Pelvic support osteotomy

Gamal El-Adl[a] and Gamal A. Hosny[b]

[a]Orthopaedic Department, Mansoura University Hospital, Mansoura Faculty of Medicine, Mansoura and [b]Orthopaedic Department, Benha University Hospital, Benha Faculty of Medicine, Benha, Egypt

Correspondence to Gamal El-Adl, Orthopaedic Department, Mansoura University Hospital, Mansoura Faculty of Medicine, 35516 Mansoura, Egypt
Tel: +20 111 917 9559; fax: +20 50 66 99 555;
e-mail: egaeladl@yahoo.com

Received 15 May 2011
Accepted 15 March 2012

Egyptian Orthopedic Journal 2012, 47:246–252

Background
Pelvic support osteotomy can address all the complaints of painful and unstable hips in adolescents and young adults as it eliminates the Trendelenburg gait, equalizes limb-length discrepancy, and stabilizes the hemipelvis. The purpose of this study is to report the clinical and functional outcomes after pelvic support osteotomy used for treatment of painful and unstable hips in a group of patients.

Patients and methods
Forty-four patients (26 female and 18 male) with an average age of 17.2 years complaining of painful and unstable hips resulting from different etiologies and presenting with pain, limping, shortening, and limited range of hip motion were studied. At the end of the follow-up period, which was averaged at 8.2 years, all patients were evaluated for hip pain and limping, hip range motion, lumbar lordosis, limb-length measurement, ambulatory state and pain-free walking distance, the Harris hip score, and overall patient satisfaction.

Results
Hip pain, limping, hip range of motion, lumbar lordosis, ambulatory state, and pain-free walking distance showed improved in all patients. Limb-length equalization was achieved in 38 patients and within 2 cm in five patients with an average residual limb-length discrepancy of 0.8 cm. One patient had 3.5 cm residual shortening. The average amount of bone lengthening achieved was 5.1 cm. The mean radiology consolidation index for callus distraction was 1.4 month/cm, and the mean Ilizarov frame index was 1.7/cm. The Trendelenburg sign became negative in 37 patients and the Harris hip score increased from 48 preoperatively to 83 postoperatively. The following complications were reported: knee stiffness in extension (three); knee stiffness in flexion (one); fracture of the regenerate and loss of valgus correction (three each); and knee sublaxation and premature consolidation (one each).

Conclusion
Pelvic support osteotomy proved to a reliable treatment option among adolescents and young adults with unsuccessfully treated or untreated complex hip disorders presenting with painful unstable hip with shortening and functional ankylosis. A painless and functional hip can be achieved in most of the patients.

Keywords:
bone lengthening, Ilizarov hip reconstruction, painful unstable hip problems, pelvic support osteotomy

Egypt Orthop J 47:246–252

1110-1148

Introduction

Hip pain, instability, and limping resulting from unsuccessfully treated or neglected developmental dysplasia of the hip (DDH), septic arthritis of the hip, osteomyelities of the proximal femur, traumatic dislocation of the hip with instability, femoral neck pseudoarthrosis, Girdle stone resection arthroplasty, and paralytic hip dislocation present a challenge for treatment, especially in adolescents and young adults. The available options for surgical treatment are total hip replacement (THR), arthrodesis, and pelvic support osteotomy (PSO) [1–3].

The term 'pelvic support' is attributed to Lance (1936) [4] who references it to subtrochanteric osteotomy for the treatment of congenital dislocation of the hip. Since then, several modifications in surgical techniques have been described. The techniques by Lorenz [5], Schanz [6], and Ilizarov [7] are noteworthy.

A successful PSO reduces limping by abolishing the Trendelenburg lurch and equalizing limb length and, through the stability provided to the hemipelvis, facilitates a more energy-effective gait [1,3,8]. The aim of the treatment for unstable hips in young adults and adolescents is to reduce pain, improve hip range of motion, and equalize limb length. THR is now the first choice for treatment of this hip instability, especially with the current surgical techniques and prosthesis designs. However, many authors have reported specific technical difficulties such as irreducibility, overshortening, nerve palsy, and displaced femoral shaft fracture. Also THR for this unstable hips is subjected to high mechanical stresses with early component loosening and difficulty

to revise it [8–11]. Arthrodesis remains a good solution for these painful and unstable hips in these younger age groups but it has adverse effects on the lower back, contralateral hip, and knee [3,12–14].

PSO offers a significant improvement in posture, gait, and walking tolerance. The PSO is a useful definite surgical procedure for salvaging damaged hips of patients in whom performing THR or arthrodesis is not feasible. It is a procedure that can give a valuable mechanical and functional advantage for adolescents and young adults who have painful limping, limited hip range of motion, shortening, and independent walking ability [1,2,15–17].

