. We measured the acetabulum-head index [8] to examine the degree of coverage of the femoral head by the acetabulum. Finally, the lever arm ratio according to the method of Pauwels [18] was obtained as the ratio of the distance between the center of the femoral head and the symphysis pubis to that between the center of the femoral head and the tip of the greater trochanter. A decreasing lever arm ratio indicates an increasing lever arm of the hip abductors.

We performed kinematic and kinetic analyses using the VICON 370 Motion Analysis System (Oxford Metrics, Oxford, UK) with six infrared cameras, and information on ground reaction force was gathered using multiple force platforms (Advanced Mechanical Technology, Watertown, MA). Force plates under the path were used to record ground reaction forces during walking trials, and internal joint moments were calculated to counter the ground reaction force using a traditional inverse dynamics approach and normalized to body mass (Nm/kg) [12, 21]. Kinematic and kinetic data from successful trials were averaged and used for statistical analysis. The normal range for kinematics was defined as two standard deviations around average. We considered values outside the two-standard-deviation range abnormal. Kinematic and kinetic parameters of the hip and pelvis in the frontal plane before surgery and at the final followup were analyzed. The hip abductor moment was analyzed by averaging all the data points during a single stance phase.

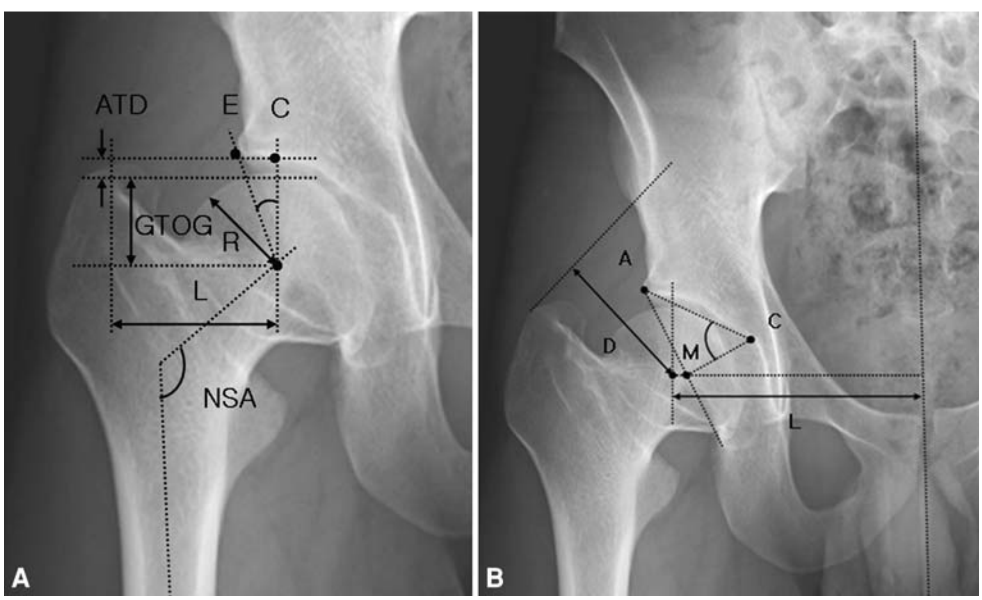

Fig. 2A–B Radiographic evaluations on the standing anteroposterior radiographs with the hips in neutral position were performed. (**A**) Shown are measurements of the radius of the femoral head (R), neck-shaft angle (NSA), articulotrochanteric distance (ATD), greater trochanteric overgrowth (GTOG), lateral displacement of the greater trochanter (L), center-edge angle of Wiberg (CE); and (**B**) the ACM angle of Idelberger and Frank [9], and frontal plane lever arm ratio (L/D).

We (JSY) determined the clinical outcomes using the Iowa hip score [13]. In addition, the patients were evaluated using the criteria of Eilert et al. [4]: patients with good results were defined as having no pain with vigorous activity and a negative delayed Trendelenburg sign; a fair result meant the Trendelenburg sign was still positive with fatigue; patients with poor results had pain and a persistent unimproved limp.

