Ilizarov Hip Reconstruction for the Late Sequelae of Infantile Hip Infection

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Ilizarov Hip Reconstruction for the Late Sequelae of Infantile Hip Infection

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Background: The late sequelae of infantile hip infection include absence of the femoral head and neck, proximal migration of the femur, lower-extremity length discrepancy, abnormal gait, and pain. The Ilizarov hip reconstruction includes an acute valgus and extension osteotomy at the proximal part of the femur combined with gradual distraction for realignment and lengthening at a second, more distal, femoral osteotomy. The purpose of this study was to determine whether this technique can successfully treat the sequelae of infantile hip infection.

Methods: We performed a retrospective review of a series of eight consecutive patients with a Type-IV or V hip deformity, according to the classification system of Hunka et al., after an infantile hip infection. The patients' mean age at surgery was 11.2 years. All hips were unstable, with a mean of 3.8 cm of proximal migration. A mean valgus angulation of 44° and a mean extension angulation of 19° were created with the proximal osteotomies. Distal femoral lengthening averaged 5.7 cm, and distal femoral varus angular correction averaged 10°. The mean time in the Ilizarov frame was 4.7 months. Outcomes were evaluated clinically and radiographically. The clinical evaluation included gait analysis and the use of a modified Harris hip score.

Results: At the time of follow-up, at a mean of five years, the mean lower-extremity length discrepancy had improved from 4.6 cm preoperatively to 0.7 cm. The mean modified Harris hip score had improved from 51 points to 73 points ($p = 0.007$). All extremities were well aligned, with a mean pelvic mechanical axis angle of 89°. The mean deviation of the mechanical axis was 2 mm in a lateral direction. The mean stance-time asymmetry improved from 16% to 5.4% ($p = 0.0037$), and the mean ground-reaction force (second peak) improved from 102% of body weight to 122% of body weight ($p = 0.0005$).

Conclusions: The Ilizarov hip reconstruction can successfully correct a Trendelenburg gait and simultaneously restore knee alignment and correct lower-extremity length discrepancy. When the procedure is performed on a young patient, remodeling of the proximal osteotomy site and development of lower-extremity length discrepancy should be expected and the procedure may need to be repeated.

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

The sequelae of infantile septic arthritis and osteomyelitis of the hip are diverse and can include premature closure of the triradiate cartilage, acetabular dysplasia, lower-extremity length discrepancy, premature or asymmetrical closure of the capital femoral physis, necrosis of the articular cartilage, osteonecrosis, pseudarthrosis of the femoral neck, and complete destruction of the femoral head and neck[1]. Children with late sequelae of neonatal hip infection often present with the clinical problems of pain, a Trendelenburg gait, lower-extremity length discrepancy, and hip instability, all related to absence of part or all of the femoral head and neck and proximal migration of the femur.

Reconstructive procedures for this difficult problem have not been satisfactory. Most authors have reported poor results with the current reconstructive procedures, including trochanteric arthroplasty, hip arthrodesis, pelvic osteotomy, and femoral osteotomy[1-5].

A proximal femoral subtrochanteric osteotomy (pelvic support osteotomy) also has been described. Support is achieved by means of a valgus osteotomy of the proximal part of the femur that places the superior end of the femur against the lateral aspect of the pelvis[6-10]. In addition, the valgus angulation improves hip biomechanics by increasing the mechanical efficiency of the abductor muscles[11]. This approach also has shortcomings, however. The optimal extent of angulation is difficult to achieve. If the angle is too small, the hip biomechanics will not be sufficiently improved; if it is too large, there will be excessive knee valgus, fixed pelvic obliquity, and impingement pain when the patient adducts the lower extremity to a neutral position. Also, lower-extremity length discrepancy is not addressed by the pelvic support osteotomy.

Ilizarov combined the pelvic support osteotomy with a second, separate distal femoral varus lengthening osteotomy (Figs. 1-A through 1-E)[12,13]. Furthermore, he emphasized the importance of not only valgus but also extension at the proximal osteotomy site. This procedure is called the Ilizarov hip reconstruction[11-13]. The purpose of the present study was to evaluate the results of this technique for the treatment of the sequelae of infantile hip infection.

Materials and Methods

A retrospective review of the cases of eight consecutive patients with late sequelae of infantile hip infection was conducted. The two senior authors (D.P. and J.E.H.) performed all of the procedures. Five of the eight patients returned for a physical examination and gait analysis for the purpose of this study. The others could not return because of travel and logistical issues. They were interviewed by telephone, and data on the range of motion of the hip were obtained from their local physicians or physical therapists, who had performed a physical examination. Standardized radiography and physical examination were performed for all patients, and hip scoring was also done for seven patients. The outcomes were evaluated on anteroposterior standing radiographs of both lower extremities and 91-cm anteroposterior and lateral radiographs of the femur. Clinical assessment included a history, physical examination, gait analysis, and the use of a modified Harris hip score[14].

Hips were classified according to the system described by Hunka et al.[15]. Type I indicates no or slight femoral head changes; Type IIa, deformity of the femoral head with an intact physis; Type IIb, deformity of the femoral head with premature physeal closure; Type III, pseudarthrosis of the femoral neck; Type IVa, complete destruction of the capital femoral epiphysis with a stable neck fragment; Type IVb, complete destruction of the capital femoral epiphysis with an unstable small neck fragment; and Type V, complete destruction of the head and neck to the intertrochanteric line with dislocation of the hip.

