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Total Hip Arthroplasty in Patients With Multifactorial Perceived Limb Length Discrepancy

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ABSTRACT

Background: Patients with advanced hip arthritis can present with multifactorial limb length discrepancies (LLDs) owing to bony shortening from growth arrest, proximal hip migration, soft-tissue contractures, and pelvic obliquity. The patient perceives an LLD that is a combination of true LLD and apparent LLD.

Methods: We retrospectively reviewed 7 cases with multifactorial mean perceived LLD of 7.7 cm (range, 3.6-11 cm) that underwent primary total hip arthroplasty and auxiliary soft-tissue procedures. Perceived LLD, true LLD, and apparent LLD were defined and were compared before and after surgery in this cohort of patients with a mean follow-up of 57.4 months.

Results: The mean perceived LLD at final follow-up was 1.0 $\pm$ 0.9 cm compared with that of 7.7 $\pm$ 2.6 cm preoperatively ($P < .05$). Postoperative true LLD was 0.7 $\pm$ 0.8 cm compared with that of 3.2 $\pm$ 0.8 cm preoperatively ($P < .05$). At final follow-up, all 7 patients were ambulating without any assistive devices and were satisfied with their surgical outcome.

Conclusion: With careful preoperative clinical and radiographic assessments as well as planning for multifactorial perceived LLD, this can be adequately corrected with primary total hip arthroplasty and auxiliary soft-tissue procedures resulting in good radiologic and functional outcomes.

Limb length discrepancy (LLD) associated with hip arthritis can lead to disability including impaired gait, low back pain, pelvic obliquity, and the necessity to use shoe lifts for correction. According to Jasty et al [1], preoperative LLD of >2 cm presents social problems. Total hip arthroplasty (THA) remains the most commonly performed procedure for patients with hip osteoarthritis, and restoration of LLD is an important goal of any THA procedure as it affects functional outcome. If not addressed promptly, such a problem can in some cases lead to the need for surgical revision [2,3]. Although THA has the option to equalize leg lengths, this is not always attainable with large discrepancies.

LLD can be classified as true, apparent, and perceived LLD [4]. True LLD arises from actual shortening of the affected lower extremity bones from growth arrest or congenital etiology. In the case of true femoral shortening frequently encountered with hip deformities and arthritis, this could be at the level of the femoral head owing to wear of the articular cartilage interface of the hip joint, at the level of the femoral neck and intertrochanteric area, or at a subtrochanteric level which extends to the distal femur. Apparent LLD may be the result of scoliosis with pelvic obliquity [5], proximal hip migration in developmental dysplasia of the hip, and contractures of the hip, knee, ankle, or foot [4]. Perceived LLD is the clinical perception of shortening or lengthening that the patient experiences (perceives), and is usually reflected by the shoe lift the patient wears or the height of the block placed under the short extremity required to achieve comfort.