We compared radiographic, kinematic, and kinetic parameters between normal and affected hips using the Mann-Whitney U test; the Wilcoxon signed-rank test was used to compare differences between radiographic, kinematic, and kinetic parameters before surgery and those at the final followup. We used SPSS 12.0 software (SPSS Inc, Chicago, IL) for analysis.

Results

The Iowa hip score did not substantially change from before surgery to final followup (mean 85.0, range, 75.5–87.0 before surgery versus mean 89.1, range, 83.0–97.0 at the final followup). Only three patients had good clinical outcomes according to the criteria of Eilert et al. [4]; two hips belonged to Class II and one hip to Class III [26], and all had Grade 4 abductor muscle strength at followup. Ten patients were classified as having fair outcomes; seven hips belonged to Class II and three hips to Class III [26], and abductor strength was Grade 4 in six and Grade 3 in four patients. Two patients, whose class was III [26] and abductor strength was Grade 3, had poor outcomes. The average postoperative range of the hip abduction was 38° (range, 30°–45°). In the kinematic and kinetic analyses, the pelvic obliquity angle of affected and contralateral normal hips in ipsilateral stance and contralateral swing phases remained unchanged after surgery (Table 1; Fig. 3). Furthermore, the hip adduction angle and the hip abductor moment during single stance phase of affected and contralateral normal hips were not changed after surgery.

The osteotomy site was healed at an average of 9 weeks (range, 7–10 weeks) after surgery, as evidenced by nonvisualization of the radiolucency between the transferred trochanter and the lateral aspect of the proximal femur. Operation-related complications such as nonunion, metal failure, or myositis ossificans were not encountered. We observed no additional flattening of the femoral head or degenerative arthritis in any of the patients. The neck-shaft angle ($p = 0.691$), acetabular angle of Sharp ($p = 0.310$), and the acetabulum-head ($p = 0.965$) in the affected hips were similar to those in contralateral normal hips. Radiographic measurements involving the greater trochanter between affected hips and contralateral normal hips differed before surgery but were similar at the final followup (Table 2). Although lateral displacement of the greater trochanter-head radius ratio was increased ($p = 0.008$) after surgery, it was still less ($p = 0.011$) than that of a normal hip. The hip abductor lever arm ratio in the affected hip remained unchanged ($p = 0.314$) after surgery and remained greater ($p = 0.011$) than that of the contralateral normal hip, indicating a shorter lever arm of the hip abductors.

Discussion

Varying degrees of greater trochanteric overgrowth are common after treatment of many children's hip diseases. Although trochanteric distal displacement has been known to increase gluteal tension and abolish impingement that limits hip abduction, comparison of outcomes among studies is difficult because of different etiologies of the diseases of the patients enrolled and the different criteria for outcomes used. Previous studies highlighted the effectiveness of the procedure merely in terms of nonrigid criteria such as improvements of pain and limp and disappearance of Trendelenburg sign. Furthermore, no studies have been done to date examining the effects of trochanteric advancement performed exclusively in patients with Perthes disease.

We used the Iowa hip score as a contemporary validated instrument; however, it may be more suitable for patients with advanced osteoarthritis undergoing reconstructive hip surgeries. Although a categorical outcome measure should be used only for comparison to multiple historical studies

Table 1. Kinematic and kinetic parameters of the pelvis and the hip in frontal plane

Parameter	Preoperative contralateral normal hip	Postoperative contralateral normal hip	p Value*	Preoperative affected hip	Postoperative affected hip	p Value†
Pelvic obliquity angle (°)						
Ipsilateral stance phase	2.6 ± 3.7	−0.9 ± 2.4	0.859	1.8 ± 2.4	1.2 ± 2.8	0.374
Contralateral swing phase	−2.4 ± 3.4	−3.4 ± 2.7	0.260	−3.4 ± 2.7	−2.9 ± 2.7	0.441
Hip adduction angle (°)	4.3 ± 2.8	4.6 ± 4.7	0.678	2.0 ± 2.4	0.1 ± 3.4	0.066
Hip abduction moment (Nm/kg)	0.69 ± 0.35	0.88 ± 0.24	0.214	0.63 ± 0.27	0.51 ± 0.15	0.139

Values are mean ± standard deviation; * preoperative normal versus postoperative normal; †preoperative affected versus postoperative affected.

