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Case Report

Robotic Arm–Assisted Total Hip Arthroplasty to Correct Leg Length Discrepancy in a Patient With Spinopelvic Obliquity

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ABSTRACT

Leg length discrepancy is not an uncommon result of total hip arthroplasty and a major cause of patient dissatisfaction. Spinopelvic obliquity is a less-recognized cause of limb length differences in patients undergoing total hip arthroplasty. The robotic arm has recently been introduced to enhance implant positioning during surgery and to achieve more predictable leg length and offset goals. In this article, we illustrate the case of a patient who presented with a leg length discrepancy associated with significant spinopelvic obliquity. We show the use of the robotic arm total hip application to improve her pelvic obliquity and limb length discrepancy. This approach helped with the patient's symptoms and gait as well as her radiographic pelvic alignment.

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Introduction

Leg length discrepancy is one of the main reasons for patient dissatisfaction after total hip arthroplasty [1]. The difference in leg lengths can be multifactorial, and it is important to distinguish between true and apparent leg length variations. While the former is related to real changes in the "bone" length, the latter may be the result of added soft-tissue contractures and/or spinopelvic obliquity [2].

Oftentimes, in a total hip arthroplasty, the focus is on the "hip length." Assessment of the operative hip relative to the contralateral hip is performed based on lines drawn through reproducible landmarks, such as the ischial tuberosities or acetabular teardrops (Fig. 1) [3]. In the setting of spinopelvic obliquity, these lines may accurately compare hip lengths on both sides (Fig. 2), but they do not take into account the contribution of spinopelvic obliquity to the overall leg lengths (Fig. 3) [4].

This article highlights a case where a patient presents with significant leg length discrepancy after unilateral total hip arthroplasty. While her hip lengths appear to be similar on both sides, a notable spinopelvic obliquity contributes to her leg length discrepancy. A total hip arthroplasty was planned on the contralateral side using a computed tomography (CT)–based total hip software and executed using a robotic arm system to correct her leg length discrepancy secondary to her spinopelvic obliquity.

Case history

The patient is a 62-year-old African-American woman with bilateral hip avascular necrosis secondary to sickle cell disease. She underwent a right total hip arthroplasty several years before presentation. She was very dissatisfied with her arthroplasty, and her primary complaint was a leg length discrepancy, with the right limb uncomfortably longer than the left. She also complained of left groin and back pain. She walked with a bent-knee gait on the longer right side to allow both feet to touch the ground during ambulation. She tried extensive physical therapy, stretching exercises, and shoe lifts without relief.

On standing films, she had an obvious pelvic obliquity with tilt of the pelvis toward the longer (right) side (Figs. 2 and 3). The standing long leg films estimated a leg length discrepancy of about 2.5 cm. The standing films also revealed that she had no lower

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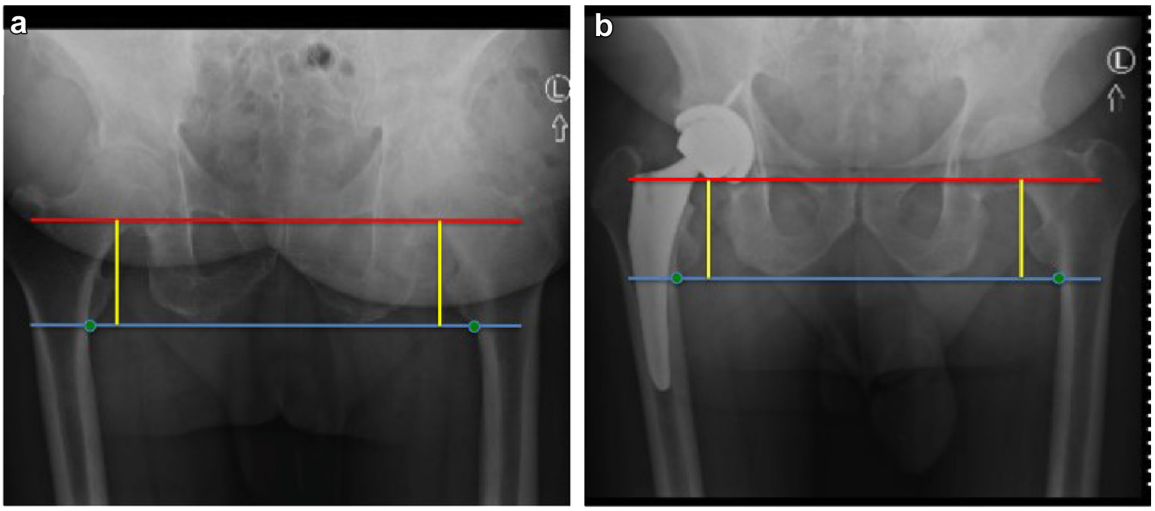