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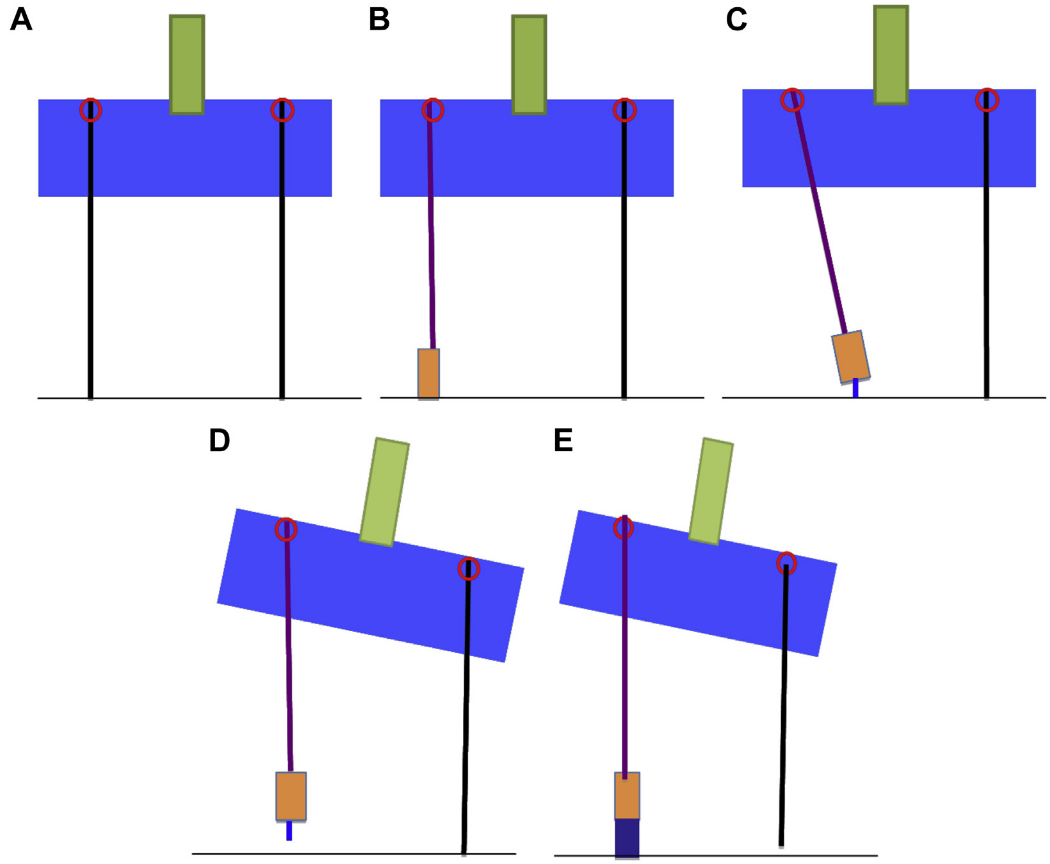

Fig. 1. Schematic diagram representing development of perceived limb length discrepancy (LLD) with pelvic obliquity because of adduction contracture of the hip. (A) Normal leveled pelvis with equal limb lengths. (B) A pelvis with true LLD (orange block) because of actual shortening of the bones of the right lower extremity. (C) Further development of adduction contracture of the right hip leads to schematic D. (D) Compensatory elevation of the hemipelvis on the right side to bring the extremity perpendicular to the ground to facilitate walking. (E) True LLD (orange block) and apparent LLD (blue block) contribute to the patient's perceived LLD (blue and orange blocks).

When there is fixed hip adduction (from contracture or ankylosis) with advanced arthritis, the ipsilateral pelvis is tilted proximally or hiked up. This causes the patient to perceive an LLD that is greater than what is true LLD (Fig. 1). This perceived LLD represents the overall contributions from true LLD and apparent LLD. Patients with advanced hip arthritis can present with multifactorial LLD owing to bony shortening from growth arrest, proximal hip migration, soft-tissue contractures, and pelvic obliquity [6].

Operatively, after THA and soft-tissue release, the hip is mobilized and the pelvis levels as it rotates through the new hip. This apparent lengthening comes from the correction of pelvic obliquity, and this does not actually lengthen or stretch the sciatic nerve. In cases where the hip is contracted and the pelvic obliquity is long standing, there can be fixed obliquity at the spinal-pelvic junction that does not allow full correction.

In assessing large perceived LLD with hip arthritis, it is essential to analyze all factors contributing to such perceived discrepancy and determining whether it is actually caused by a true difference in the lengths of the limbs (true LLD), an apparent discrepancy, or a combination of both. Careful clinical and radiologic assessment in the preoperative planning addresses all these components contributing to perceived LLD and is therefore crucial to obtain an optimal outcome with THA. Both true and perceived LLDs are quantifiable by measuring them on long, standing radiographs and clinical examination via block test. However, an apparent LLD at or below the level of the pelvis owing to soft-tissue contractures is only measured clinically and is sometimes difficult to assess. Apparent LLD and the contribution of soft-tissue contractures to limb length inequality can therefore be calculated by subtracting true LLD from perceived LLD.

The aim of this retrospective case series is to report on the radiologic, clinical, and functional LLD assessments before and outcome after primary THA in patients with multifactorial perceived LLD and hip arthritis. Assessment of the components of the LLD and preoperative surgical planning is outlined.