Preoperatively, an anteroposterior radiograph of the pelvis, an anteroposterior standing radiograph (teleoroentgenogram) of both lower extremities, a single-limb stance

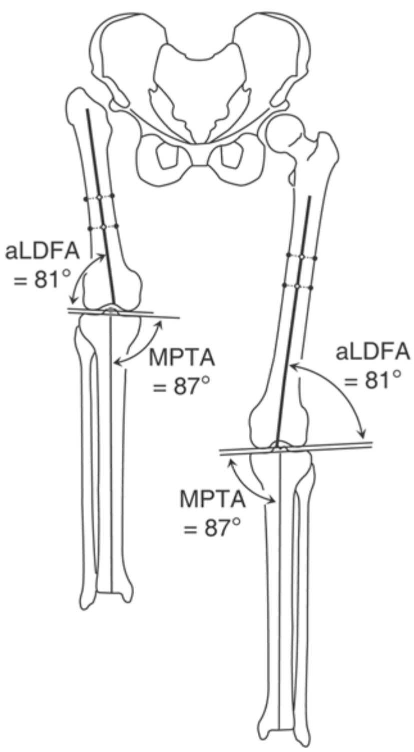

Fig. 1-A

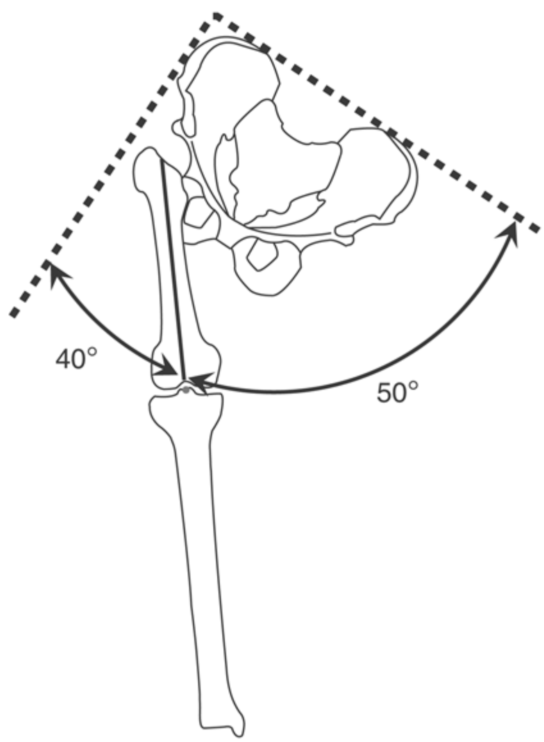

Fig. 1-B

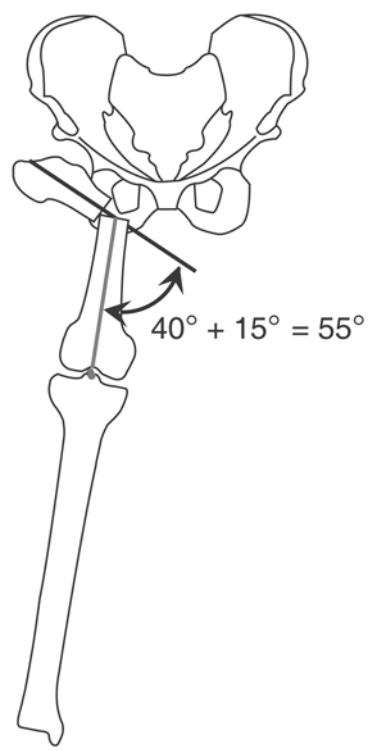

Fig. 1-C

Figs. 1-A through 1-E Schematic diagrams of the surgical planning. (Reprinted, with permission, from: Paley D. Principles of deformity correction. New York: Springer; 2002. p 689-90.) **Fig. 1-A** Schematic representation of a bipedal stance radiograph showing lower-extremity length discrepancy. A block is placed under the short lower extremity to make the horizontal line of the pelvis parallel to the floor. The lower-extremity length discrepancy is measured on this radiograph. **Fig. 1-B** Schematic representation of a single-limb-stance radiograph showing 40° of adduction and a Trendelenburg sign. The adduction of the femur relative to a horizontal pelvic line represents the pelvic drop associated with the Trendelenburg sign. **Fig. 1-C** Calculation of the desired angle of the proximal osteotomy. Fifteen degrees is added to the amount of adduction seen in Fig. 1-B.

anteroposterior radiograph of each lower extremity, an anteroposterior standing radiograph of the affected side, and a maximum-adduction cross-legged anteroposterior radiograph of the pelvis (made with the patient supine with the lower extremities adducted and the involved hip flexed and adducted over the top of the uninvolved hip) were made[16,17]. Proximal migration was calculated as the difference between the distance from a transverse line through the sacroiliac joints to the tip of the greater trochanter on both sides. Lower-extremity length discrepancy was calculated from the teleoroentgenogram. The pelvic mechanical axis angle comprised a horizontal pelvic line and a mechanical axis line that was extended proximally from the ankle joint center through the knee joint center.

Pain and functional outcomes were analyzed with use of a modified Harris hip score that includes only the subjective part of the original score. This modification also incorporates "shoe lift" (substituted for "cane") into the "support" category because of its clinical relevance to our patient group (see Appendix). The initial score was for patients with hip arthritis, but we found the remainder of the scoring system to be relevant. A score of 0 to 50 points indicates a poor result; 51 to 60 points, a fair result; 61 to 70 points, a good result; and 71 to 79 points, an excellent result.

Gait Analysis

Gait analysis was conducted with our previously described method[18]. Two strain-gauge force-platforms (AMTI; Advanced Medical Technologies, Watertown, Massachusetts) were arranged end to end in the frontal plane and were offset in the sagittal plane in the middle of a walkway that was 30 ft (9.1 m) long and 4.5 ft (1.4 m) wide. Data were gathered from the force-plates at a frequency of 1000 Hz. An analog-to-digital converter connected to an IBM-compatible computer was used to collect amplified force data, and the ground-reaction-force vectors were analyzed with use of AMTI software.

