Evaluation of the Gluteus Medius Muscle After a Pelvic Support Osteotomy to Treat Congenital Dislocation of the Hip

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Background: Many authors have reported that the pelvic support osteotomy prevents a Trendelenburg gait by restoring the biomechanics of the abductor muscle in patients with congenital dislocation of the hip. However, we are not aware of any studies in which the hip abductor muscles were examined following pelvic support osteotomy. The purpose of this study was, first, to use magnetic resonance imaging to measure alterations in the length and volume of the gluteus medius muscle after pelvic support osteotomy and, second, to determine which factors influence the results of the Trendelenburg test.

Methods: Eleven patients with a history of congenital hip dislocation who had been treated with a pelvic support osteotomy were examined clinically with the Harris hip score and the Trendelenburg test, radiographically to measure limb-length discrepancy and valgus angulation of the proximal part of the femur, and with magnetic resonance imaging to measure changes in the gluteus medius length and volume.

Results: The pelvic support osteotomy achieved a functional and painless hip in all eleven patients. Five of the eleven patients had a persistently positive Trendelenburg gait at the time of the last follow-up visit, at an average of three years after the osteotomy. The muscle volumes were restored to 43% to 89% of the muscle volumes on the normal contralateral side, and the postoperative muscle volume correlated significantly with the result of the Trendelenburg test ($r = -0.63$; $p = 0.03$). There was a positive association between age and the result of the Trendelenburg test ($p = 0.01$): four of the five patients who had a positive test were at least thirty-one years of age at the time of the operation. There was no correlation between the Trendelenburg test and the change in the length of the gluteus medius muscle, which averaged 19.2 mm in the patients with a positive test and 19.3 mm in those with a negative test.

Conclusions: Patient age at the time of the operation and the postoperative change in the volume of the gluteus medius muscle have a significant influence on the result of the Trendelenburg test after a pelvic support osteotomy. Moreover, our study demonstrated that restoration of the muscle volume after a pelvic support osteotomy is not sufficient to prevent a Trendelenburg gait in older patients with congenital dislocation of the hip.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

A Trendelenburg gait develops when a congenital dislocation of the hip is neglected, causing an unstable fulcrum and reduced tension in the abductor muscles related to the high position of the greater trochanter[1]. Proximal femoral osteotomy, called *pelvic support osteotomy,* has been presented as a treatment alternative for elimination of the Trendelenburg gait and restoration of hip function in patients with congenital dislocation of the hip[2-6]. Although elimination of the Trendelenburg gait has been described by many authors, we are not aware of any published studies addressing the status of the hip abductor muscles after the operation. The purpose of this study was to measure alterations in the length and volume of the gluteus medius muscle with magnetic resonance imaging in patients treated with a pelvic support osteotomy and to determine factors that may have a significant influence on the results of the Trendelenburg test.

Materials and Methods

Between December 1996 and October 2001, eleven female patients with a history of Crowe type-IV[7] congenital dislocation of the hip were treated at our institution with simultaneous pelvic support osteotomy and distal femoral lengthening

TABLE I Demographics and Magnetic Resonance Imaging Data for Eleven Patients Treated with Pelvic Support Osteotomy

Case	Age *(yr)*	Interval Between Op. and Magnetic Resonance Imaging *(mo)*	Preop. Limb-Length Discrep. *(cm)*	Change in Gluteus Medius Length *(mm)*	Valgus Angulation *(deg)*	Trendelenburg Test	Muscle Recovery Time *(mo)*	Harris Hip Score *(points)*	
								Preop.	Postop.
1	26	30	5.5	21	52	–	14	52	98
2	19	41	5	19	42	–	11	40	92
3	21	30	4.5	18	61	–	16	48	96
4	22	32	3.8	28	50	–	13	73	95
5	13	64	5.6	16	37	–	12	46	83
6	14	49	4.8	14	45	–	9	54	91
7	36	36	4.5	22	44	+	No	58	93
8*	39	54	5.5	24	47	+	No	54	97
9	34	36	5.8	14	52	+	No	32	77
10	31	36	5.2	22	58	+	No	60	98
11	22	52	5.2	14	48	+	No	54	95

*This patient had a 3-cm limb-length discrepancy.

with a hybrid Ilizarov external fixator[6] (Table I). The primary indications for the procedure were severe pain caused by degenerative changes in the hip, limping with a positive Trendelenburg sign, and a unilateral hip dislocation. The secondary indications were back and knee pain resulting from a dislocated hip.