Materials and Methods

From 2006 to 2012, 7 patients with hip arthritis and concomitant multifactorial perceived LLD received primary THA. Patients were chosen consecutively after retrospective review on those treated with perceived LLD that was greater than actual LLD. All patients had hip adduction contractures with elevation of the ipsilateral hemipelvis. Preoperative perceived LLD mean was 7.7 ± 2.6 cm (range, 3.6-11 cm) with the affected arthritic limb being shorter than the contralateral normal hip. These patients included 5 males and 2 females; the mean age was 47.9 ± 15.8 years at the date of surgery. All patients were operated on by the senior author via a posterolateral hip approach for a primary THA and had a minimum follow-up period of 4 years. Patient demographics, including preoperative diagnosis and implant details are provided in Table 1.

Clinical assessment of perceived LLD was performed on the initial assessment of each patient preoperatively and postoperatively. The patient was asked to stand in an upright position in the examination room without any assistive devices, and wooden blocks of various sizes were put under the short lower extremity

Table 1
Patient Demographics.

Patient	Age, y	Gender	Preoperative Pathology	Pelvic Obliquity	Femoral Component	Acetabular Component
1	34	M	Neonatal septic arthritis	Fixed	S-Rom: ceramic head	Pinnacle Cup: polyethylene liner
2	55	M	Proximal femur bone cyst at 12 y	Fixed	Summit: ceramic head	Pinnacle Cup: polyethylene liner
3	71	M	Proximal femur osteomyelitis at 10 y	Fixed	Synergy Stem: metal head	Synergy Cup: polyethylene liner
4	26	F	Slipped capital femoral epiphysis with avascular necrosis	Flexible	Ceramic summit	Duroloc ceramic
5	62	M	Hip dislocation at 16 y	Fixed	Ceramic summit	Duroloc ceramic
6	41	M	Slipped capital femoral epiphysis with avascular necrosis	Fixed	S-Rom: ceramic head	Pinnacle Cup: polyethylene liner
7	26	F	Legg-Calve-Perthes Disease	Fixed	Ceramic summit	Pinnacle Cup: polyethylene liner

F, female; M, male.

until the patient was comfortable and felt equal even though the pelvis was now hiked up. The height of the block(s) was then measured and recorded (Fig. 2).

For radiologic assessment of true LLD, we obtained digital anteroposterior (AP) radiographs of the pelvis, lateral radiographs of the hip, as well as 51-inch standing AP radiographs of the pelvis and both lower extremities (long leg and hip-to-ankle films) before and after THA at 3, 12, and 24 months (Fig. 3). Long-leg digital radiographs were taken in a standing position with the patient's feet shoulder width apart and the knee joints extended and patellae facing forward. All radiographs were imported to an electronic patient archiving and communication system and corrected for magnification error by software calibration of a metal sphere (25 mm diameter) placed on all films [7]. We measured true pelvic LLD as the distance from the interischial (bi-ischial) [8] line to the bilateral tips of the lesser trochanter and to the centers of bilateral femoral heads on the AP radiographs of the pelvis. In addition, we measured true-whole LLD on the long-leg AP radiographs from the interischial line to the ankle joint. The length of the whole femoral segment from the center of the femoral head to the center of the intercondylar notch was also measured to identify supra-trochanteric from infratrochanteric LLD. Two observers, including the senior author and a joint arthroplasty fellowship-trained fellow, performed the analyses separately. Each observer performed the analysis twice on 2 separate occasions. The images were presented in the same order given to the patients on the excel sheet. Radiologic parameters were measured twice independently by each observer.