The variables measured were stance-time asymmetry and the second peak of the ground-reaction force. Both of these parameters have been shown to correspond well to limb-length differences of >2 cm in the absence of pain and muscle

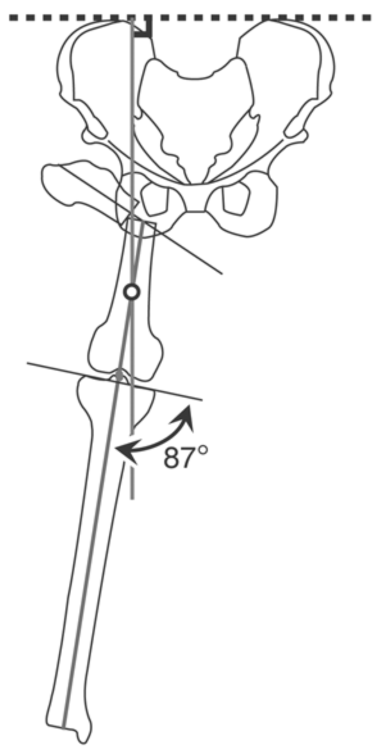

Fig. 1-D

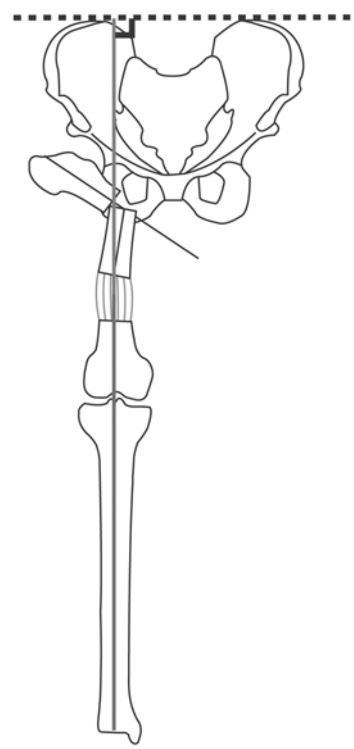

Fig. 1-E

Fig. 1-D Determination of the distal osteotomy level and the degree of varus correction required according to the intersection between the proximal and distal mechanical axis lines. The proximal mechanical axis is a line perpendicular to the horizontal line of the pelvis that passes through the proximal femoral osteotomy site. The distal mechanical axis line is a line from the center of the ankle that passes through the center of the knee. **Fig. 1-E** Schematic diagram of a radiograph made at the end of distraction, showing both the proximal and the distal osteotomy. Note the lengthening and the varus correction with the distal osteotomy to achieve equal lower-extremity lengths and a 90° pelvic mechanical axis.

weakness[18,19]. Stance-time asymmetry was expressed as the percentage of stance-time reduction on the short side as compared with the stance time on the long side. The second-peak ground-reaction-force vector was expressed as a percentage of body weight. Normalization of these parameters in our study signified successful equalization of the limb lengths, absence of pain, and adequate muscle strength for stabilization during walking. There is no stance-time asymmetry in a normal gait. Five of the eight patients underwent this gait analysis.

Surgical Planning

The Ilizarov hip reconstruction involves a proximal femoral osteotomy for valgus angulation and extension and a distal femoral osteotomy for lengthening and limb realignment. The level of the proximal femoral osteotomy is determined from the maximum-adduction anteroposterior cross-legged radiograph of the pelvis. For this view, the affected lower extremity and hip are maximally adducted over the normal side, a maneuver that requires some flexion of the affected side. The osteotomy is performed at the level at which the femoral shaft crosses the ischium. This osteotomy level is similar to the one proposed by Schanz, as reported by Hass[6]. The amount of valgus angulation to be achieved with the proximal osteotomy is determined by adding 15° to the femoropelvic adduction measured on the anteroposterior standing radiograph of the affected side rather than on the maximum-adduction anteroposterior radiograph of the pelvis (Figs. 1-A, 1-B, and 1-C). The overcorrection of 15° is based on experience and is used to compensate for fatigue of the abductor muscles. Extension at the proximal osteotomy site is equal to the amount of fixed flexion deformity of the hip. Finally, internal rotation at the osteotomy site is determined, at the time of surgery, as the amount of external rotation of the hip that occurs with maximum adduction of the hip. As the hip is maximally adducted, external rotation of the femur occurs. This amount of external rotation of the hip is corrected with internal rotation at the proximal femoral osteotomy site.

The goal of the distal femoral osteotomy is to lengthen and realign the lower extremity (Figs. 1-D and 1-E). A perpendicular line from a horizontal pelvic line that passes through the proximal osteotomy site should ultimately pass through the center of the knee and the center of the ankle. The distal femoral osteotomy is needed to achieve this. The level of the distal femoral osteotomy is determined on the basis of the amount of valgus angulation of the proximal femoral osteotomy. A paper tracing of the planned correction was performed. A line perpendicular to the top of the pelvis is drawn through the region of the apex of angulation of the proximal osteotomy and is extended distally (Fig. 1-D). A distal line is drawn from the center of the ankle through the center of the knee joint and is extended proximally. The intersection of these two lines is the level of the second center of rotation of angulation, which corresponds to the level of the hinges controlling varus at the distal osteotomy site. The level of the distal femoral osteotomy is either at this level or slightly more distal. In the latter situation, the distal part of the femur will translate medially with varus angulation. The magnitude of the varus alignment of the distal osteotomy is equal to the magnitude of the angulation measured between the intersecting distal and proximal axis lines on the preoperative drawing, as described above.