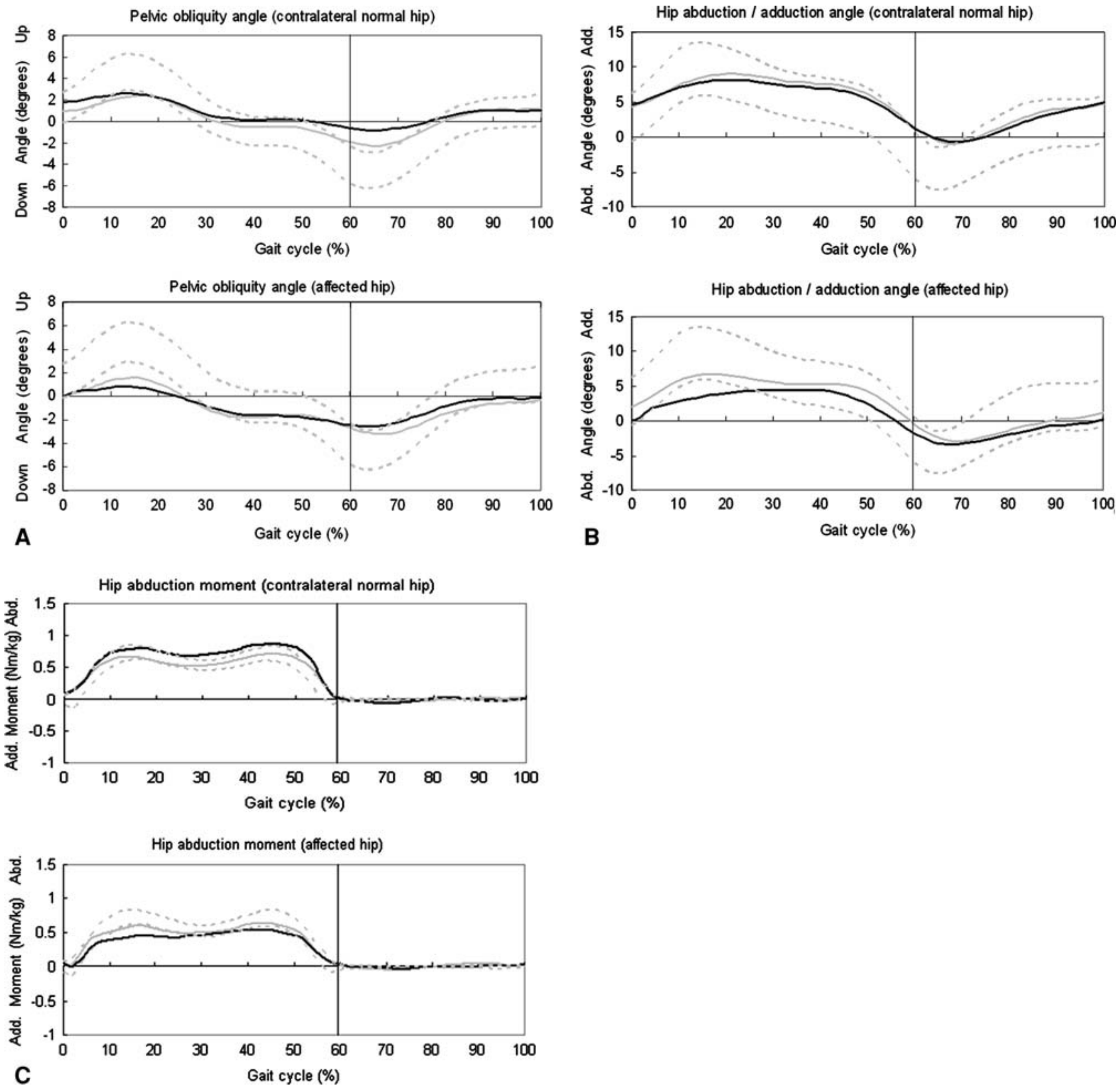

Fig. 3A–C The kinematics and kinetics of the pelvis and the hip are shown in terms of (**A**) pelvic obliquity angle, (**B**) hip abduction angle, and (**C**) hip abductor moment. The gray line indicates the preoperative value, the black line the postoperative value, and the dotted lines normal values. The vertical line represents the division between stance and swing phases of the gait cycle.