Figure 1. Interteardrop and interischial lines drawn across the weight-bearing pelvis to compare leg lengths by intersection point with the lesser trochanters (green dot). The difference in leg length is also sometimes assessed by the difference in the distance between the 2 lines, shown here in yellow. In panel a, both hips lengths are the same. In panel b, the left hip is shorter. Both pelvises in these images appear level.

extremity deformities and that her tibial lengths were the same (Fig. 3).

Her interischial and interteardrop lines with her in the supine position and the legs pointing straight showed the hip on the left to be about 4 mm shorter than the right. Traction films on the left side demonstrated that her pelvic obliquity was somewhat flexible and at least partially correctable (Fig. 4).

She was offered a total hip on the left side to address her primary hip pathology, with the intent to improve her limb length compared to the contralateral side. Informed consent was obtained for the procedure.

The patient underwent a preoperative supine CT scan using the MAKO (Stryker Corporation, Mahwah, NJ) scan protocol for total hip arthroplasty per manufacturer recommendations. Once CT

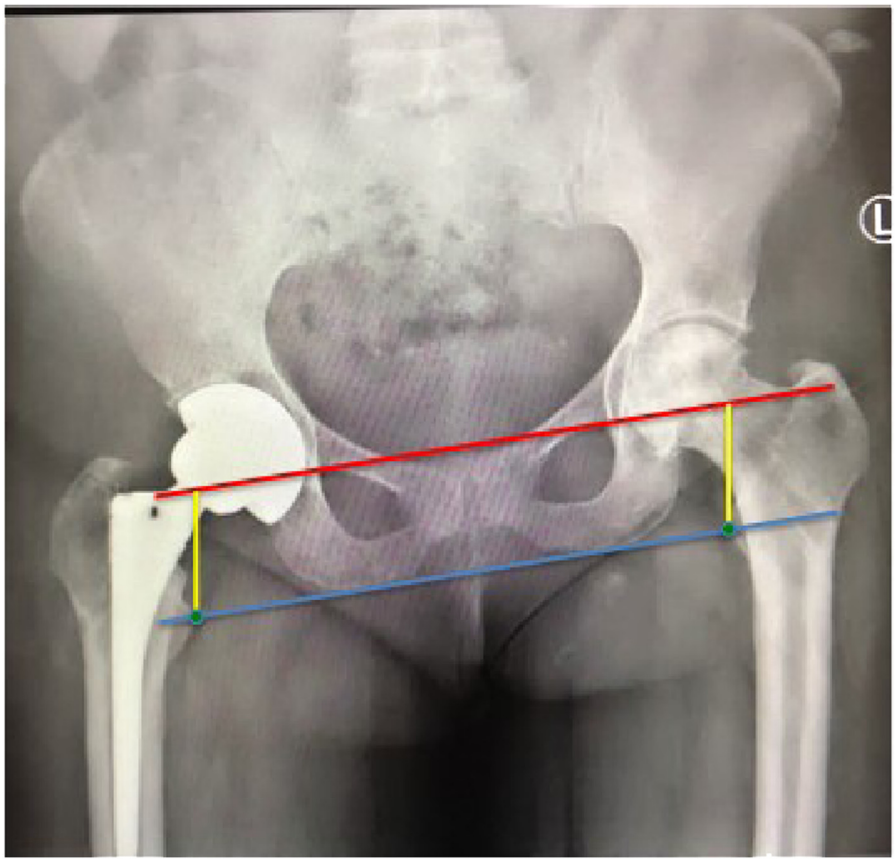

Figure 2. Interteardrop and interischial lines show the left hip shorter by about 4 mm (interischial line crosses the lesser trochanter on the left hip at a point about 4 mm lower than the lesser trochanter on the right: green dot). Pelvic obliquity is demonstrated here with the pelvis tilted to the right.