Surgical Technique

Preoperatively, an Ilizarov external fixation frame is constructed with two rings connected by a hinge at the anticipated level of the distal femoral osteotomy. The magnitude of varus angulation of the distal osteotomy is fixed in the hinges. A femoral arch is connected parallel to the proximal ends of the two rings, and the frame is sterilized before surgery.

The patient is positioned on a radiolucent operating table with sheets placed under the sacrum to maintain a level pelvis and to avoid any rotation. With use of an image intensifier, a 1.8-mm Ilizarov wire, and a surgical marking pen, a line is marked across the inferior edge of the two sacroiliac joints. This is called the *horizontal line of the pelvis*.

The involved extremity is then maximally adducted and is crossed over the contralateral extremity. The involved hip flexes and adducts over the uninvolved hip. This places the proximal part of the femur in an adducted and flexed position. In this position, the femur externally rotates because maximal adduction of the hip results in some flexion and external rotation. This is also a unique function of the pathological anatomy in this region. This rotation must be taken into consideration during pin placement.

The proximal part of the femur is now in the position that it will assume after the proximal osteotomy. This is the pelvic support position. The surgeon should observe that the proximal part of the femur cannot adduct farther. This is important to eliminate the Trendelenburg gait. The first proximal pin is then inserted. Because the proximal part of the femur is in its post-osteotomy position, it has moved relative to the overlying skin and subcutaneous tissues, such that a pin placed in this position will enter the skin over the underlying bone without tethering or displacing the skin after the osteotomy. A 6-mm threaded half-pin is inserted parallel to the horizontal line of the pelvis from the lateral side and parallel to the floor. The pin is connected to a free femoral arch. The arch is kept perpendicular to the floor with the extremity crossed, automatically imparting extension to the osteotomy. For more or less extension, the arch can be tilted in a posterior or anterior direction, respectively.

A second 6-mm threaded half-pin is then inserted anterolaterally into the proximal fragment, parallel to the same femoral arch. The femoral arch is then fixed to the proximal part of the femur at the correct angle. The extremity is then uncrossed and is placed parallel to the other extremity with the patella facing forward, or anteriorly. The skin at the proximal end of the thigh is now tented over the proximal two pins. This corrects after the proximal osteotomy.

In the supracondylar region of the distal part of the femur, a 1.8-mm Ilizarov wire is inserted parallel to the knee joint line. It is fixed and tensioned to the distal ring of the

Fig. 2-A

Fig. 2-B

Figs. 2-A through 2-K Images of a female patient with residual sequelae of a neonatal hip infection. She was born prematurely, after twenty-seven weeks of gestation, and the hip infection developed during the first week of life. (Figs. 2-F through 2-K reprinted, with permission, from: Paley D. Principles of deformity correction. New York: Springer; 2002. p 692-3.) **Fig. 2-A** Preoperative anteroposterior radiograph of the pelvis, made when the patient was nine years of age, showing a Hunka type-V hip. **Fig. 2-B** Standing anteroposterior radiograph of the lower extremities, made when the patient was nine years of age, showing 1.5 cm of proximal femoral migration and a 7.3-cm lower-extremity length discrepancy.

preconstructed frame. A 6-mm threaded half-pin is inserted from the posteromedial direction on the distal ring[17]. A second half-pin is inserted from the proximal ring on the lateral side. The proximal femoral osteotomy is then performed. Through a 1-cm lateral incision, multiple drill holes are made with a 4.8-mm drill bit at the planned osteotomy level. An osteotome is then used to complete the osteotomy. All procedures are performed under fluoroscopic guidance[20].

After the proximal femoral osteotomy is completed, the distal femoral fragment is rotated until the distal wire is parallel to the first half-pin that was inserted. The distal fragment is then displaced medially by manipulating the arches before connecting them. Finally, the extremity is abducted to make the distal arch parallel to the proximal arch. When the surgeon does this, the proximal arch is also flexed to effect the extension correction. Two threaded rods with a conical washer at each end are connected between the two arches. It is very important not to lose contact between the femoral segments during the medial translation. If contact is lost, the osteotomy site will be unstable. One more 6-mm threaded half-pin is inserted from a posterolateral direction into the distal segment, and another half-pin is inserted from the distal arch.

If there is any residual tenting of the skin by the proximal pins, a third small pin is inserted temporarily to allow removal and reinsertion of each of the proximal pins to eliminate skin tenting. The pin is removed, a new incision is made at the level of the pin, and the pin is reinserted in the previously drilled and tapped bone hole. This is preferable to creating the long deep scars that result from pin site releases.

The distal femoral osteotomy is then performed at the planned level in the same percutaneous manner as described above. Next, the distal femoral wire is removed. A third 6-mm threaded half-pin is added proximally and distally in larger children and in adults.

Rotatory instability of the knee is associated with this condition in some patients, who demonstrate a tendency for the knee to subluxate during lengthening. If this is recognized preoperatively, extension of the external fixation to the tibia with knee hinges should be considered. The knee hinges should be located at the intersection of the Blumensaat line and the posterior cortex of the femur[21]. Two tibial half-pins are connected to a single half-ring suspended from the hinges with threaded rods.

Statistical Analysis

Statistical analysis was conducted with use of the StatView package of programs (SAS Institute, Cary, North Carolina). The significance of the findings was evaluated with a paired t test for comparison of all paired variables, and regression analysis was conducted. A p value of <0.05 was considered significant.

Results

Clinical and radiographic data are summarized in the Appendix.