The PSO is chosen as a definite surgical procedure for salvaging these damaged painful and unstable hips of patients included in this study in whom THR is technically difficult and expensive and arthrodesis is not accepted. A reviewing of the literature on PSO highlighted some aspects that were unclear, such as the need for detailed preoperative planning regarding the level or amount of correction at the proximal and distal osteotomy and whether or not to excise the femoral head. Other aspects needing further investigation were: whether to use the PSO for cases with paralytic hip dislocation; determining whether it is primarily indicated in painless unstable hips only; and the predictability of the outcome of PSO regarding the disappearance of the Trendelenburg gait and the appearance of degenerative arthritis [1–3,12,15–17].

The aim of this study was to report the author's personal experience in using the Ilizarov technique for PSO in the treatment of painful and unstable hips in adolescents and young adults with regard to clinical and functional outcomes.

Patients and methods

Between 1993 and 2007, 49 hips from 49 patients with painful and unstable hips regardless of the degree of dislocation or the size of the femoral head or the acetabulum with shortening more than 2.5 cm were treated with the Ilizarov technique for PSO. Five patients were excluded from the study because of incomplete follow-up data or less than 2 years' follow-up period. Patients with a history of recent active bone infection and nonambulatory patients with painful unstable hips resulting from chronic paralytic hip diseases were not included in this study.

The original primary pathologies behind unstable hips for the remaining 44 patients were related to untreated or unsuccessfully treated septic arthritis (13), DDH (11), paralytic dislocation (10), fractured neck of the femur (three), congenital short femur (three), premature mild hip arthritis (three), or tuberculous hip arthritis (one). Twenty-six patients were female and 18 were male with an average age of 17.2 years (range: 12–26); the left hip was affected in 30 patients.

The patients' complaints at the time of presentation were mainly hip pain with instability, shortening, and restricted range of hip motion. Thirty-nine patients needed a walking aid for outdoor ambulation. All patients were evaluated clinically before PSO for hip pain, limping, hip range of motion, lumbar lordoses, Trendelenburg sign, limb-length discrepancy (LLD), ambulatory state and pain-free walking distance, and the Harris hip score [18].

Preoperative planning

The preoperative radiological workup had included an anteroposterior (AP) view of the pelvis with the affected hip in maximum abduction and adduction and an AP view of both lower limbs with the patient standing (parallel beam scanogram). Intraoperatively, the site of the proximal valgus osteotomy was determined at the site of contact (abutment) between the proximal femur and the pelvis. In some patients, it was decided at the acetabular level and in others it was at the subacetabular level of the ischial tuberosity on the AP view of the pelvis, whereas the affected lower limb was in maximum adduction with the patient supine. No overcorrection angle was added to the valgus angle achieved at the proximal osteotomy. The limb segment distal to the proximal osteotomy level was kept in a way to be parallel to the contralateral healthy lower limb.

The amount of extension added to the valgus correction angle was equal to the amount of flexion contracture without any extra-added extension angle. The amount of rotation correction added to the proximal valgus extension osteotomy was equal to the amount of rotation in order to keep the patella parallel to the ground.

The level of the distal osteotomy was chosen just distal to the junctional area between the middle and lower third of the femur. The amount of varus at the distal osteotomy was determined intraoperatively so as to keep the mechanical axis of the lower limb in a straight line from the point of contact of the proximal femur segment to the pelvis down to the knee and the ankle joint without any intention to leave any valgus inclination of the ipsilateral knee.

The amount of lengthening at the distal osteotomy was determined preoperatively using a parallel beam scanogram or block test and estimated and closely observed postoperatively during the lengthening process by means of a regular parallel beam scanogram or a computed tomography scanogram, as well as by means of clinical evaluation using blocks. Extreme care was taken to avoid overlengthening as it will not be tolerated in these cases, especially with the hip in full adduction.

Surgical technique

The utilized surgical technique in this study had followed the Ilizarov hip reconstruction principles for PSO with some modifications as per the discretion of the senior author. The proximal valgus osteotomy was performed at the level of the acetabulum in nine patients and at the level of the ischial tuberosity in 35 patients. The hip joint was not opened and no proximal femoral stump or femoral head excision was performed in this study.

The frame was prepared intraoperatively. It consisted of two femoral arches to fix the proximal femur, one 5/8 ring for the middle segment and one complete and 5/8 rings for the distal segment.

After routine preparation, the proximal femoral segment was fully adducted and fixed with two or three Schanz pins 6 mm in diameter proximal and distal to the planned proximal osteotomy site over two arches. The proximal Schanz pins were inserted parallel to the horizontal axis of the pelvis and the pelvic arch was held inclined in the sagittal plan to a degree equal to the amount of the planned extension preoperatively. The arch as well as the Schanz pins should allow tridimensional correction (valgus, internal rotation, extension). The middle femoral segment was fixed by three Schanz pins inserted perpendicular to the mechanical axis of its ring. The distal femoral segment was fixed with one or two rings through three 1.8 mm pins inserted parallel to the knee joint.