Figure 3. LLD with left limb shorter than right one. The patient feels even when she has a 2.5-cm block under the left foot (not shown here). Otherwise, she has to bend the right knee to get both legs on the ground (shown here). There is also clear pelvic obliquity when the patient is standing without any blocks (shown here).

Figure 4. Traction on the left foot partially corrects the pelvic obliquity indicating that the obliquity is at least partially flexible and correctable (compare to Fig. 2).

segmentation was carried out and the appropriate landmarks were identified, the planning page calculated a leg length discrepancy of 13 mm (Fig. 5). The cup and stem were planned per routine fashion with the intent to lengthen the left hip by 13 mm (Fig. 6). The plan was executed using the robotic arm through a direct anterior approach on the Hana table. For registration, the pelvic tracker was placed on the right iliac crest and preoperative leg length and offset were registered using the express robotic platform. On completion of the procedure, the leg length of the operative side was matched to that of the contralateral side (ie, the operative hip was lengthened by 13 mm (Fig. 7).

The final leg length on the left side was tailored to match the right side. The patient's supine postoperative film demonstrated a more level pelvis with a longer left hip by about 8 mm (Fig. 8).

Figure 5. CT-based plan showing a 13-mm LLD between the right and the left hips.

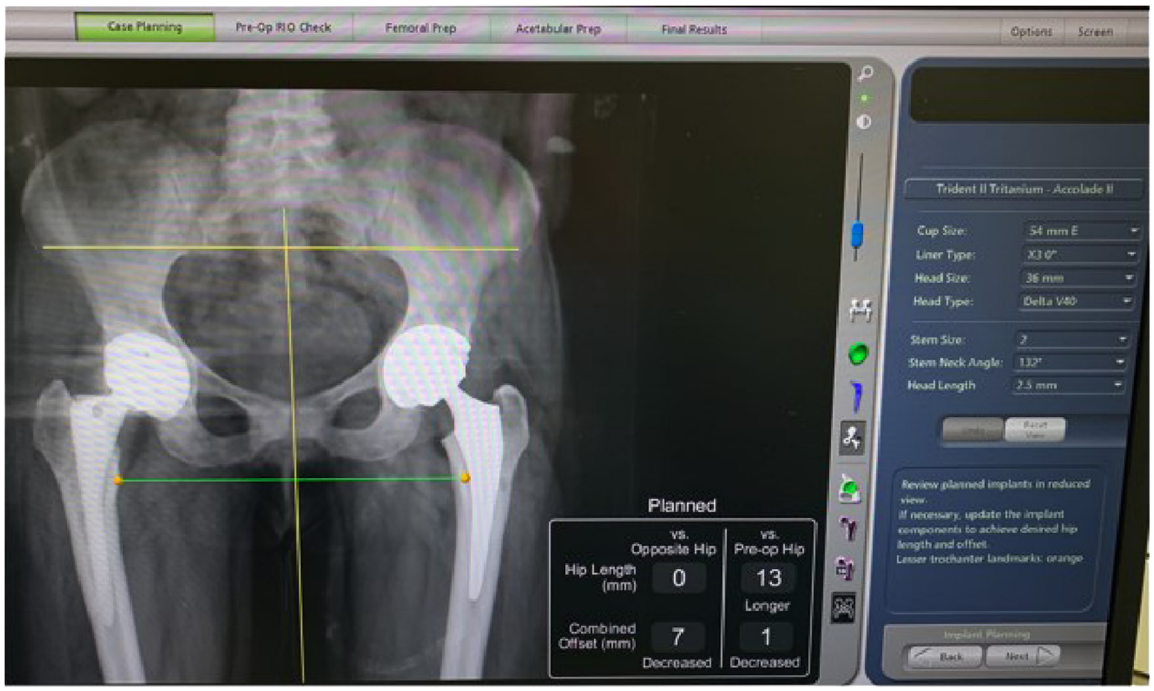

Figure 6. CT-based plan after the virtual implantation of a left total hip with lengthening of 13 mm on the left side to "equalize" hip lengths.