All patients had a Type-IV or V hip, according to the classification system of Hunka et al.[15]. There were two Type-IVa, two Type-IVb, and four Type-V deformities. The patients' mean age at surgery was 11.2 years (range, 7.8 to 14.2 years). All hips were unstable preoperatively, with a positive push-pull sign. Proximal migration was diagnosed and quantified with a physical examination, on the basis of a push-pull sign, and with observation of a limb-length discrepancy on standing radiographs made with blocks placed under the lower extremity. The standing anteroposterior radiographs of both lower extremities revealed that the mean proximal migration was 3.8 cm (range, 1 to 5.5 cm). The proximal osteotomy was performed at a mean of 7.2 cm (range, 5.5 to 9.2 cm) distal to the tip of the greater trochanter. The mean valgus angulation

Fig. 2-C

Fig. 2-D

Fig. 2-E

Fig. 2-C During femoral lengthening, pins were inserted into the pelvis to prevent proximal migration of the femur. A hinged articulation was created between the pelvis and the proximal part of the femur to allow hip flexion and extension while maintaining axial stability. **Fig. 2-D** Standing anteroposterior view radiograph obtained three years postoperatively, when the patient was twelve years of age, showing 4.6 cm of proximal migration of the proximal part of the femur and a 5.7-cm lower-extremity length discrepancy. This was the preoperative radiograph made before the Ilizarov hip reconstruction. **Fig. 2-E** Clinical photograph made during the early distraction phase after Ilizarov hip reconstruction. Note that the lower extremity has a valgus malalignment. The lengthening and the varus realignment had not yet occurred at the distal femoral osteotomy site.

created by the osteotomy was 44° (range, 16° to 70°), and the mean extension angulation created by the osteotomy was 19° (range, –5° to 30°). The mean varus angulation correction with the distal femoral osteotomy was 10° (range, 0° to 23°), and the mean lengthening was 5.7 cm (range, 4.4 to 7 cm). The mean time in the Ilizarov frame was 4.7 months (range, three to seven months). The mean duration of follow-up was five years (range, 1.9 to 9.8 years).

Knee flexion averaged 130° (range, 125° to 135°) preoperatively and 121° (range, 70° to 135°) at the time of follow-up. The decrease in knee flexion probably can be explained by tightening of the quadriceps muscle associated with the femoral lengthening. Hip flexion averaged 94° (range, 30° to 130°) preoperatively and 70° (range, 40° to 105°) at the time of follow-up. The mean hip flexion contracture decreased from 14° (range, 0° to 30°) preoperatively to 9° (range, 0° to 20°) at the time of follow-up. Internal rotation of the hip in extension increased from a mean of 10° (range, –20° to 30°) preoperatively to a mean of 25° (range, 10° to 35°) at the time of follow-up. External rotation of the hip in extension averaged 40° (range, 5° to 90°) preoperatively and 41° (range, 10° to 90°) at the time of follow-up. The mean hip abduction increased from 28° (range, 0° to 70°) preoperatively to 35° (range, 30° to 40°) at the time of follow-up, whereas hip adduction averaged 28° (range, 0° to 50°) preoperatively and 23° (range, 5° to 45°) at the time of follow-up. The decrease in hip flexion, increase in hip extension, and increase in hip abduction can be explained by the direction of the proximal femoral osteotomy.

The mean lower-extremity length discrepancy improved from 4.6 cm (range, 0.6 to 6.4 cm) preoperatively to 0.8 cm (range, 0 to 1.2 cm) at the time of follow-up. The mean modified Harris hip score improved from 51 points (range, 21 to 67 points) to 73 points (range, 64 to 79 points) ($p = 0.007$). All extremities were well aligned. At the time of follow-up, the mean pelvic mechanical axis was 89° (range, 84° to 94°) and the mean deviation of the mechanical axis was 2 mm in a lateral direction (range, 16 mm in a medial direction to 23 mm in a lateral direction). The pelvic drop associated with trunk lean (the Trendelenburg sign) was eliminated in six patients and reduced in two.

Fig. 2-F

Fig. 2-G

Fig. 2-H

Fig. 2-F Radiograph made after completion of the distraction, showing 55° of valgus at the proximal femoral osteotomy site and 7 cm of lengthening, with varus realignment at the distal femoral osteotomy site. **Fig. 2-G** Standing anteroposterior radiograph, made two years postoperatively, when the patient was fourteen years of age, showing normal alignment of the extremity with a 91° pelvic mechanical axis. **Fig. 2-H** Clinical photograph showing that no Trendelenburg sign is present during single-limb stance.

TABLE I Gait Analysis Data

Case	Stance-Time Asymmetry (*% Stance Time Reduced on Short Side Compared with Long Side*) Preoperative	Postoperative	Second-Peak Ground-Reaction-Force Vector* (*% Body Weight*) Preoperative	Postoperative
1	18	4	105	125
2	19	5	94	114
3	12	1	105	134
4	15	12	97	114
5	17	8	107	123
Mean	16	6	102	122
P Value	0.0037		0.0005	

*Normal is 112% to 131% of body weight.

Five patients underwent gait analysis both preoperatively and postoperatively, at a mean of 1.2 years (range, one to two years) after frame removal (Table I). The mean stance-time asymmetry (measured in milliseconds and shown as the percent difference compared with the contralateral side) improved from 16% to 5.4% (p = 0.0037). The mean ground-reaction force (second peak) improved from 102% to 122% of body weight (normal, 112% to 131% of body weight) (p = 0.0005). The parameters of stance-time asymmetry and second-peak ground-reaction-force vector were normalized

Fig. 2-I

Fig. 2-J

Fig. 2-K

Fig. 2-I Clinical photograph showing maximum hip flexion. **Fig. 2-J** Clinical photograph showing the range of internal rotation. **Fig. 2-K** Clinical photograph showing the range of external rotation.