The proximal osteotomy was performed between the femoral arches under image intensifier control to check its completeness and to ensure the proximal segment was locked into its proper position to support the hemipelvis. Finally, distal osteotomy was performed and checked for its completeness. Finally, the limb rotation, the mechanical axis, and the frame orientation were assessed intraoperatively (Figs 1–3).

Postoperative care

Regular daily pin site care was ensured by the patients and their families. After a latency period of 7–10 days according to the age of the patient, lengthening was started by distraction between the two distal rings at a rate of 1 mm/day. This rate of lengthening was modified according to the quality of the regenerate on regular radiological follow-up studies, which were conducted every 2 weeks for checking the orientation, consolidation at the proximal osteotomy, and the state of regenerate at the distal osteotomy. Further, any adjustment to the mechanical axis deviation was performed as required.

Early joint mobilization and weight-bearing ambulation were started during the first few days after the operation by the patients themselves. Once the limb-length equalization and bony consolidation at both osteotomy sites were achieved, the frame was removed without administering general anesthesia. No protection braces or casts were applied, except in cases with postoperative knee stiffness after manipulation or soft tissue release for 4–6 weeks.

Assessment

At the final follow-up visit clinical evaluation was performed for hip pain, limping, hip range of motion, lumbar lordosis, limb-length measurement, ambulatory state and pain-free walking distance, Trendelenburg sign, for the patient's overall degree of satisfaction, and for the Harris hip score [18]. All these data were compared with the preoperative ones.

The bone healing index and the Ilizarov frame index were reported.

All the collected data were analyzed using SPSS statistical package version 13 (SPSS Inc., Chicago, Illinois, USA). The Student *t*-test and the χ^2-test were used to compare preoperative and postoperative data. Significant *P*-value was set at 0.05.

Results

The mean follow-up period was 8.2 years (range: 2–12). The mean period for frame application was 6.5 months (range: 4–12). Hip pain, limping, hip flexion contracture, lumbar lordosis, hip flexion, hip abduction, LLD walking ability and pain-free walking distance significantly improved in all patients postoperatively. Limb-length equalization was achieved in 38 patients and within 2.5 cm in five patients with an average residual LLD of 0.8 cm. One patient was left with a shortened limb of 3.5 cm as a result of a fracture of the regenerate that occurred twice, which required frame extension for a longer period of time. The patient refused to go for another trial of limb lengthening after consolidation of the regenerate at the fractured osteotomy site. This patient preferred to use a shoes raise for walking.

The average amount of bone lengthening achieved was 5.1 cm (range: 3.5–12). The mean radiology consolidation index for callus distraction was 1.4 months/cm (range: 1–2.5). The mean Ilizarov frame index was 1.7/cm (range: 1.5–2.6). Walking ability and pain-free walking distance improved in all patients. Walking aids were not required for 39 patients who had been using it preoperatively and the average pain-free walking distance increased from 25 m (0–50) to 750 m (500–1500). This difference was statistically significant.