Clinical Evaluations

The Harris hip score, which represents pain, walking function, activities of daily living, and range of motion of the hip joint, was calculated preoperatively and at the time of the last follow-up. The Trendelenburg test, described by Hardcastle and Nade[8], was performed preoperatively and at the time of the last follow-up by two independent orthopaedic surgeons. The patient was asked to stand on the affected limb with the hip on the non-stance side flexed to about 30° and the knee flexed enough to allow the foot to be clear of the ground. A positive Trendelenburg test was recorded if the iliac crest was high on the affected side and low on the unaffected side. A delayed positive Trendelenburg test was recorded if the patient had an initially negative test, but, after standing on one leg for a short time, the pelvis gradually began to fall toward the unsupported side and the patient was not able to maintain the initial pelvic stability. All patients had a positive Trendelenburg test preoperatively. The postoperative recovery time needed to achieve a negative Trendelenburg test was recorded for each patient.

Magnetic Resonance Imaging

The patients were placed supine on the magnetic resonance imaging table. Imaging of the gluteus medius muscle was performed in the coronal plane with a 1.5-T magnet (Gyroscan Intera Master; Philips, Best, The Netherlands) and a Q body coil. The coronal T2-weighted sequence was performed with a repetition time of 3800 msec, an echo time of 100 msec, a field of view of 35 cm, a slice thickness of 5 mm, an interslice gap of 0 mm, a matrix of 400 × 512 pixels, and three acquisitions with a total imaging time of three minutes and forty-five seconds.

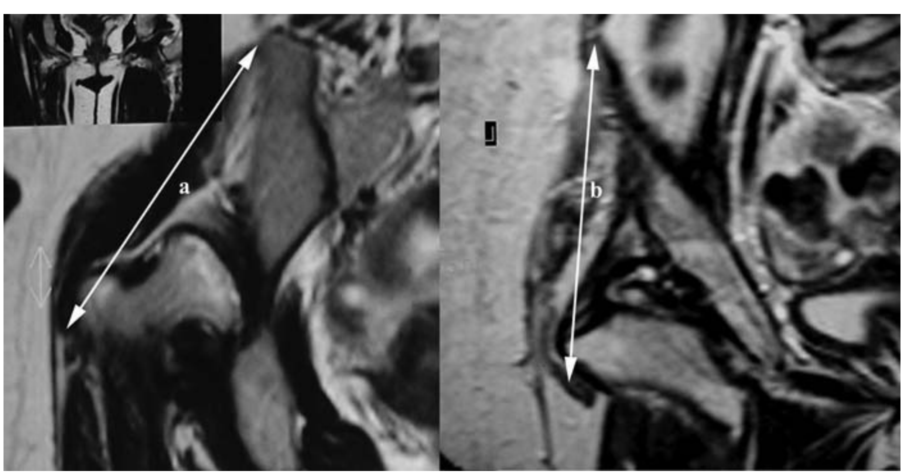

Fig. 1
A T2-weighted magnetic resonance image showing measurement of gluteus medius length from the origin to the insertion preoperatively (left) and postoperatively (right).

Fig. 2

A T2-weighted magnetic resonance image showing contours drawn around the gluteus medius muscles in a patient with a dislocated right hip.

The length of the gluteus medius muscle from its origin to its insertion was measured as a straight line preoperatively and postoperatively (Fig. 1), and the difference between the measurements was considered to be the change in the gluteus medius length.