Apparent LLD was thus deducted by subtracting values of true LLD from perceived LLD. This was confirmed by careful clinical

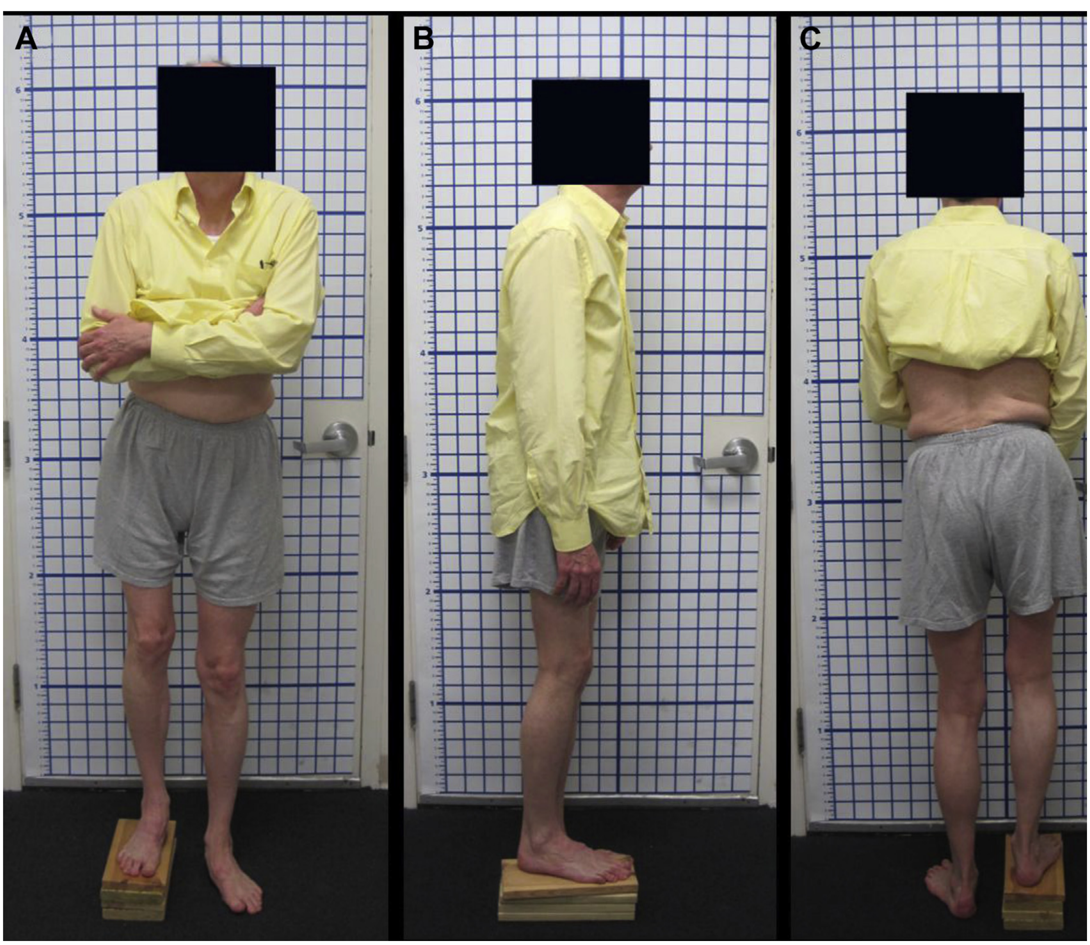

Fig. 2. (A-C) Patient 2: preoperative clinical photographs of the (A) front, (B) side, and (C) back view of the patient showing a massive perceived LLD, with the patient feeling comfortable with a 10-cm block under the right lower extremity. Notice the elevated right hemipelvis.