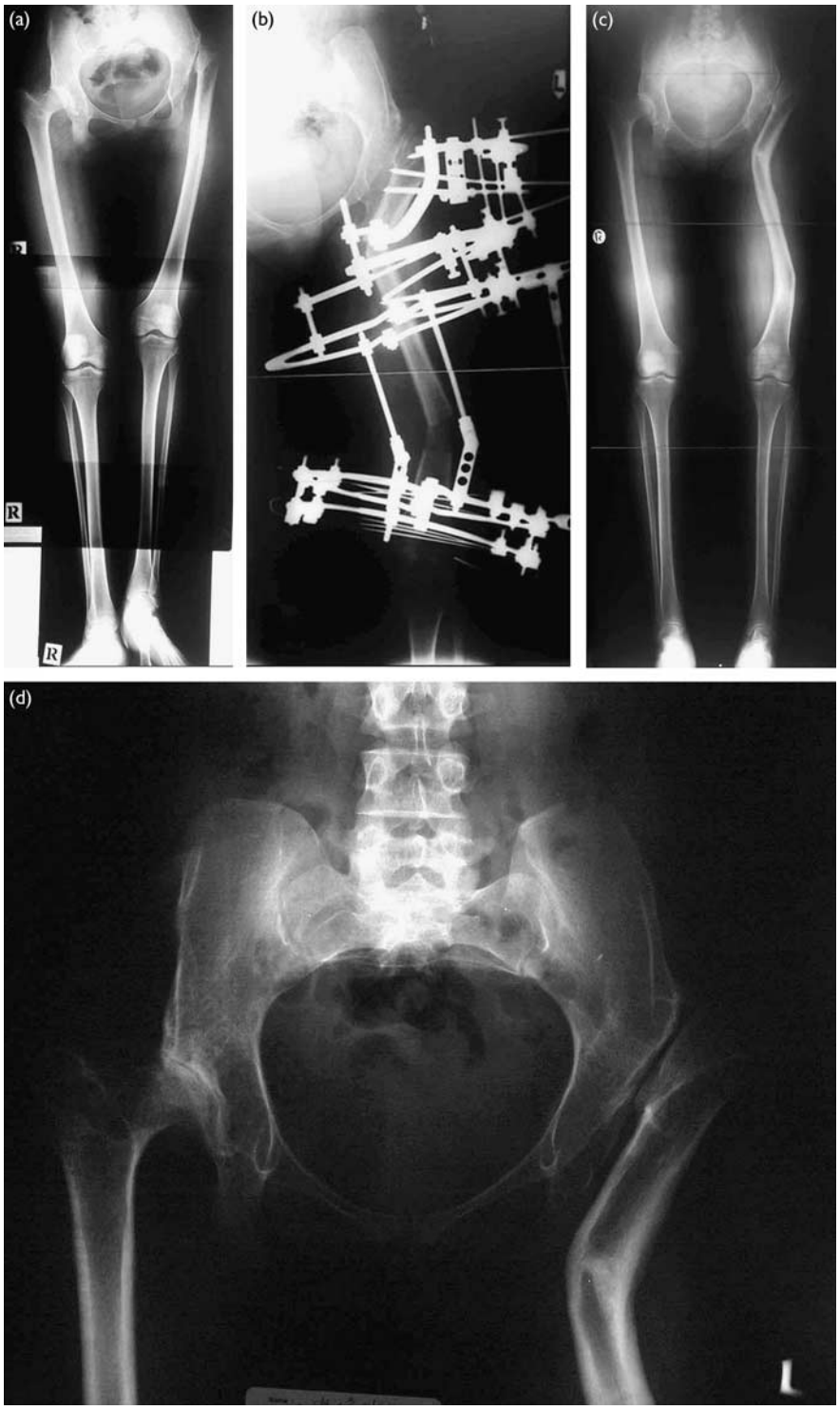
The Trendelenburg sign became negative in 37 patients, with a persistent lurching gait in seven patients. The patients with a persistent lurching gait were those who had paralytic hip dislocation (four patients), high DDH (two patients), and late sequelae of septic arthritis (one patient) as primary hip pathologies.

The final average postoperative hip flexion range of motion was 120° (range: 100–130°) in comparison with 80° (range: 70–110°) preoperatively. Also, the average postoperative hip abduction range of motion was 20° (range: 10–35°) in comparison with 8° (range: 0–10°) preoperatively. This difference was statistically significant for both directions of hip motion.

The average valgus angulation at the end of the follow-up period was 41° (range: 30–50°). The average extension angulation was 14° (range: 10–20°). The average varus angulation was 30° (range: 20–38°). Three patients, all of them being younger than 15 years of age, were reported to have progressive loss of their valgus correction during the follow-up period.

The mean Harris hip score [18] postoperatively was 83 (range: 70–90) in comparison with 48 (range: 35–65) preoperatively. This difference was statistically significant. The following complications were reported: pin-tract infection to some extent in 40 patients around the most proximal and distal femoral pins; knee stiffness in four patients (three in extension and one in flexion); fracture of the regenerate in three patients; and knee subluxation and premature consolidation in one patient each.