The volume of the gluteus medius muscle was determined with three-dimensional image-processing on an independent workstation. The image data were transferred to the workstation, and an isotropic voxel size was then obtained by a trilinear interpolation routine. The volume of the muscle was isolated from the total volume by manually drawing contours around the muscle boundaries on a section-by-section basis (Fig. 2). All contouring was done independently by one radiologist and one orthopaedic surgeon. These data were then resampled by means of bilinear and cubic interpolation for the final three-dimensional rendering. The volume of the muscle was then determined by summing all of the pertinent voxels within the resultant binary volume.

Radiographic Evaluation

Limb-length discrepancy was measured with computerized tomography preoperatively and at the time of the last follow-up. Valgus angulation of the proximal part of the femur was measured on the anteroposterior supine radiographs of the pelvis at the time of the last follow-up (Fig. 3). The radiographic measurement was done by one of us.

Surgical Technique

The proximal osteotomy level and the valgus angle were determined on an anteroposterior radiograph of the pelvis with the involved limb held in maximum adduction.

After induction of general anesthesia, the patient was placed supine on a fracture-table. The arthritic femoral head was resected in all patients through an anterolateral incision with fluoroscopic guidance. With use of an image intensifier, a 5 or 6-mm pin was inserted laterally from the greater trochanter at a predetermined angle. A second pin was inserted 15 cm distally from the first pin and perpendicular to the distal part of the femoral shaft. An arch was attached to each pin, and one or two pins were added to each arch. The proximal osteotomy was performed between the two arches. Valgus angulation was achieved by bringing the arches parallel. For distal femoral fixation, a Kirschner wire-and-pin combination was used, and a distal femoral osteotomy was performed between the second pin and the distal femoral fixation to equalize limb-length discrepancies and to restore the mechanical axis of the lower extremity (Fig. 4).

Postoperative Management

Following a recovery period of seven to ten days postoperatively, gradual lengthening was started from the distal osteotomy site at a rate of 0.25 mm four times daily (total maximum daily lengthening of 1 mm per day) to eliminate any limb-length discrepancy. The mechanical axis was corrected at the end of the distraction period by making frontal plane adjustments at the distal osteotomy site.

There was no standardized rehabilitation program for the patients. However, passive knee motion was initiated on

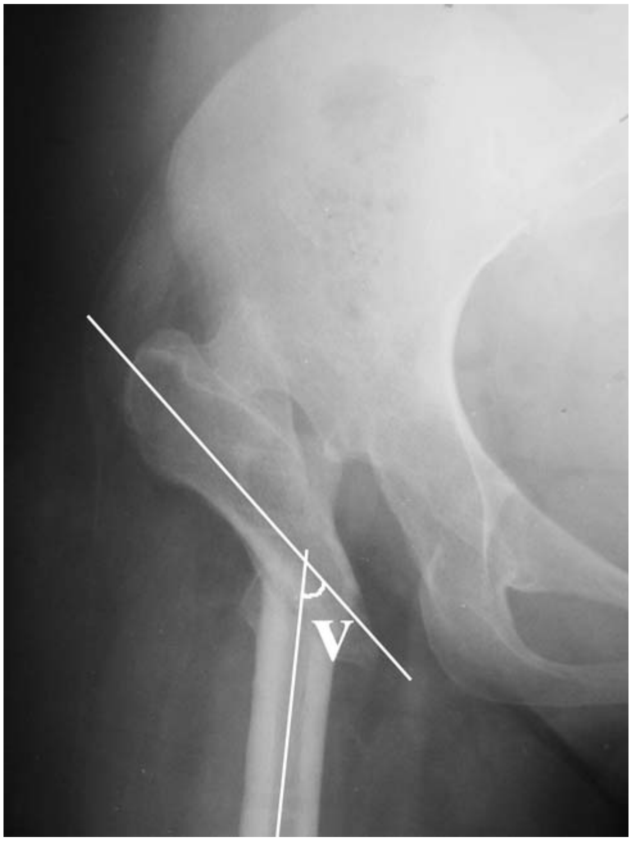

Fig. 3
Radiograph showing measurement of the valgus angulation of the proximal part of the femur (V).

the day following the surgery. On the third postoperative day, partial weight-bearing with crutches and active flexion-extension of the knee were started. Weight-bearing was increased gradually, as tolerated by the patients.