TABLE II Complications

Case	Complication	Treatment
1	Superficial pin infection	Oral antibiotic
	Knee stiffness, flexion to 20°	Soft-tissue release
2	None	None
3	Premature consolidation	Repeat osteotomy
4	Premature consolidation	Repeat osteotomy
	Knee stiffness	Soft-tissue release
5	Superficial pin infection	Oral antibiotic
6	Proximal migration of femur	Increase of valgus at proximal osteotomy site
	Knee subluxation	Extension of frame across knee
7	None	None
8	Superficial pin infection	Oral antibiotic

following treatment, signifying that equalization of limb lengths, absence of pain, and adequate muscle strength for stabilization during walking had been achieved in our patients.

Two patients underwent a repeat Ilizarov hip reconstruction because the index procedure had been performed at a young age and, consequently, the lower-extremity length discrepancy had recurred with growth. One of these children had undergone the first Ilizarov hip reconstruction at 8.5 years of age and the discrepancy had decreased from 4.9 cm to 1 cm. At thirteen years of age, the proximal femoral osteotomy site had remodeled, the Trendelenburg gait had returned, and the lower-extremity length discrepancy had increased to 3.1 cm. As a result, the Ilizarov hip reconstruction was repeated. The second patient had undergone the initial surgery at 7.8 years of age, and the lower-extremity length discrepancy had decreased from 4.8 cm to 1.0 cm. At the age of fourteen years, the patient had 3.8 cm of length discrepancy and a Trendelenburg gait and the proximal osteotomy site had remodeled. The Ilizarov hip reconstruction was repeated. Both patients had an almost normal gait at skeletal maturity.

Three patients had undergone previous femoral lengthening without a proximal osteotomy (Figs. 2-A through 2-C). At the time of the previous femoral lengthening in each of those patients, a hinged hip-distraction external fixator was attached to the Ilizarov frame to prevent the femur from migrating proximally. Two pins were placed in the pelvis. This construct allowed hip flexion and extension while stabilizing the hip articulation. No other patients had undergone relevant surgery previously.

Nine complications occurred in six patients (Table II). Three patients had pin-track infections, which responded to oral antibiotics. Knee stiffness occurred in two patients, with flexion decreased to 20° in both, and was treated with surgical soft-tissue release. At the time of follow-up, both patients had regained a full range of flexion (130° and 135°). Premature consolidation occurred in two patients and was treated with repeat osteotomy. One patient had proximal migration of the femur, which was treated with a revision of the proximal femoral osteotomy with a greater degree of valgus angulation. Another patient had knee subluxation, which was treated with extension of the frame across the knee. No neurologic injuries or fractures were present after frame removal.

Discussion

As outlined by Hass[6], the proximal femoral subtrochanteric osteotomy (pelvic support osteotomy) as a treatment for instability of the hip has a long history in orthopaedic surgery. With early procedures, the resulting increased stability of the hip was due to actual support of the pelvis on the osteotomized proximal part of the femur. In this type of reconstruction, the hip joint is not directly approached. Milch[7-9] expanded the concept and popularized the pelvic support osteotomy in the United States during the mid-twentieth century. He advocated subtrochanteric valgus osteotomy to improve hip mechanics but cautioned against excessive valgus. Excessive valgus at the osteotomy site leads to abutment of the proximal part of the femur against the pelvis and even to pelvic tilt when the patient tries to bring the involved extremity into a neutral abduction-adduction position. This is not desirable because it limits adduction and results in pain. Thus, there were two competing goals. Although excessive subtrochanteric valgus improved hip stability, it also caused valgus malalignment of the knee and abutment of the proximal part of the femur against the pelvis as the patient attempted to bring the hip into neutral abduction-adduction. The compromise is less abduction than would be ideal to stabilize the hip and eliminate the Trendelenburg gait.

The optimal level for a pelvic support osteotomy has been controversial. Although some authors have recommended a proximal osteotomy with insertion of the lesser trochanter into the acetabulum, others have preferred a longer proximal segment[6]. We favor a more distal osteotomy, similar to that recommended by Schanz, as reported by Hass[6]. The specific area of weight-bearing is not absolute. Although it likely varies with the level of the osteotomy, the aim is to achieve a soft-tissue interpositional weight-bearing surface between the apex of the proximal femoral osteotomy and the pelvis. With a distal osteotomy, this weight-bearing probably occurs at the inferior aspect of the pelvis, near the ischial tuberosity.

Surgical reconstruction of the hip for the treatment of late sequelae of infantile and early childhood hip infection has generally not yielded satisfactory results, leading several authors to conclude that reconstruction should not be attempted[1-5]. One of these reconstructive options was a greater trochanteric arthroplasty[4], with the greater trochanter redirected into the acetabulum to substitute for the absent femoral head. The expectation was that the apophyseal cartilage would remodel to the shape of the acetabulum. However, the subsequent progressive subluxation that was encountered in most patients necessitated additional procedures, such as femoral osteotomy, pelvic osteotomy, and acetabuloplasty, to maintain coverage and containment[4]. Satisfactory results were unusual, even after multiple operations. Hip stiffness was common, and abductor insufficiency was typical.

Choi et al.[2] reported poor results after treatment of late sequelae of neonatal hip infection. They used a variety of procedures, including Pemberton osteotomy, trochanteric arthroplasty, arthrodesis, epiphysiodesis of the contralateral extremity, and lengthening of the ipsilateral tibia. Satisfactory results were achieved in only four of thirteen hips with a Choi type-4 deformity, which is comparable with the Hunka Type-IV and V deformities treated in our study.

Wopperer et al.[5] reviewed the results of nine hips in eight patients who had had infantile hip infection and had not undergone any reconstructive procedure on the hip joint. On the basis of their long-term observations of this group of patients, the authors concluded that, after hip joint infection, neither reconstructive efforts designed to relocate an inadequate femoral head to address persistent dislocation nor transfer of the greater trochanteric epiphysis into the acetabulum yielded results comparable with those of nonoperative treatment. They recommended only contralateral distal femoral epiphysiodesis in adolescence to minimize the lower-extremity length discrepancy; they did not recommend proximal tibial or fibular epiphysiodesis.