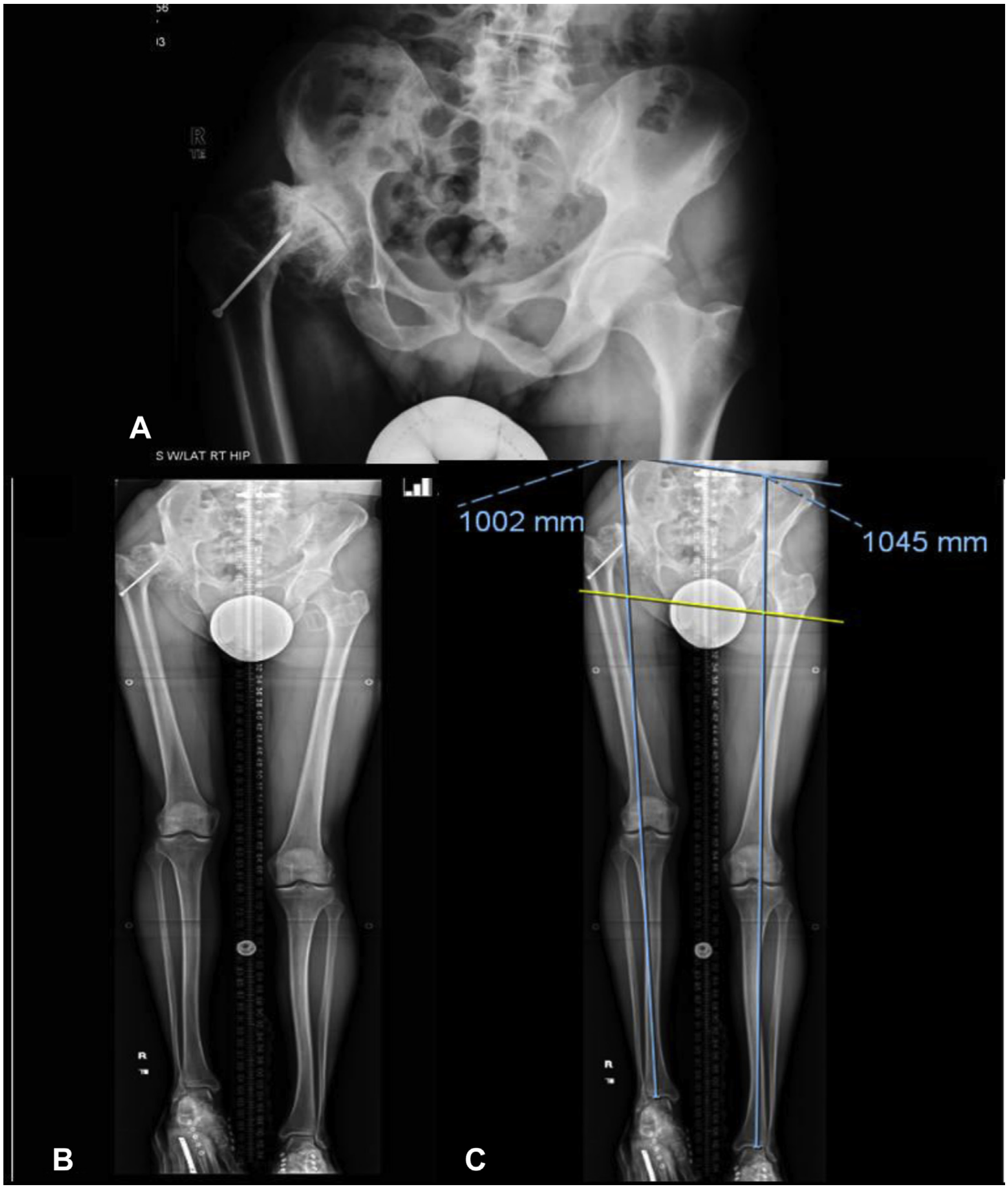

Fig. 3. (A-C) Patient 2: preoperative. (A) Anteroposterior (AP) view of the pelvis demonstrating a deformed femoral head and end-stage arthrosis. (B, C) Long standing radiographs of the hip to ankle demonstrate a true LLD of 4.3 cm because of bony deformity (shortening and varus of the femoral neck and the large mushroom-shaped femoral head), as well as flexion contracture of the hip. The apparent LLD of $10 - 4.3 = 5.7$ cm was from pelvic obliquity because of adduction contracture of the hip. With adduction contracture, the hemipelvis is elevated causing shortening of the leg. True LLD = 4.3 cm, perceived LLD = 10 cm, and apparent LLD = 5.7 cm.

examination for hip flexion contracture using the Thomas test and hip adduction contracture by abducting the shorter limb to level the pelvis of the patient in the supine position while steadying the pelvis with the contralateral hand of the examiner.

Once it was determined that apparent LLD was due to both flexion and adduction hip contractures, a combination of soft-tissue releases were used for each procedure. The techniques used in all 7 patients were performed using a posterior approach with an in situ neck cut, adductor tenotomy, psoas, anterior capsule, rectus femoris, and tensor fascia releases. Lowering of the hip center with placement of the acetabular cup was performed in 3 of 7 patients with a mean of 1.8 ± 0.2 cm.