Her standing film also showed a more level pelvis with a longer hip on the left side (Fig. 9a), but similar total limb length (Fig. 9b).

On presentation at her 6-month follow-up, the patient had similar patellar and medial malleolar heights. She also had complete resolution of her low back and hip pain and was walking with no assistive devices. She felt her limb lengths were even (Fig. 10). Clinically, the lower extremity alignment also appeared to have similar limb lengths as well (Fig. 10). Her Western Ontario and McMaster Universities Osteoarthritis Index score improved from 91 preoperatively to 32 postoperatively.

Discussion

Leg length discrepancy is not an uncommon occurrence in patients with diseased hips. Hip arthroplasty often aims to address the difference in leg lengths secondary to arthritis. It does so by bringing back the hip center to its native position and mating that with a femoral stem and head that mimic the contralateral (normal) hip. Manual or digital templating is routinely performed preoperatively to achieve these goals [5-10].

The relationship between the spinopelvic complex and the hip has been gaining traction in the arthroplasty community. It is

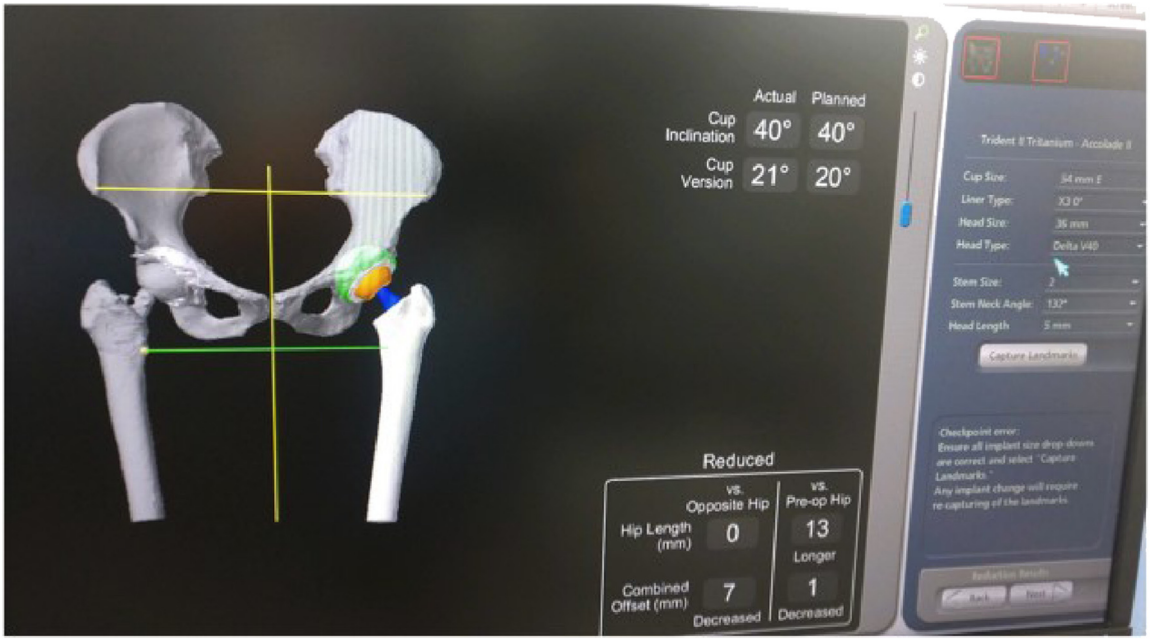

Figure 7. Final result after the implantation of a left hip with "lengthening" of 13 mm on the left side to "equalize" hip lengths.