Figure 1

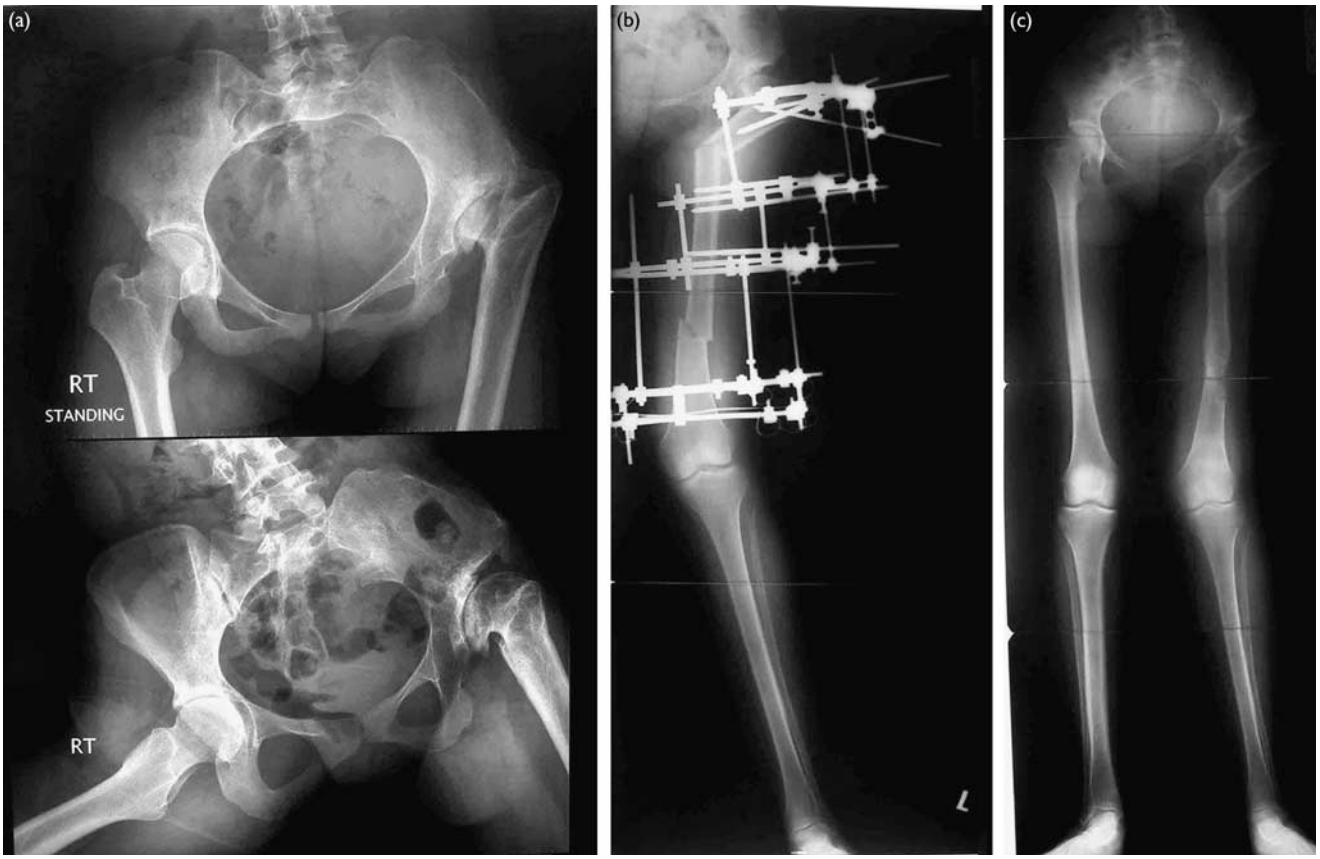


(a) Preoperative full-length anteroposterior (AP) view of the pelvis and both lower limbs showing late sequelae of septic arthritis of the left hip. (b) Postoperative 2.5-month follow-up AP view of the left hip and left femur and proximal tibia showing the Ilizarov frame for pelvic support osteotomy. (c) Final follow-up full-length AP view of the pelvis and both lower limbs showing full correction of limb-length discrepancy and the mechanical axis after full consolidation of the proximal and distal osteotomies and frame removal. (d) Final postoperative 15-year follow-up AP view of the pelvis showing absent degenerative changes in the left hip after pelvic support osteotomy, whereas it is evident in the contralateral side.

Discussion

PSO using the Ilizarov hip reconstruction technique proved to be a viable and effective treatment option for young adult and adolescent patients with chronic painful and unstable hips. The available options for treatment of these challenging chronic complex hip problems in these active younger age groups are arthroplasty, arthrodesis, and PSO [1–3,8]. A review of the literature on arthroplasty and arthrodesis as a treatment option for painful unstable

Figure 2



(a) Preoperative anteroposterior (AP) view of the pelvis and hip joints with the patient standing on the right leg (above), and full adduction in the supine position (below) showing neglected developmental dysplasia of the left hip. (b) Postoperative AP view of the left hip and left femur showing the Ilizarov frame for pelvic support osteotomy 1 week postoperatively. (c) Final follow-up full-length AP view of the pelvis and both lower limbs showing full correction of limb-length discrepancy and the mechanical axis after full consolidation of the proximal and distal osteotomies and frame removal.