During and after placement of the THA prosthetic trials, assessment of range of motion of the hip dictated the sequential release of periarticular soft tissues. If hip extension was impeded, flexion contractures were managed by releasing the anterior hip capsule, followed by recessing the iliopsoas tendon insertion onto the lesser trochanter, followed by the anterior part of the tensor fascia and rectus femoris if necessary. Likewise, if hip abduction was restricted, adduction contracture was managed by percutaneous adductor tenotomy at the end of the THA procedure. Bone lengthening surgery using distraction osteogenesis was not performed on any of these patients.

In addition to the radiographic outcomes, we conducted a basic functional questionnaire postoperatively by asking each patient (1) whether he/she was satisfied with the outcome of the surgery and (2) if there was any malfunctioning owing to perception of a residual LLD.

For statistical analysis, the Student *t* test was performed on different sets of preoperative and postoperative radiographic data

Fig. 4. (A, B) Patient 2: postoperative clinical photographs of the (A) front and the (B) back view of the patient showing an almost complete correction of the perceived LLD. The patient was able to reduce the height of his shoe lift from 35 mm at 2 weeks postoperatively to 17 mm at 1 year postoperatively because of gradual stretching and rehabilitation of the released flexors and adductors of the right hip. He had improved functional outcome and was satisfied with his surgery.

using commercially available software (SPSS Inc, Chicago, IL). Owing to the study's small sample size, statistical significance was calculated working backward from an alpha error of 0.05 and a sample size of 7, with resulting P values of <.0001. In addition, the results were tested with the nonparametric Wilcoxon signed rank test, which also showed a significant difference at an alpha level of 0.05.

This retrospective study was conducted with the approval of the institutional review board of the institution of the senior author.

Results

The mean preoperative perceived LLD was 7.7 $\pm$ 2.6 cm and true LLD measured 3.2 $\pm$ 0.8 cm. The mean postoperative perceived LLD was 1.0 $\pm$ 0.9 cm and true LLD at 0.7 $\pm$ 0.8 cm (Fig. 4). There were no postoperative complications in the 24-month follow-up and no sciatic nerve injuries (Table 2).

At final follow-up, all 7 patients reported satisfaction with the outcome of their surgery. Four patients did not use a shoe lift, and 3 patients used a 1- to 2-cm shoe lift at final follow-up. All patients were ambulating without any assistive walking aids and reported no malfunctioning owing to perception of a residual LLD (Fig. 5) or obtained almost complete correction (Fig. 6).

Discussion

Patients with hip arthritis in the setting of multifactorial perceived LLD present a challenging problem. Many factors can contribute to LLD pathology including pelvic obliquity, scoliosis, soft-tissue (adduction and flexion) contractures, proximal migration of the hip center, and shortening of the femur from growth arrest. Correcting LLD associated with hip arthritis through THA is

Table 2
Preop and Postop Radiographic Results.

Patient	Apparent Preop LLD, cm	True Preop LLD, cm	Perceived Preop LLD, cm	Shoe Lift (Preop/postop), cm	Apparent Postop LLD, cm	True Postop LLD, cm	Perceived Postop LLD, cm
1	5.1	2.9	8	7.5/1.0	1.2	0	1.2
2	5.7	4.3	10	12/1.9	0	1.9	1.9
3	7.6	3.4	11	9/2	0.4	1.6	2
4	3.9	2.4	6.3	6/0	0	0	0
5	5.7	3.1	8.8	8.8/2.0	1	1	2
6	1.5	2.1	3.6	3.6/0	0	0	0
7	2	4	6	8/0	0	0.3	0.3
Mean ± SD	4.5 ± 2.2	3.2 ± 0.8	7.7 ± 2.6		0.4 ± 0.5	0.7 ± 0.8	1.0 ± 0.9

LLD, limb length discrepancy; postop, postoperative; preop, preoperative; SD, standard deviation.

of utmost importance. Both bony and soft-tissue pathology must be addressed to obtain an overall correction of the normal length alignment and length.