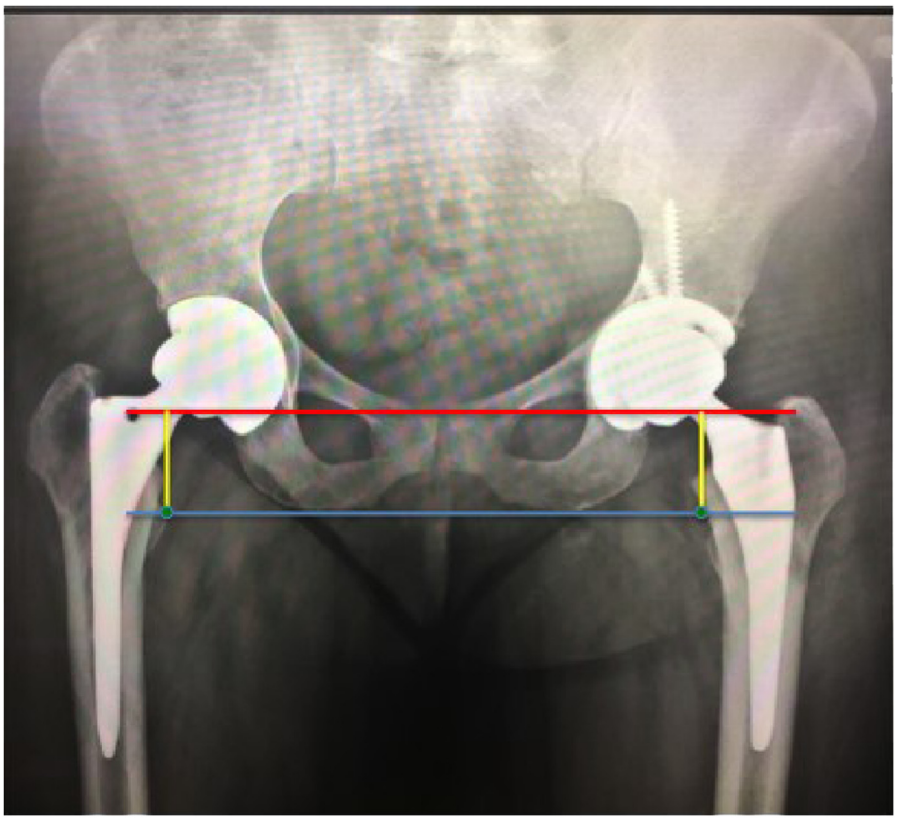

Figure 8. Supine pelvis radiograph shows the left hip is longer than the right hip and the pelvic obliquity is corrected.