Isometric hip exercises were started on the third postoperative day, and the patient was encouraged to lie on the unaffected side to achieve maximum passive adduction of the affected hip to obtain bone contact between the pelvis and the adducted proximal part of the femur. Passive range-of-motion exercises of the hip in all directions within the limits of pain were initiated four weeks postoperatively. Active-assisted and active range-of-motion exercises to strengthen the hip abductor, extensor, and flexor muscles were commenced as tolerated by the patient. After removal of the fixator, intensive abductor muscle-strengthening exercises were initiated, guided by physical therapists, until a negative Trendelenburg test was achieved or for a maximum of six months. After six months, patients with a positive Trendelenburg test were usually responsible for their own physical therapy program at home.

Statistical Analysis

The preoperative and postoperative Harris hip scores and measurements of the length and volume of the gluteus medius muscle were analyzed with the Student t test with use of SPSS software (version 12.0; Chicago, Illinois). The Spearman correlation coefficient test was used to calculate the correlation between the Trendelenburg sign and proximal femoral valgus angulation, lengthening of the gluteus medius, change in the gluteus medius volume, and age; $p < 0.05$ was considered significant.

Results

The mean interval between the surgical procedure and the magnetic resonance imaging was forty-two months (range, thirty to sixty-four months). The mean follow-up time was three years (range, twenty-three to fifty-nine months) after removal of the fixator. The average age was 25.2 years (range, thirteen to thirty-nine years) at the time of the operation.

Clinical Results

The average preoperative and last follow-up Harris hip scores were 52 points (range, 32 to 73 points) and 92 points (range, 77 to 98 points), respectively ($p < 0.01$). All patients had a painless range of motion and function of the hip and knee by the last follow-up visit. Two patients (Cases 5 and 9) continued to experience recurring back pain with activity at the time of the last follow-up.

Of the eleven patients, three (Cases 7, 8, and 11) had a persistently positive Trendelenburg test and two (Cases 9 and 10) had a delayed positive Trendelenburg test at the time of the

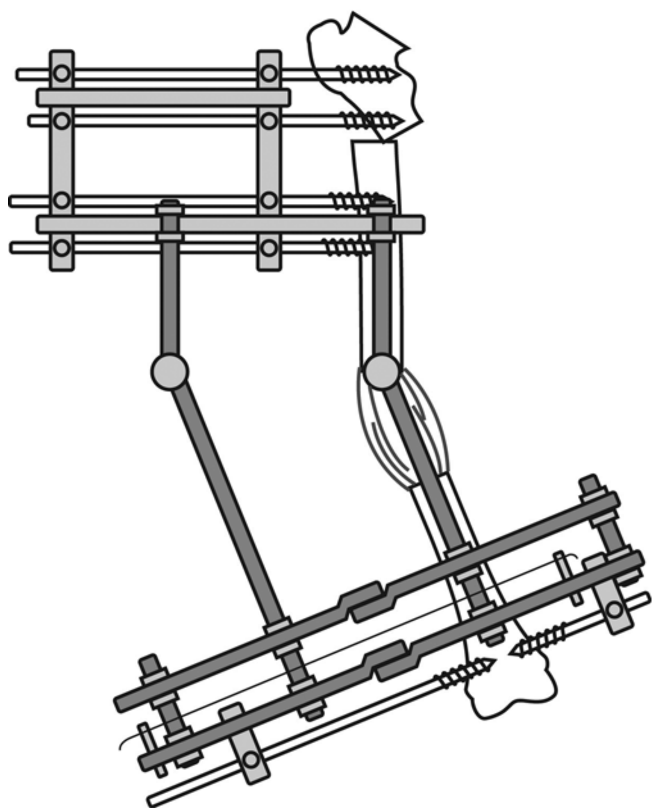

Fig. 4
Drawing showing application of the hybrid advanced Ilizarov fixator in association with the pelvic support osteotomy.