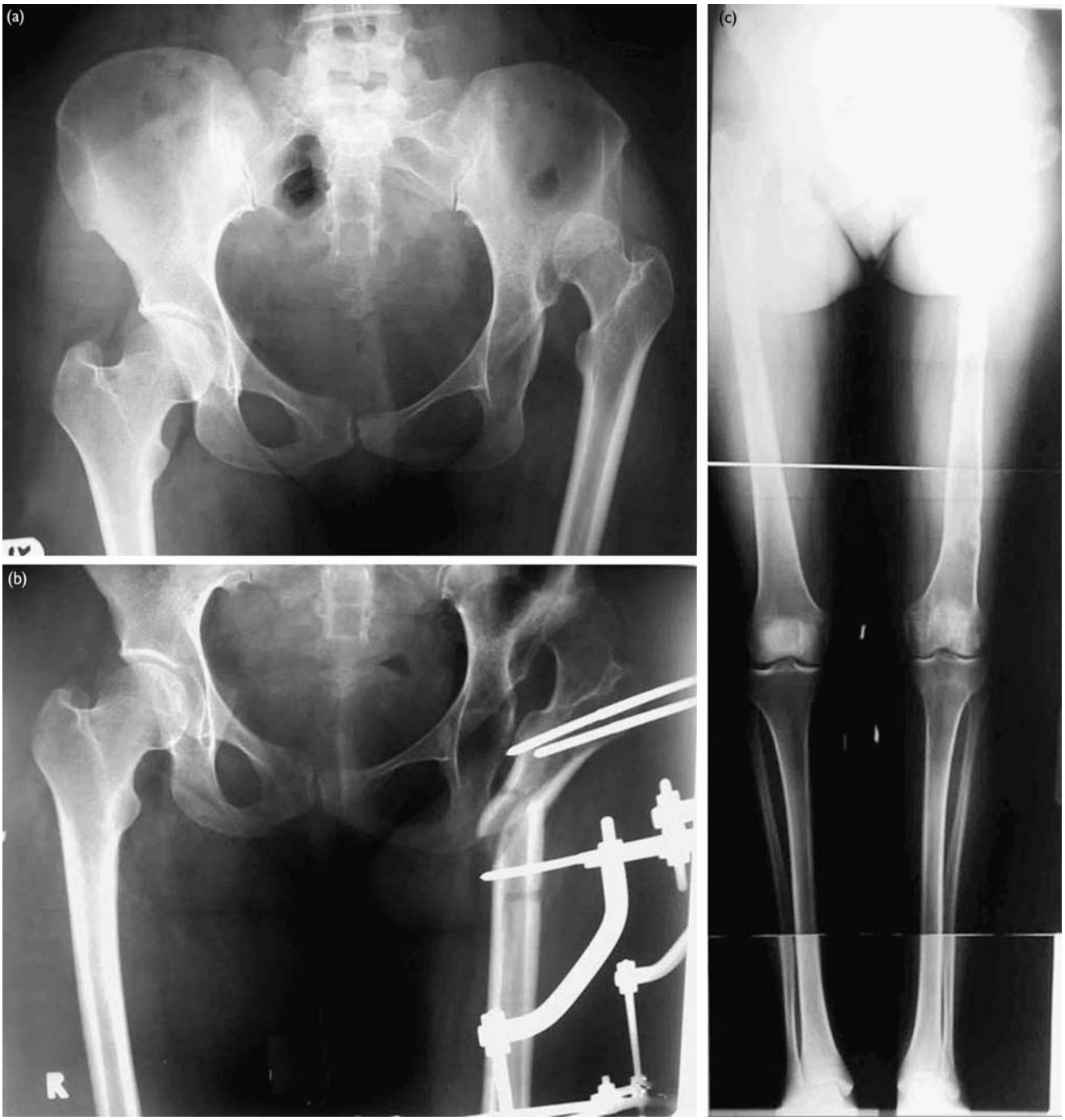
hips with shortening and restricted range of motion showed that many successes and failures have been reported on the functional outcomes [8–11,13,14]. PSO has many advantages as it addresses the whole dilemma of painful and unstable hips with the resulting shortening and functional ankylosis.

PSO can result in functional hip stability, functional hip mobility, better mechanical advantage for the abductor mechanism, limb-length equalization, realignment of the mechanical axis, and little or no risk of reactivation of previous bone and joint infection because of the absence of metal work inside [1–3,7,8,12,14,19–22]. PSO was considered a highly successful treatment modality in our female patients as they were very satisfied from the gained range of hip motion, especially the abduction, which allowed better personal hygienic care and better sexual life in addition to a better cosmetic appearance of the limbs. Moreover, no patient had complaints from limited hip flexion and adduction on either sitting or standing position as a result of valgus and extension angulations created at the proximal osteotomy.

Although PSO can address most of the possible etiologies of the Trendelenburg gait in these particular hip problems, the Trendelenburg gait may persist in some patients, with unclear explanation in the literature.