In our study, 7 patients underwent successful primary THA in the presence of preoperative multifactorial massive perceived LLD mainly because of a larger contribution from soft-tissue hip contractures resulting in accentuation of the apparent component of the LLD. This was scrutinized via thorough clinical examination to detect contractures around the involved hip joint as well as calculation from the difference in measurements between perceived and true LLD values.

The aforementioned correction methods with THA resulted in large preoperative to postoperative gains in length from correction of flexible pelvic obliquity. It is worth mentioning that longer intervals between disease onset and THA tended to have incomplete resolution of LLD secondary to fixed obliquity partially from degenerative scoliosis lumbosacral spine changes.

The large apparent acute increase in leg length did not result in sciatic nerve injury since only modest increase in true leg length was performed. The rest of the correction was that of apparent LLD from pelvic obliquity, adduction contracture, and flexion contracture, which did not stretch the sciatic nerve.

In the hip arthroplasty literature, opinions vary widely on the amount of discrepancy that is clinically acceptable as an outcome of THA. It, therefore, remains relatively uncertain what is acceptable as the gold standard because of differences in interpretation in terms of patients' perceived LLD vs objective and radiographic LLDs, as well as development of complications, including alterations in gait kinematics [9]. Some reports have shown that a range of 0.7-1.5 cm of LLD does not cause significant trouble to patients [10–12]. However, other studies have shown that a discrepancy >1-2 cm is responsible for perception of LLD [13], gait abnormalities [9,14] and pelvic obliquity, as well as increased risk of aseptic loosening and implant failure [15].

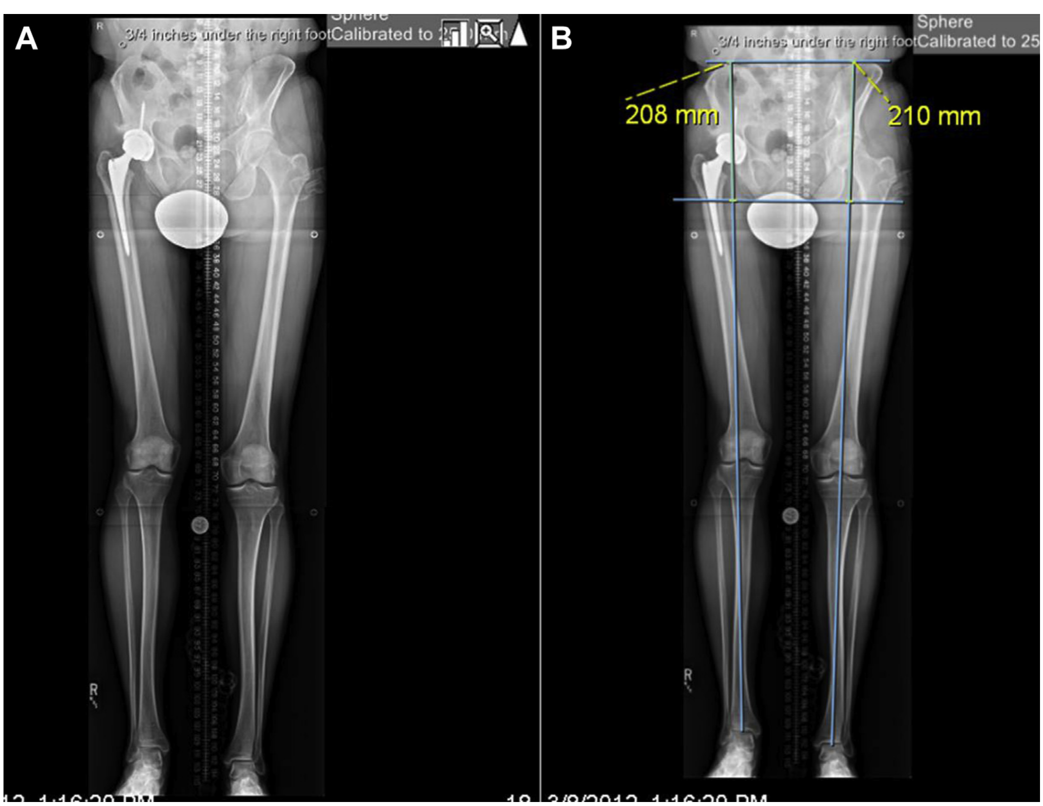

Fig. 5. (A, B) Patient 2: postoperative 51-inch, long, standing radiographs of the hip to ankle demonstrate a perceived LLD of 17 mm at 1 year after total hip arthroplasty. The patient felt comfortable with a ¾-inch (17 mm) shoe lift under the right lower extremity that leveled his pelvis on the long, standing radiograph. Residual LLD seemed to be from spinal-pelvic deformity.