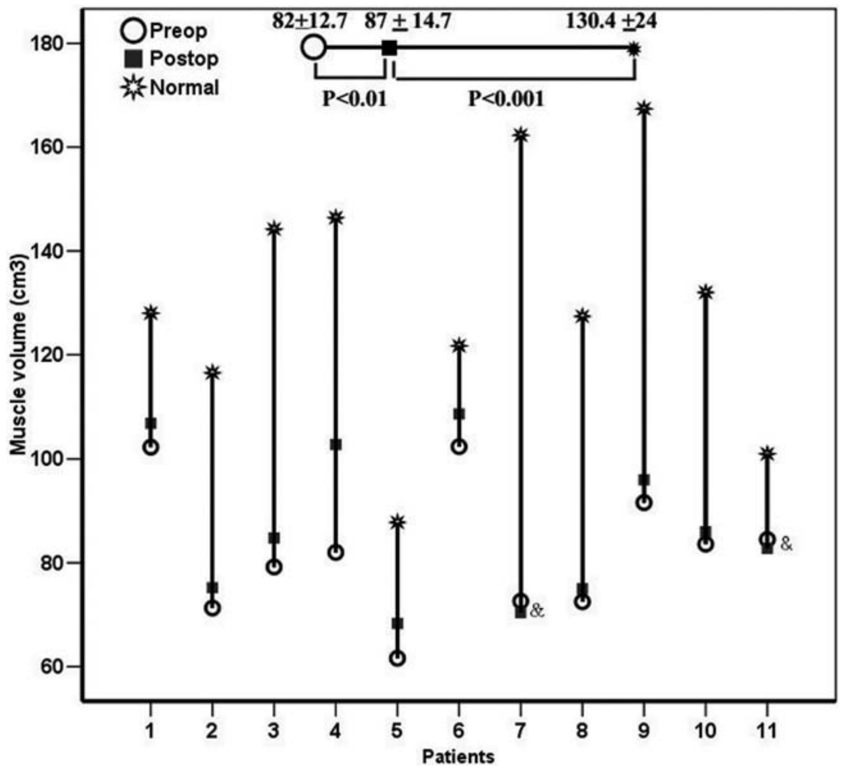

Fig. 5

Graph showing the changes in the gluteus medius volume, compared with the muscle volume on the contralateral side, before and after the pelvic support osteotomy. & = the patient had atrophy of the gluteus medius after the pelvic support osteotomy.

last follow-up. For the six patients with a negative Trendelenburg test, the average recovery time from the operation to the negative test was 12.5 months (range, nine to sixteen months). There was a significant association between the patient's age at the time of the operation and a positive Trendelenburg test at the time of final follow-up ($p = 0.01$): four of the five patients who had a positive test were at least thirty-one years old at the time of the operation. The average age was 32.4 years for the patients who had a positive Trendelenburg test and 19.2 years for those who had a negative Trendelenburg test.

Magnetic Resonance Imaging

There was a significant improvement in muscle length following the pelvic support osteotomy ($p < 0.001$). The average change in the gluteus medius length was 19.3 mm (range, 14 to 28 mm); however, with the numbers available, there was no association between the change in muscle length and the result of the Trendelenburg test ($p = 0.86$): the average change was 19.2 mm in those with a positive test and 19.3 mm in those with a negative test.