using the same outcome measure, we used the functional outcome measure proposed by Eilert et al. [4] as this instrument is the only one that uses pain, limp, and Trendelenburg sign as the primary components for assessing clinical results after trochanteric advancement. Our study also is limited by having no tool to accurately assess in vivo changes of hip loading. The force acting on the hip is determined by the external moment attributable to the body weight and the counteracting moment of the hip abductor muscles [24]. The abductor muscle moment has been used frequently as a primary parameter for characterizing hip loading [1, 11, 18, 21, 24], and a cycle-to-cycle comparison of in vivo measured and calculated hip contact forces and moments showed good agreement [7]. However, computation of joint loading is a complex overdetermined mathematical problem and many loadings can satisfy a given computed moment [2], and therefore, resultant intersegmental moment does not necessarily represent the actual hip loading. Nevertheless, our findings of no changes in the hip abductor lever arm ratio and the hip abductor moment after surgery may suggest the abductor lever arm was not effectively lengthened even after trochanteric advancement.

Table 2. Radiographic measurements

Measurement	Contralateral normal hip	Preoperative affected hip	Postoperative affected hip	p Value*	p Value†	p Value‡
Head radius (mm)	26.3 ± 4.3	31.0 ± 4.0		0.031		
Acetabular angle (°)	38.7 ± 3.3	42.2 ± 5.5		0.310		
ACM angle (°)	45.1 ± 1.4	49.8 ± 2.8		0.002		
NSA (°)	130.3 ± 4.6	128.7 ± 6.9		0.691		
ATD (mm)	21.7 ± 5.6	−1.9 ± 3.6	23.1 ± 10.2	< 0.001	0.008	0.965
GTOG (mm)	3.9 ± 3.3	27.3 ± 6.2	5.8 ± 6.3	< 0.001	0.008	0.401
L (mm)	50.7 ± 8.9	37.2 ± 5.9	50.0 ± 7.7	0.009	0.008	0.691
LR	2.01 ± 0.24	1.26 ± 0.77	1.63 ± 0.18	0.003	0.008	0.011
LAR	1.61 ± 0.15	1.88 ± 0.19	1.80 ± 0.11	0.004	0.314	0.011
CE angle (°)	27.2 ± 3.8	19.7 ± 3.6	19.8 ± 3.4	0.004	0.767	0.004
AHI	0.80 ± 0.08	0.79 ± 0.08	0.78 ± 0.07	0.965	0.438	0.595

Values are mean ± standard deviation; * normal versus preoperative affected; †preoperative affected versus postoperative affected; ‡normal versus postoperative affected; ACM = Idelberger and Frank's angle; NSA = neck-shaft angle; ATD = articulotrochanteric distance; GTOG = greater trochanter overgrowth; L = lateral displacement of greater trochanter; LR = lateral displacement of greater trochanter-head radius ratio; LAR = lever arm ratio; CE angle = center-edge angle of Wiberg; AHI = acetabulum-head index.

Our results suggest the operation does not necessarily improve clinical symptoms and signs related to ROGT, as assessed by instrumented gait analysis and by clinical outcome measures. Two factors have been suggested to increase the incidence of poor results after greater trochanteric transfer: primary conditions such as infantile septic arthritis and DDH and the number of surgeries performed before transfer [11, 14, 15]. The association of these factors with poor results could most likely be the result of the onset of the disorder at an earlier age, resulting in a longer period of abnormal growth of the hip and greater need for surgical correction of the deformity and a prolonged rehabilitation period. Weakness of the hip abductors by repeated surgery also may be responsible for incompetent abductor function, even after trochanteric advancement.