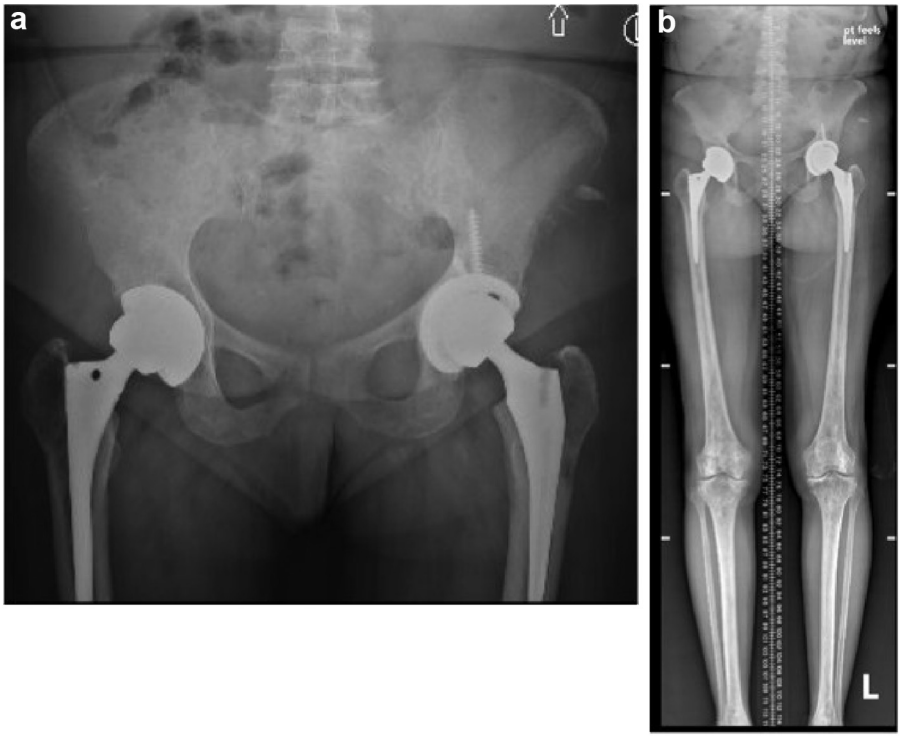

Figure 9. (a) Standing film showing the pelvis is more level and the left hip is longer, but the patient feels even. (b) Full-length standing film showing the knees are even, implying the correction of LLD.

Figure 10. Clinical picture showing equal perceived leg lengths.