Fig. 6. Patient 4: Preoperative and postoperative AP pelvis and long standing radiographs of the hip to ankle demonstrate right hip bony deformity because of slipped capital femoral epiphysis with avascular necrosis as well as flexion-adduction contracture of the hip. Postoperatively, the patient was corrected to true/apparent/perceived LLD of 0 cm from a true LLD = 2.4 cm, perceived LLD = 6.3 cm, and apparent LLD = 3.9 cm.

Although it is generally safe in the adult reconstruction to lengthen the lower extremity with a THA up to 2-4 cm without any complications, the most concerning complication is sciatic nerve palsy. This is of less concern in multifactorial perceived LLD owing to flexion and adduction hip contractures. We have not encountered any cases of postoperative sciatic nerve palsy. This is due to the fact the sciatic nerve lies posterior to the plane of correction of the adduction hip deformity (the coronal plane) and is therefore not subjected to any stretch on correction from hip adduction to an abducted position. Moreover, correction of the fixed flexion deformity of the hip does not pose any jeopardy to the sciatic nerve. The sciatic nerve lies in the convexity of the deformity of the flexed hip in the sagittal plane. Therefore, correction of the flexion contracture of the hip actually relieves the stretch on the sciatic nerve as the hip is brought into extension.

Our data isolate and describe the apparent, perceived, and true LLD changes throughout treatment. A study by Nakanowatari et al [16] found that apparent LLD can be a better predictor of patient-perceived inequality and physical performance than the true LLD. Treating the preoperative LLD at the time of the initial surgery is ideal because treating an LLD that is symptomatic after THA is challenging. LLDs of <1 cm can be treated with physiotherapy or a small shoe lift. Larger discrepancies after THA can be lengthened over an intramedullary nail with external fixator or with an internal lengthening nail, and these techniques have shown promising results [17].

There are limited reports in the literature that comment on the effect of correction of LLD after THA. Fujimaki et al [18] found that a whole LLD >0.5 cm after THA resulted in worse clinical outcome scores compared with patients with discrepancies <0.5 cm postoperatively. However, the reported preoperative LLD in their patient population (−1.3 cm) was much lower than that in our case series. They did point out, however, that correcting pelvic LLD did not necessarily correspond to correcting whole-leg LLD and emphasized on analyzing the whole length of the affected short lower extremity and plan to correct the whole-leg LLD, especially for patients with a significant perceived discrepancy between the affected and unaffected legs.

There are a number of limitations to this study. First, there are a small number of cases in this study, in addition to its retrospective nature. We recognize the problem with small sample sizes and the associated difficulty with statistical power in this pilot study. To supplement the small sample sizes, the less-powerful, nonparametric, Wilcoxon signed rank test was also calculated and showed a significant difference at an alpha level of 0.05. Second, the radiographic analyses were performed by unblinded observers, which may introduce observer bias. Although there might have been bias owing to the lack of blinding, this is minimized by using standardized landmarks as standard points of reference for measuring each limb segment on radiographs, which caused negligible variance in measurements across all readings.

Third, there were no clinical functional outcome hip scores collected to reflect patient functionality preoperatively and postoperatively, and we relied on performing the previously aforementioned simple questionnaire, which is not validated for measurement of THA clinical outcomes. This is due to the retrospective nature of the study and the fact that its primary outcome was objective radiographic assessment of LLD rather than subjective clinical outcome scores.

In conclusion, this study demonstrates that patients with hip arthritis and associated multifactorial perceived LLD can be successfully treated with primary THA and auxiliary soft-tissue releases. One must pay close attention to detail to understand all the factors contributing to the LLD and then execute a surgical plan that addresses all the components of the LLD.

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