The muscle volume increased from a mean (and standard deviation) of 82 ± 12.7 cm^3 preoperatively to a mean of 87 ± 14.7 cm^3 at the time of the last follow-up ($p < 0.01$) (Fig. 5). There was a significant negative correlation between the change in muscle volume and the result of the Trendelenburg test ($r = -0.63$; $p = 0.03$), with an average increase in the gluteus medius volume of 10% (range, 4.9% to 25.6%) in the patients with a negative Trendelenburg test and 1% (range, –4.2% to 4.3%) in those with a positive test. In two patients (Cases 7 and 11) who had a positive Trendelenburg test, atrophy of the gluteus medius was seen on the magnetic resonance images acquired thirty-six and fifty-two months postoperatively.

The increased muscle volumes were still less than the volumes on the normal contralateral side ($p < 0.001$): the average muscle volume on the affected side was restored to only 66% (range, 43% to 89%) of that on the normal side. The volume was restored to 74% (range, 58% to 89%) of the normal volume in the patients who had a negative Trendelenburg test and to 61% (range, 43% to 82%) of the normal volume in the patients who had a positive test.

Radiographic Results

The average limb-length discrepancy (and standard deviation) was 5 ± 0.6 cm preoperatively. At the time of follow-up, only one patient had a persistent discrepancy, with 3 cm of shortening on the affected side secondary to loosening of the fixator clamp during the lengthening procedure.

The mean valgus angulation of the proximal part of the femur was 48.7° (range, 37° to 61°) at the time of the last follow-up. One thirteen-year-old patient (Case 5) had some loss of angular correction in the proximal part of the femur caused by bone-remodeling; however, it did not lead to a positive Trendelenburg gait. With the numbers available, there was no correlation between the valgus angulation of the proximal part of the femur and the result of the Trendelenburg test ($r = 0.14$; $p = 0.66$).

Discussion

This study demonstrates that pelvic support osteotomy is an effective method for restoring abductor muscle length and volume even if a Trendelenburg gait persists, as it did in five of our eleven patients. Critical factors influencing the resolution of a Trendelenburg gait include restoration of the volume of the gluteus medius muscle and a younger age at the time of the operation. In contrast, with the numbers available, we found no correlation between a positive Trendelenburg test and the change in the gluteus medius length or the valgus angle of the proximal part of the femur.

The high percentage of patients with a positive Trendelenburg sign in the present study is not consistent with the findings in previous reports. Manzotti et al.[9] reported that nine of eleven patients who had late sequelae of septic arthritis and were treated with a pelvic support osteotomy had improvement in lower-limb function with resolution of the Trendelenburg gait. However, the interval between the onset of symptoms and the operation, which might have affected the amount of muscular atrophy, was not recorded. Also, there were no patients with a high dislocated hip in the study by Manzotti et al., which may explain the high success rate in that series. In another study, Kocaoglu et al.[10] performed a pelvic support osteotomy in fourteen patients, eleven of whom had a congenital dislocation. All patients with a congenital dislocation had a negative Trendelenburg gait after the operation. The authors attributed the high success rate to increased tensioning of the abductor muscles, accomplished by moving the greater trochanter distally. In contrast, we found that the amount of distal transfer of the greater trochanter (as measured by increased gluteus medius length) alone was not adequate to prevent a Trendelenburg gait.

Age appears to be an important factor for retaining hip function after pelvic support osteotomy[11]. In the present study, four of the five patients who had a persistently positive Trendelenburg test were at least thirty-one years of age. On the basis of these results, we speculated that an atrophied muscle might not be restored by a pelvic support osteotomy in patients older than this age.

Restoration of the abductor muscle volume was closely correlated with elimination of a positive Trendelenburg test. Atrophy of the muscle can cause insufficiency of muscle contraction[11]. In the present study, atrophy of the gluteus medius occurred in two patients and resulted in a Trendelenburg gait. Even though the cause of muscle atrophy is unknown, it may explain why one twenty-two-year-old patient had a positive Trendelenburg test.