However, two studies reported better outcomes in their small subset of patients with Perthes disease than in patients with DDH [4, 14]. However, neither provided details of patients, such as severity of the femoral head deformities and the head-acetabular relationship, and no information exists concerning the conditions for good outcomes of the trochanteric advancement in Perthes disease. Residual hip deformities in our series were classified as either Class II or III, but the femoral head was not flat (Class IV [26]) in any of the patients. Although the classification system of Stulberg et al. [26] has interrater variability and intrarater variability [17], class did not seem to be related to the final outcomes in our series. Femoral head coverage by the acetabulum, as represented by the acetabular-head index, was similar in affected and contralateral normal hips despite decreased center-edge angle of Wiberg and increased ACM angle in affected hips. This means an enlarged femoral head in our series was contained in the sloping acetabulum, and the acetabulum had developed to match the altered femoral head shape (congruous incongruity).

The effectiveness of the abductor musculature is dependent not only on the height of the greater trochanter relative to the femoral head but also on the distance of the greater trochanter from the center of the femoral head [10, 29]. In a normal hip, the distance from the tip of the greater trochanter to the center of the femoral head is 2 to 2.5 times the radius of the femoral head [20, 29]. Considering the fact that affected hips in our series had an enlarged femoral head, an increased absolute value of lateral displacement of the greater trochanter after surgery does not necessarily represent sufficient lateralization of the trochanter. Although there was no difference in the lateral displacement of the greater trochanter after surgery between normal hips and affected hips, the greater trochanter was located laterally from the center of the femoral head at an average distance of only 1.63 times the radius of the enlarged femoral head in the affected hips.

Lateralization of the trochanter has been suggested as the most important component because less force is required by the pelvitrochanteric musculature to maintain the pelvis level during single stance [11], whereas others [7, 20] believe distal transfer alone is sufficient for improvement of gait. However, "distal and lateral transfer of the greater trochanter" would be a misnomer. Distal transfer of the greater trochanter places it on a portion of the femur with a lesser diameter than its original site and, therefore, moves the greater trochanter medial, not lateral. Our findings that distal transfer produced no changes in the abductor lever arm ratio and the hip abductor moment after surgery might have been the result of failure of actual lateralization of the trochanter. In contrast to patients with osteonecrosis of the femoral head associated with DDH, sufficient lateral displacement of the greater trochanter in patients with coxa magna associated with Perthes disease may not be possible. A more complicated interposition graft under the transferred trochanter might produce undue prominence and cause friction under the fascia lata and patient discomfort.

Increased subluxation of the hip after trochanteric advancement was observed in patients with DDH [22], but Porat et al. [19] reported only one child with such subluxation. We did not perform ancillary acetabular augmentation because there was sufficient acetabular coverage of the femoral head preoperatively. In hips with marked acetabular dysplasia or with considerable subluxation, the lever arm of the abductor muscles becomes shortened; therefore, trochanteric advancement in this situation may fail to provide a solid and stable fulcrum for effective abductor contraction. We found no patients with subluxation of the femoral head at the final followups as evidenced by an unchanged center-edge angle and acetabulum-head index. However, additional studies are necessary to examine whether the operation enhances the development of osteoarthritis because many of our patients showed congruous incongruity of the hip.

Hip abductor insufficiency associated with greater trochanteric overgrowth is attributable to the muscle physiology of a shortened origin to insertion length of the abductor muscles plus the negative mechanical effect of a shortened abductor muscle lever arm. Also, physiologic cross-sectional area may be altered by muscle atrophy, thus decreasing peak isometric force. Trochanter advancement theoretically alters resting tension in the muscle presuming no subsequent biologic adaptation in resting length, thereby placing the muscle in a more advantageous portion of the length-tension curve. However, our data show it does little to correct the negative mechanical effect of a shortened abductor muscle lever arm in patients with symptomatic ROGT and coxa magna associated with Legg-Calvé-Perthes disease. In hips with an enlarged femoral head, a method that elongates the femoral neck and downwardly displaces the greater trochanter might provide these patients with biomechanical benefits. With such a method, the abductor lever arm may be extended effectively and the accompanying lower limb shortening also could be corrected. However, merely transferring the trochanter distally does not achieve these goals.

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