Inan *et al.* reported the changes in the volume and length of the gluteus medius before and after PSO and concluded that restoration of the muscle volume and length is not sufficient to prevent Trendelenburg gait in older patient with congenital dislocation of the hip [22]. Although this study did not explain why the Trendelenburg gait did not disappear, it was found that all patients with persistent Trendelenburg gait had long-standing higher hips resulting from paralytic hip dislocation, DDH, and late sequelae of septic arthritis. The results of this study are consistent with those of the study by Inan *et al.* in terms of their speculations that the long-standing muscle fibrosis and atrophy may be the possible explanation for persistent Trendelenburg sign, especially in a long-standing proximally migrated proximal femur in older aged patients [22]. All our patients with a persistent Trendelenburg gait had long-standing higher hips resulting from paralytic hip dislocation, DDH, and late sequelae of septic arthritis. We believe that including a gait analysis study before and after PSO may help to explain why the Trendelenburg gait did not disappear after PSO.

Figure 3



(a) Preoperative anteroposterior (AP) view of the pelvis and both hip joints showing neglected developmental dysplasia of the left hip. (b) Postoperative AP view of the pelvis and both hip joints and proximal femora showing the Ilizarov frame for pelvic support osteotomy 1 week postoperatively. (c) Final follow-up full-length AP view of the pelvis and both lower limbs showing full correction of limb-length discrepancy and the mechanical axis after full consolidation of the proximal and distal osteotomies and frame removal.

Our study did demonstrate clearly that PSO can result in painless and functional hips in most cases of painful and unstable hips, which was reflected by the higher Harris hip score [18] in most of our patients. To the best of our knowledge this study highlighted the efficacy of PSO in patients with painful unstable hips, as most of the previous studies had used it for painless unstable hips [1–7,15,19,21]. Complications that may result from PSO, such as pin-tract infection, the risk of premature consolidation and fracture of the regenerate, knee subluxation, knee stiffness, and poor patient compliance and cooperation, should not be ignored. Because of these possible complications the PSO should be considered a definitive treatment modality to salvage these complex hip problems in these young adults and adolescents who are not good candidates for arthroplasty or arthrodesis. Also, the possible issue of converting PSO to THR in the future in this younger age group is still a technically

demanding procedure, with some documented intraoperative complications, although no studies have been reported comparing the outcome and complication rates of THR between dislocated hips with and without PSO [9,10,24,25].

Three of our patients presented with early degenerative changes in their painful unstable hip, which was treated successfully with PSO without further deterioration of the degenerative changes at the proximal femoral stump; in fact it disappeared over the follow-up period (Fig. 1). To the best of our knowledge, nothing has been mentioned in the literature regarding the fate of the proximal femoral stump and the remaining hip joint if the femoral head was not resected, which was the implemented policy in this study regarding the incidence of degenerative hip arthritis in long-term follow-up. Milch [17] had reported some arthrosis in patients treated with angulation osteotomy and femoral head resection. None of the patients included in this study developed hip arthrosis or had required conversion to THR even after more than 8.2 years of follow-up on average (Fig. 1). This study agreed with those by Kocaoglu and colleagues and El-Mowafi in that a long-term follow-up study is needed to determine whether osteotomy can prevent degenerative changes at the pelvic support point.

This study support the conclusions drawn by many authors that PSO should be done after the age of 15 years as 3 of our patients below 15 years had lost some of their valgus correction with time due to remodeling [3,20,26,27]. El-Mowafi [20] reported no loss of valgus overcorrection angle in his series as the age of his patients was above 19 years.

The weakness of this study is that it is a retrospective study for many different primary hip pathologies. Also, the abductor muscles were not studied further either by MRI or by gait analysis. However, some aspects that may not be commensurate with the current approach for PSO – for example, performing PSO for cases with paralytic hip dislocation, the detailed preoperative planning for the proximal and distal osteotomy site and the amount of correction, and finally the resection of the proximal femoral stump or the femoral head – were highlighted in this study. Many aspects related to PSO, such as persistent Trendelenburg gait and future degenerative arthrosis, need to be studied further.

Conclusion

PSO proved to be effective and reliable as a treatment option for adolescents and young adults with unsuccessfully treated or untreated hip disorders who presented with painful unstable hip with shortening and functional ankylosis. In these particularly challenging hip disorders in this overactive age group, a functional painless hip can be achieved in most of the patients. Because of the longer treatment period with the frame and the possible complications thereof, proper patient and family counseling should be highlighted before treatment.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Pafilas D, Nayagam S. The pelvic support osteotomy: indications and preoperative planning. Strategies Trauma Limb Reconstr 2008; 3:83–92.

2 Catagni MA, Malzev V, Kirienko A. Treatment of disorders of the hip joint. In: Maiocchi AB, editor. *Advances in Ilizarov assembly*. Milan: Medi Surgical Video; 1998. pp. 119–122.