Fabry and Meire[3] reviewed the cases of seventeen patients with absence of the femoral head and neck from a group of twenty-nine children with sequelae of septic arthritis of the hip who were comparable with our group of patients. Eleven patients had undergone reconstructive surgery, including Salter osteotomy, greater trochanteric arthroplasty, femoral osteotomy, and Chiari osteotomy. Only two of the seventeen patients had a satisfactory result, and the authors concluded that late reconstructive surgery is difficult and unpredictable. They did not address the issue of lower-extremity length discrepancy.

Betz et al.[1] reported the results of a multicenter long-term follow-up study of thirty-two hips in twenty-eight patients who had had septic arthritis of the hip during infancy or childhood. They concluded that patients who had undergone hip reconstruction functioned more poorly than did those who had not. They advised against reconstructive surgery of the hip joint but did advocate femoral osteotomy to reposition the extremity into a more functional position; they also recommended treatment of the lower-extremity length discrepancy.

Cheng et al.[22] used a new technique involving placement of pedicled vascularized iliac crest graft to replace the destroyed femoral neck and head. They reviewed their experience with eight hips in seven children with Choi[2] type-4B sequelae of septic arthritis (equivalent to a Hunka Type-V deformity). Three of the eight hips had excellent substitution of the femoral head and neck. Lower-extremity length discrepancy was not addressed, and there were symptoms related to this discrepancy at the time of final follow-up. Cheng et al. speculated that this hip reconstruction would restore hip stability to a degree that would allow subsequent distraction lengthening to be performed without causing dislocation.

In other reports[22,23], Cheng et al. reviewed the results of femoral lengthening in four patients with a Choi[2] type-4B deformity due to septic arthritis of the hip. Three of them had previously undergone reconstruction with a pedicled vascularized iliac crest graft. A mean of 9 cm of lengthening was achieved, all hips remained stable, and there was no substantial loss of motion of the hip or knee.

Ilizarov hip reconstruction is a combination of the pelvic support osteotomy and a second, distal femoral osteotomy to correct lower-extremity length discrepancy and to realign the extremity. The proximal femoral osteotomy was designed to eliminate hip adduction. If the hip cannot adduct, the Trendelenburg sign and gait cannot occur because the pelvis cannot drop. Elimination of hip adduction requires overcorrection with the valgus osteotomy—by 15°, according to previous experience. This places the extremity in a fixed abduction position relative to the pelvis, and this was one of the problems with the previous pelvic support osteotomies as they led to problems with the knee joint. To address this problem, Ilizarov introduced a second femoral osteotomy, which was performed more distally, to realign the knee joint and to correct the lower-extremity length discrepancy[12,13]. It solved two of the problems that had not been previously addressed. Furthermore, Ilizarov emphasized extension of the proximal femoral osteotomy to correct the fixed flexion deformity of the hip and to permit locking of the hip joint. The biomechanics of the hip are substantially improved by these corrections. The valgus alignment of the proximal part of the femur positions the greater trochanter and the abductor muscle insertion laterally and distally. The lateralization increases the length of the abductor lever arm, while the distal shift tensions the previously redundant muscle. The valgus alignment also creates a fulcrum at the medial end of the pelvic support. The lower the level of the proximal osteotomy, the more medial the fulcrum. Medialization of the fulcrum decreases the abductor force needed to balance the weight of the body in single-limb stance. The net effect is a marked improvement in the function of the hip abductor mechanism. Extension of the osteotomy contributes to this by stabilizing the hip in the sagittal plane during single-limb stance. If any fixed flexion deformity is present, the pelvis unlocks itself from the "pelvic support" and the fulcrum is lost, destabilizing the hip and the abductor lever arm. Finally, equalization of the lower-extremity length discrepancy is also important to improve gait mechanics. With a lower-extremity length discrepancy and without use of a shoe lift, the pelvis is tilted. This alters the abductor lever arm and leaves room for adduction of the femur on the pelvis in single-limb stance. Therefore, without equalization of lower-extremity length, pelvic drop cannot be prevented.

A Trendelenburg gait is one of the hallmarks of this condition. Younger children often do not manifest a pelvic drop during gait because of their lighter weight and shorter stride length. As they become adolescents and their height, lower-extremity length, and weight increase, the pelvic drop becomes more apparent. With time, this is associated with increased pain and fatigue while walking, especially toward the end of the day. We found the Ilizarov hip reconstruction to be very effective in eliminating the Trendelenburg gait and sign in these patients. No other treatment method, except for arthrodesis, has been able to address this aspect of the problem successfully. In contrast to arthrodesis, the Ilizarov hip reconstruction preserves an acceptable, painless range of motion of the hip, at least early on. If the patient presents with a painful stiff hip, which was not typical in our series, arthrodesis may be a better option. Ilizarov hip reconstruction is best suited for a patient with an unstable hip that is mobile and associated with a lower-extremity length discrepancy and a Trendelenburg gait. Hip arthrodesis may be avoided in these patients, which is beneficial because that procedure has been associated with pathologic conditions of the ipsilateral knee, contralateral hip, and back[24].