In addition to abductor weakness, an unstable fulcrum can be a causative factor in a Trendelenburg gait. The pelvic support osteotomy produces a stable fulcrum with the altered weight-bearing surfaces and diminishes the abductor torque required to achieve pelvic equilibrium by moving the fulcrum point medially[2,4,5]. However, our study showed that, despite the creation of a stable fulcrum in all patients, insufficient restoration of the gluteus medius led to a positive Trendelenburg test in five of them.

The disadvantage of the pelvic support osteotomy is limitation of hip motion, particularly adduction and flexion, because of the valgus and extension angulation of the proximal part of the femur[3,11]. This limitation is especially important in the sitting position because an individual can compensate for it only by tilting the pelvis in the standing position[11]. Our study did demonstrate that a pelvic support osteotomy can result in a painless and functional hip (a good or excellent Harris hip score) despite limitations of hip adduction and flexion.

Several authors have recommended a total hip arthroplasty with or without femoral shortening to achieve a painless hip and a negative Trendelenburg sign in patients with degenerative arthritis as a result of congenital dislocation[7,12-23]. Even though this procedure is commonly successful, complications such as peroneal nerve palsy, femoral nerve palsy, early postoperative dislocation, late infection, femoral shaft fracture, nonunion or delayed union of the femoral osteotomy site, and aseptic loosening have been reported in the literature[7,13,14,16,18,21-24]. Patients retain an active lifestyle following a pelvic support osteotomy, which may be converted to a total hip arthroplasty later in life. However, conversion of a pelvic support osteotomy has a high risk of intraoperative complications[15,16,25,26]. To our knowledge, there have been no studies comparing the outcomes and complication rates of total hip arthroplasty between dislocated hips with and without a previous pelvic support osteotomy.

A weakness of this study was that we investigated only the effect of gluteus medius geometry on abductor torque. Other hip abductor muscles may also generate important abductor torque that serves as a static stabilizer of the pelvis during unilateral stance[27,28]. However, magnetic resonance imaging measurements of the other muscles, especially on the affected site, were difficult technically.

In conclusion, pelvic support osteotomy achieved a functional, painless hip; however, five of eleven patients still had a positive Trendelenburg test. This study strongly suggests that restoration of abductor muscle volume after pelvic support osteotomy is not sufficient to prevent a Trendelenburg gait in older patients with congenital dislocation of the hip. ■

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References

1. Maquet P. [Importance of the position of the greater trochanter]. Acta Orthop Belg. 1990;56:307-22. French.

2. Milch H. The "pelvic support" osteotomy. 1941. Clin Orthop Relat Res. 1989; 249:4-11.

3. Milch H. The pelvifemoral angle of flexion and extension at the hip joint. Clin Orthop Relat Res. 1963;31:58-64.

4. Paley D, Herzenberg JE, editors. Principles of deformity correction. New York: Springer; 2002. Hip: pelvic support osteotomy joint considerations; p 689-94.

5. Ilizarov GA, Green SA, editors. The transosseous osteosynthesis: theoretical and clinical aspects of the regeneration and growth of tissue. New York: Springer; 1992. Treatment of disorders of the hip; p 668-96.

6. Catagni MA, Malzev V, Kirienko A. Treatment of hip disorders. In: Maiocchi AB, editor. Advances in Ilizarov apparatus assembly. 1st ed. Milan: Il Quadratino; 1994. p 119-22.

7. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am. 1979;61:15-23.

8. Hardcastle P, Nade S. The significance of the Trendelenburg test. J Bone Joint Surg Br. 1985;67:741-6.

9. Manzotti A, Rovetta L, Pullen C, Catagni MA. Treatment of the late sequelae of septic arthritis of the hip. Clin Orthop Relat Res. 2003;410:203-12.