3 Kocaoglu M, Eralp L, Sen C, Dinçyürek H. The Ilizarov hip reconstruction osteotomy for hip dislocation: Outcome after 4–7 years in 14 young patients. Acta Orthop Scand 2002; 73:432–438.

4 Lance PM. *Osteotomies sous-trochanterience dans Le traitment des luxations congenitales inveterees de la hanche*. Paris: Massen & Cie; 1936.

5 Lorenz A. Ueber die Behandlung der irreponiblen ange borenen Hufflluxationen und der schenklehalsp-seudo arthrosen miltels Gabelung (Bifurkation des oberen Femurendes). Wien Klin Wchnschr 1919; 32:997.

6 Schanz A. Zur Behandlung der veralteten angebs ovenen Huftverrenkung Munch Med Wchnschr. 1922; 69:930–941.

7 Ilizarov GA, Samchukov ML. Reconstruction of the femur by the Ilizarov method in the treatment of arthrosis deformans of the hip joint. Ortop Travmatol Protez 1988;10–13.

8 Lai K-A, Lin C-J, Jou I-M, Su F-C. Gait analysis after total hip arthroplasty with leg-length equalization in women with unilateral congenital complete dislocation of the hip – comparison with untreated patients. J Orthop Res 2001; 19:1147–1152.

9 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.

10 Berry DJ. Total hip arthroplasty in patients with proximal femoral deformity. Clin Orthop Relat Res 1999; 369:262–272.

11 Dearborn JT, Harris WH. Acetabular revision after failed total hip arthroplasty in patients with congenital hip dislocation and dysplasia: results after a mean of 8.6 years. J Bone Joint Surg Am 2000; 82:1146–1153.

12 Choi IH, Shin YW, Chung CY, Cho TJ, Yoo WJ, Lee DY. Surgical treatment of the severe sequelae of infantile septic arthritis of the hip. Clin Orthop Relat Res 2005; 434:102–109.

13 Sponseller PD, McBeath AA, Perpich M. Hip arthrodesis in young patients. A long-term follow-up study. J Bone Joint SurgAm 1984; 66:853–859.

14 Callaghan JJ, Brand RA, Pedersen DR. Hip arthrodesis. A long-term follow-up. J Bone Joint Surg Am 1985; 67:1328–1335.

15 Aksoy MC, Musdal Y. Subtrochanteric valgus-extension osteotomy for neglected congenital dislocation of the hip in young adults. Acta Orthop Belg 2000; 66:181–186.

16 Ilizarov GA. *Transosseous osteosynthesis*. 1st ed. New York: Springer-Verlag; 1983. pp. 701–727.

17 Milch H. The 'pelvic support' osteotomy. Clin Orthop Relat Res 1989; 249: 4–11.

18 Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969; 51:737–755.

19 Schiltenwolf M, Carstens C, Bernd L, Lukoschek M. Late results after subtrochanteric angulation osteotomy in young patients. J Pediatr Orthop B 1996; 5:259–267.

20 El-Mowafi H. Outcome of pelvic support osteotomy with the Ilizarov method in the treatment of the unstable hip joint. Acta Orthop Belg 2005; 71:686–691.

21 Inan M, Bowen RJ. A pelvic support osteotomy and femoral lengthening with monolateral fixator. Clin Orthop Relat Res 2005; 440:192–198.

22 Inan M, Alkan A, Harma A, Ertem K. Evaluation of the gluteus medius muscle after a pelvic support osteotomy to treat congenital dislocation of the hip. J Bone Joint Surg Am 2005; 87:2246–2252.

23 Masonis JL, Patel JV, Miu A, Bourne RB, McCalden R, MacDonald SJ, Rorabeck CH. Subtrochanteric shortening and derotational osteotomy in primary total hip arthroplasty for patients with severe hip dysplasia: 5-Year follow-up. J Arthroplasty 2003; 18 **(Suppl 1):** 68–73.

24 Papagelopoulos PJ, Trousdale RT, Lewallen DG. Total hip arthroplasty with femoral osteotomy for proximal femoral deformity. Clin Orthop Relat Res 1996; 332:151–162.

25 Rozbruch SR, Paley D, Bhave A, Herzenberg JE. Ilizarov hip reconstruction for the late sequelae of infantile hip infection. J Bone Joint Surg Am 2005; 87:1007–1018.

26 Inan M, Bomar JD, Küçükkaya M, Harma A. A comparison between the use of a monolateral external fixator and the Ilizarov technique for pelvic support osteotomies. Acta Orthop Traumatol Turc 2004; 38:252–260.

27 Samchukov ML, Birch JG. Pelvic support femoral reconstruction using the method of Ilizarov: a case report. Bull Hosp Jt Dis 1992; 52:7–11.