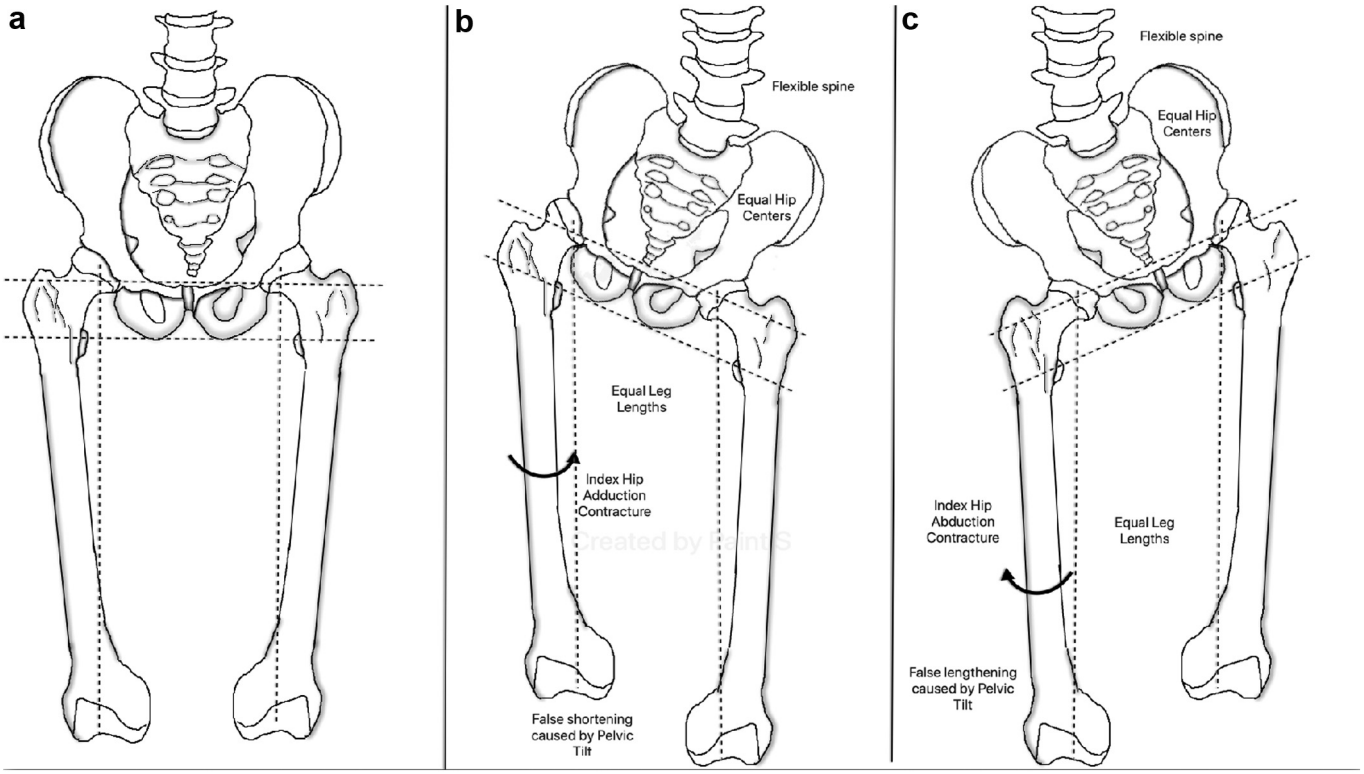

Figure 11. Schematic illustrating how spinopelvic obliquity can affect apparent limb lengths even when hip lengths are the same, as measured using standard interischial and interteardrop lines. (a) A level pelvis with equal leg lengths. (b) Pelvic obliquity with right hip adduction contracture (similar to our case). (c) Pelvic obliquity with right hip abduction contracture.

increasingly recognized that pelvic tilt changes from standing to sitting vary with the degree of spine stiffness and deformity [11]. A change in pelvic tilt in the sagittal plane can have implications on implant positioning, particularly the acetabular component, with subsequent effects on hip stability [12,13].

It is known that differences in limb lengths can introduce spinopelvic obliquity as a compensatory mechanism [14]. Total hip arthroplasty resulting in a limb length discrepancy can invite rotational compensatory changes in the spinopelvic complex [15]. The prolonged consequences of these mechanisms are commonly sacroiliac [16] and back pain [17]. Primary changes in the spine, such as deformity and scoliosis, may also cause pelvic obliquity and leg length inequalities. It is clear that the spine, pelvis, and leg lengths are all closely inter-related. The component of soft-tissue contractures should also not be ignored as a potential etiology of length differences.

In patients with routine hip arthritis and mild limb length discrepancies, spinopelvic alterations may be subtle and less important. Most leg length discrepancies in these cases may be secondary to hip length differences due to arthritis. The greater the spinopelvic obliquity a patient has, the greater the effect it will have on the leg length (Fig. 11). Templating in these patients and measuring the contribution of pelvic obliquity to leg length discrepancy is often difficult.

In this article, a case was presented where a significant component of leg length discrepancy was secondary to spinopelvic obliquity. A CT-based software was used to estimate the contribution of the obliquity to the total leg length. Software planning indicated a length discrepancy of 13 mm. This was interpreted as 13 mm of hip lengthening was needed to equalize the limb lengths and make the patient feel even.

The effect of lengthening the hip introduces an interesting dynamic rotation concept. While the standing films indicated a leg length discrepancy of about 25 mm, the planning software estimated only a 13-mm difference. We believe that the reason for this discrepancy is because, as the pelvis levels, the operative side is lengthened. Concurrently, the contralateral hemipelvis (and limb) may shorten. It also explains why the total lengthening needed was less than the difference in limb length seen on the standing bone length study. This rotation is a complex phenomenon that causes bony rotation while adjusting soft-tissue tension (Fig. 11). The end result is a more level pelvis and apparently equal limbs, despite a longer hip. The total hip arthroplasty itself also addresses some soft-tissue contractures that contribute to the perceived length discrepancy.

Simply positioning blocks under the shorter limb on a standing radiograph may make the patient feel level, yet it does not address any soft-tissue contractures or pelvic rotation that is dynamically addressed as the hip is lengthened. The block method also does not account for contralateral limb shortening as a result of the pelvic rotation during correction.

Spinopelvic obliquity can be flexible or fixed. Leg length discrepancy correction in a flexible obliquity may require less hip lengthening than in a fixed obliquity. We believe that would be the case because the rotational movement of the pelvis described previously may not be possible in a rigid noncompliant obliquity. To demonstrate flexibility, traction films can be obtained while the patient is supine to show that the pelvis rotates when traction is pulled on the shorter limb (Fig. 4).

By correcting the pelvic obliquity on the CT scan, the robotic total hip application allowed us to estimate the hip lengthening needed to level the pelvis and create apparent leg lengths that are the same. The goal of the application, as used in this article's context, was to create equal apparent leg lengths, which in some cases may not be identical to the true leg lengths, typically generated from measurements of the interischial and intertear-drop lines.