Two patients in this study underwent the index procedure at a young age. Both had a proximal femoral osteotomy just distal to the level of the lesser trochanter (a high osteotomy). In both patients, the proximal femoral valgus osteotomy site completely remodeled, demonstrating no evidence of the pelvic support within one or two years after the operation. Three other patients had undergone lengthening without a pelvic support osteotomy at a similar young age (six to ten years old). In all three patients, a pelvic support osteotomy was subsequently combined with distal femoral lengthening when they were near skeletal maturity, without subsequent remodeling of the valgus alignment. On the basis of those results, it appears that pelvic support osteotomy is not ideal for young children. Although the procedure is not contraindicated in these young patients, one should expect to have to repeat the pelvic support osteotomy at or near skeletal maturity. Because the amount of lower-extremity length discrepancy requires two lengthenings, or one lengthening and an epiphysiodesis, the pelvic support osteotomy should be reserved for the second lengthening in most cases. The femur can be lengthened at a younger age with extension of the external fixation to the pelvis (Fig. 2-C). Extension of the external fixation to the tibia should also be considered if rotatory subluxation of the tibia is identified.

Ilizarov hip reconstruction is most suitable for skeletally mature adolescents and for young adults. Older adults may be best treated with total hip replacement. An Ilizarov hip reconstruction probably can be converted to a total hip replacement in later life if needed. Schiltenwolf et al.[10] reviewed the results of their long-term follow-up study of twenty-four patients who had undergone subtrochanteric valgus osteotomy without femoral head resection for the treatment of a painful congenitally dislocated hip. Pain relief and improvements in gait and in hip abduction and extension were maintained in most patients. Four of the patients underwent total hip replacement without difficulty. If necessary, the proximal femoral deformity can be straightened with an osteotomy and use of a long-stem prosthesis.

This study had limitations. The number of patients was small because of the rarity of this condition, and the follow-up was intermediate-term. Also, although the Harris hip score that was used to evaluate pain and function had been modified to fit this patient population, the modification has not been validated and it has limitations with regard to functional outcome assessment.

In conclusion, the Ilizarov hip reconstruction is a very good option for the treatment of the late sequelae of infantile hip infection in adolescents. It greatly reduces the lower-extremity length discrepancy resulting from this condition while preserving hip motion and improving hip biomechanics. Because all other alternatives for treatment yield relatively unsatisfactory and unpredictable results, Ilizarov hip reconstruction should be considered a promising choice for the management of late sequelae of infantile hip infection.

Appendix

eA Tables presenting the modified Harris hip score and the clinical and radiographic results for the individual patients are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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References

1. Betz RR, Cooperman DR, Wopperer JM, Sutherland RD, White JJ Jr, Schaaf HW, Aschliman MR, Choi IH, Bowen JR, Gillespie R. Late sequelae of septic arthritis of the hip in infancy and childhood. J Pediatr Orthop. 1990;10:365-72.

2. Choi IH, Pizzutillo PD, Bowen JR, Dragann R, Malhis T. Sequelae and reconstruction after septic arthritis of the hips in infants. J Bone Joint Surg Am. 1990;72:1150-65.

3. Fabry G, Meire E. Septic arthritis of the hip in children: poor results after late and inadequate treatment. J Pediatr Orthop. 1983;3:461-6.

4. Hallel T, Salvati EA. Septic arthritis of the hip in infancy: end result study. Clin Orthop. 1978;132:115-28.

5. Wopperer JM, White JJ, Gillespie R, Obletz BE. Long-term follow-up of infantile hip sepsis. J Pediatr Orthop. 1988;8:322-5.

6. Hass J. Congenital dislocation of the hip. Springfield, IL: Thomas; 1951. Palliative procedures; p 289-307.

7. Milch H. The pelvic support osteotomy. J Bone Joint Surg. 1941;23:581-95.

8. Milch H. The "pelvic support" osteotomy. Clin Orthop. 1989;249:4-11.

9. Milch H. Osteotomy of the long bones. Springfield, IL: Charles C. Thomas; 1947. p 163-80, 191-203, 223-34.

10. Schiltenwolf M, Carstens C, Bernd L, Lukoschek M. Late results after subtrochanteric angulation osteotomy in young patients. J Pediatr Orthop B. 1996;5:259-67.

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

12. Ilizarov GA. Transosseous osteosynthesis: theoretical and clinical aspects of regeneration and growth of tissue. Berlin: Springer; 1992. Hip dislocations; p 701-5.

13. 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;6:10-3. Russian.

14. 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;51:737-55.

15. Hunka L, Said SE, MacKenzie DA, Rogala EJ, Cruess RL. Classification and surgical management of the severe sequelae of septic hips in children. Clin Orthop. 1982;171:30-6.

16. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. Orthop Clin North Am. 1994;25:425-65.

17. Paley D. Principles of deformity correction. New York: Springer; 2002. p 689-94.

18. Bhave A, Paley D, Herzenberg JE. Improvement in gait parameters after lengthening for the treatment of limb-length discrepancy. J Bone Joint Surg Am. 1999;81:529-34.

19. Kaufman KR, Miller LS, Sutherland DH. Gait asymmetry in patients with limb-length inequality. J Pediatr Orthop. 1996;16:144-50.

20. Paley D, Tetsworth K. Percutaneous osteotomies. Osteotome and Gigli saw techniques. Orthop Clin North Am. 1991;22:613-24.

21. Hollister AM, Jatana S, Singh AK, Sullivan WW, Lupichuk AG. The axes of rotation of the knee. Clin Orthop. 1993;290:259-68.

22. Cheng JC, Aguilar J, Leung PC. Hip reconstruction for femoral head loss from septic arthritis in children. A preliminary report. Clin Orthop. 1995;314:214-24.

23. Cheng JC, Lam TP. Femoral lengthening after type IVB septic arthritis of the hip in children. J Pediatr Orthop. 1996;16:533-9.

24. Callaghan JJ, Brand RA, Pedersen DR. Hip arthrodesis. A long-term follow-up. J Bone Joint Surg Am. 1985;67:1328-35.