10. Kocaoglu M, Eralp L, Sen C, Dincyurek H. The Ilizarov hip reconstruction osteotomy for hip dislocation: outcome after 4-7 years in 14 young patients. Acta Orthop Scand. 2002;73:432-8.

11. Milch H. The resection-angulation operation for hip-joint disabilities. J Bone Joint Surg Am. 1955;37:699-717.

12. Sanchez-Sotelo J, Berry DJ, Trousdale RT, Cabanela ME. Surgical treatment of developmental dysplasia of the hip in adults: II. Arthroplasty options. J Am Acad Orthop Surg. 2002;10:334-44.

13. Sener N, Tozun IR, Asik M. Femoral shortening and cementless arthroplasty in high congenital dislocation of the hip. J Arthroplasty. 2002;17:41-8.

14. Saglam N, Sener N, Beksac B, Tozun IR. [Total hip arthroplasty and problems encountered in patients with high-riding developmental dysplasia of the hip]. Acta Orthop Traumatol Turc. 2002;36:187-94. Turkish.

15. Paavilainen T, Hoikka V, Paavolainen P. Cementless total hip arthroplasty for congenitally dislocated or dysplastic hips. Technique for replacement with a straight femoral component. Clin Orthop Relat Res. 1993;297:71-81.

16. Masonis JL, Patel JV, Miu A, Bourne RB, McCalden R, Macdonald SJ, Rorabek CH. Subtrochanteric shortening and derotational osteotomy in primary total hip arthroplasty for patients with severe hip dysplasia: 5-year follo-up. J Arthroplasty. 2003;18(3 Suppl 1):68-73.

17. Havelin LI, Engesaeter LB, Espehaug B, Furnes O, Lie SA, Vollset SE. The Norwegian Arthroplasty Register: 11 years and 73,000 arthroplasties. Acta Orthop Scand. 2000;71:337-53.

18. Hartofilakidis G, Stamos K, Karachalios T. Treatment of high dislocation of the hip in adults with total hip arthroplasty. Operative technique and long-term clinical results. J Bone Joint Surg Am. 1998;80:510-7.

19. Hartofilakidis G, Karachalios T. Total hip arthroplasty for congenital hip disease. J Bone Joint Surg Am. 2004;86:242-50.

20. Haddad FS, Masri BA, Garbuz DS, Duncan CP. Primary total replacement of the dysplastic hip. Instr Course Lect. 2000;49:23-39.

21. Fredin H, Sanzen L, Sigurdsson B, Unander-Scharin L. Total hip arthroplasty in high congenital dislocation. 21 hips with a minimum five-year follow-up. J Bone Joint Surg Br. 1991;73:430-3.

22. Davlin LB, Amstutz HC, Tooke SM, Dorey FJ, Nasser S. Treatment of osteoarthrosis secondary to congenital dislocation of the hip. Primary cemented surface replacement compared with conventional total hip replacement. J Bone Joint Surg Am. 1990;72:1035-42.

23. Bruce WJ, Rizkallah SM, Kwon YM, Goldberg JA, Walsh WR. A new technique of subtrochanteric shortening in total hip arthroplasty: surgical technique and results of 9 cases. J Arthroplasty. 2000;15:617-26.

24. Chougle A, Hemmady MV, Hodgkinson JP. Severity of hip dysplasia and loosening of the socket in cemented total hip replacement. A long-term follow-up. J Bone Joint Surg Br. 2005;87:16-20.

25. Berry DJ. Total hip arthroplasty in patients with proximal femoral deformity. Clin Orthop Relat Res. 1999;369:262-72.

26. Papagelopoulos PJ, Trousdale RT, Lewallen DG. Total hip arthroplasty with femoral osteotomy for proximal femoral deformity. Clin Orthop Relat Res. 1996;332:151-62.

27. Vasudevan PN, Vaidyalingam KV, Nair PB. Can Trendelenburg's sign be positive if the hip is normal? J Bone Joint Surg Br. 1997;79:462-6.

28. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat. 1989;166: 179-89.