Summary

We believe this to be the first report to propose the use of a robotic total hip application as a tool to address limb length discrepancy in a patient with spinopelvic obliquity in the coronal plane. We hope to expand the use of this technique in future cases to understand it further.

Conflict of interest

The family of Christopher Bejcek has stock in Stryker Corporation. Tarek A. Taha has no conflicts of interest to declare.

References

[1] Pyrko P, Zuckerman J. Leg length discrepancy in primary total hip arthroplasty. Bull Hosp Jt Dis (2013) 2016;74:82.
[2] Ranawat CS, Rodriguez JA. Functional leg-length inequality following total hip arthroplasty. J Arthroplasty 1997;12:359.
[3] Meermans G, Malik A, Witt J, Haddad F. Preoperative radiographic assessment of limb-length discrepancy in total hip arthroplasty. Clin Orthop Relat Res 2011;469:1677.
[4] Edeen J, Sharkey PF, Alexander AH. Clinical significance of leg-length inequality after total hip arthroplasty. Am J Orthop 1995;24:347.
[5] Hofmann AA, Bolognesi M, Lahav A, Kurtin S. Minimizing leg-length inequality in total hip arthroplasty: use of preoperative templating and an intraoperative X-ray. Am J Orthop (Belle Mead NJ) 2008;37:18.
[6] Kosashvili Y, Shasha N, Olschewski E, et al. Digital versus conventional templating techniques in preoperative planning for total hip arthroplasty. Can J Surg 2009;52:6.
[7] MCastroMe. The accuracy of digital templating in uncemented total hip arthroplasty – sogacot. https://sogacot.org/the-accuracy-of-digital-templating-in-uncemented-total-hip-arthroplasty/. [Accessed 25 March 2020].
[8] Sariali E, Mauprivez R, Khiami F, Pascal-Mousselard H, Catonné Y. Accuracy of the preoperative planning for cementless total hip arthroplasty. A randomised comparison between three-dimensional computerised planning and conventional templating. Orthop Traumatol Surg Res 2012;98:151.
[9] Stigler SK, Müller FJ, Pfaud S, Zellner M, Füchtmeier B. Digital templating in total hip arthroplasty: additional anteroposterior hip view increases the accuracy. World J Orthop 2017;8:30.
[10] Whiddon DR, Bono JV, Lang JE, Smith EL, Salyapongse AK. Accuracy of digital templating in total hip arthroplasty. Am J Orthop (Belle Mead NJ) 2011;40:395.
[11] Esposito CI, Miller TT, Kim HJ, et al. Does degenerative lumbar spine disease influence femoroacetabular flexion in patients undergoing total hip arthroplasty? Clin Orthop Relat Res 2016;474:1788.
[12] Buckland AJ, Ayres EW, Shimmin AJ, Bare JV, McMahon SJ, Vigdorchik JM. Prevalence of sagittal spinal deformity among patients undergoing total hip arthroplasty. J Arthroplasty 2020;35:160.
[13] Buckland AJ, Vigdorchik J, Schwab FJ, et al. Acetabular anteversion changes due to spinal deformity correction: bridging the gap between hip and spine surgeons. J Bone Joint Surg Am 2015;97:1913.
[14] Raczkowski JW, Daniszewska B, Zolynski K. Functional scoliosis caused by leg length discrepancy. Arch Med Sci 2010;6:393.
[15] Betsch M, Michalik R, Graber M, Wild M, Krauspe R, Zilkens C. Influence of leg length inequalities on pelvis and spine in patients with total hip arthroplasty. PLoS One 2019;14:e0221695.
[16] Kiapour A, Abdelgawad AA, Goel VK, Souccar A, Terai T, Ebraheim NA. Relationship between limb length discrepancy and load distribution across the sacroiliac joint—a finite element study. J Orthop Res 2012;30:1577.
[17] Khamis S, Carmeli E. Relationship and significance of gait deviations associated with limb length discrepancy: a systematic review. Gait Posture 2017;57:115.