Leg length discrepancy after total hip arthroplasty: a review of literature

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Abstract Discrepancy of leg length is often considered to be a problem after total hip replacement and can adversely affect an otherwise excellent outcome. Furthermore, it has been associated with patient dissatisfaction and remains one of the most common reasons for litigation against the orthopedic community. As a consequence of the need to equalize leg length, several authors have sought to validate methods of minimizing limb length discrepancy based on preoperative planning with preoperative radiological templates or intraoperative methods of measurement. In this article, we present a review of the limb length discrepancy in total hip arthroplasty, its implications and several techniques to avoid it. We recommend that a combination of the above mentioned methods will give the best chance for the surgeon to minimise the risk of leg length discrepancy following total hip replacement.

Keywords Total hip arthroplasty · Limb length discrepancy · Intraoperative techniques

Introduction

One of the intraoperative challenges in total hip arthroplasty (THA) is correcting limb length inequality without compromising hip stability [1]. Besides relieving pain, restoration of the

hip joint biomechanics with appropriate femoral offset, and leg length is an important goal of THA and facilitates normal gait and function [2]. Obtaining correct center of rotation and orientation of components, adequate offset, and equal leg lengths are the key components of successful primary THA. In general, achieving pain relief and improving stability take precedence over restoring equal leg length [3]. Discrepancy of leg length (LLD) is common after arthroplasty of the hip, with lengthening being the more noticeable to patients than shortening [1]. Most patients with minor leg-length discrepancy after THA have few symptoms, and the majority of patients with moderate leg-length discrepancy have readily manageable symptoms. However, a minority of patients, mostly those with marked LLD, may have substantial disability as a result of pain or functional impairment [4]. Patient dissatisfaction with LLD after THA is the most common reason for litigation against orthopedic surgeon [5].

Incidence and impact of LLD

The incidence of LLD after primary THA has been reported to range from 1 % to 27 % [6] and in the literature the LLD is reported to vary from 3 to 70 mm [7] with a mean from 3 to 17 mm [8, 9]. LLD has been associated with back pain and sciatica, neuritis [10, 11], gait disorders [12], general dissatisfaction [13], dislocation [14], and early loosening of components [15]. LLD can lead to gross dissatisfaction, morbidity, and revision surgery [16]. Love and Wright [17] reported up to 18 % of patients had lengthening of more than 1.5 cm, of whom 6 % required shoe correction. Williamson and Reckling [18] reported LLD of 16 mm in their series and up to 27 % patients needed a shoe lift for correction. Another series by Djerf and Wahlstrom [19] reported LLD up to 50 % in their patients after THA.

Undoubtedly, the literature has proved that absolute equalization of limb length is difficult to achieve and LLD cannot be eliminated after THA [20]. The boundary between

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acceptable and unacceptable levels of disparity remains undefined [21]. Though Eden et al [22] concluded that even a small disparity may be a source of dissatisfaction in some patients; however, several studies have shown that up to 10 mm of LLD is well tolerated by most patients. Most often the limb is lengthened rather than shortened after THA [23] and ≥ 1 cm LLD is noted in up to 50 % of cases; of which only 15%–20 % of patients require shoe correction for leg-length equalization [13]. Patients can detect relatively minor increase in leg length and are unhappy when they have to wear a lift in the contralateral shoe [24]. Edeen et al [22], allude that up to 32 % of patients in their series were aware of LLD with an average LLD of 15 mm.

The excessive limb lengthening can also transform an excellent clinical result with respect to range of motion, pain relief, and function into a surgical failure because of patient dissatisfaction. Parvizi et al [4] concluded that a marked postoperative LLD may lead to substantial disability as a result of pain or functional impairment, which warrants revision surgery.

Materials and methods

A Medline search (1950 to date, MEZZ), was done using ‘Dialog Datastar’. The key words ‘hip’ or ‘arthroplasty’ for title search revealed 34,026 and 1106 relevant articles respectively. Thesaurus mapping was used to explore this search. On selection of ‘arthroplasty-replacement-hip.de’ a total of 8099 searches were revealed. Combining the 3 searches with ‘and’ revealed a total of 127 relevant publications in the Medline. Furthermore, this was refined by using ‘limb length discrepancy’, which identified a total of 72 relevant publications. The identified searches were assessed for their relevance and methodology. Further studies were identified through manual searches using cross referencing.

Finally, a total number of 54 articles which were identified contained information about LLD following THA.

Methods and techniques to overcome LLD

The literature is replete with different techniques to overcome LLD during THA surgery. Most of these techniques can be grouped into 1 of the 3 categories [25]:

- (1) Those which rely on perioperative templating.
- (2) Those using intraoperative pelvic or femoral markers for reference.
- (3) Complex mathematical calculations and ultrasound probed to measure leg lengths accurately.

Although LLD cannot be eliminated after THA, it can be mitigated to a large extent through a series of steps perioperatively [6]. Several methods described for the measurement

of LLD and several devices manufactured to overcome LLD are either too complicated or too expensive to be practical for routine use [26].

Preoperative Templating

The accuracy of preoperative femoral templating relates in part to the location of landmarks from which to measure the level of femoral neck resection during surgery [27]. Several studies investigating sole reliance on templating and its efficacy in overcoming LLD in THA have concluded that correct sizing of components match in only up to 60 % of cases, hence making it unreliable in overcoming LLD [28].

Intraoperative techniques

Conventional methods of intraoperative limb length measurement are based on the distance between 2 reference points marked on the pelvis and femur. Traditionally, the greater trochanter is used as an intraoperative landmark for leg-length assessment [29]. The location of the reference point on the pelvis varies in each case. The reference can be iliac fixation pins, intraoperative callipers, infracotyloid pins, and fixed suture lengths. In order for these devices to work properly, the operating table must be level with the floor and the position of the hip must be reproduced precisely in all planes before and after reconstruction is performed [30].

To date there are around 20 different intraoperative techniques described in the literature to achieve limb length correction during THA. All of them use a stable pelvic reference point and a variable femoral reference. Some of the described techniques have been validated by radiological assessment pre or intraoperative LLD with postop operative measurements.

Mcgee and Scott [31] were the first to describe a simple intraoperative technique to correct LLD in THA. They used a fine guide wire to bend in ‘U’ shape to act as a device to mark referencing points. Though they mention it has been successfully used in 200 patients, they fail to substantiate their claim with any radiological or clinical data.

Woolson and Harris [32] later described another technique by using a cumbersome calliper device, which is more time consuming and difficult to adopt. Using this device they achieved postoperative lengthening of <6 mm in 89 % of patients. They also fail to correlate their results to any functional outcome.

Though techniques by using large Steinmann pin have been described in literature [33, 34], they have been criticized as unreliable as they are recommended to be removed and replaced during the surgery in between the measurements. Jasty et al [23] used a similar calliper technique in a consecutive series of 85 THAs, of which 80 cases were still longer postoperatively. The study has several limitations as it

is retrospective, measurements being made by the operating surgeon, who was not blinded, and scanograms were used only pre operatively.

Naito et al [35], Bose [36], and Shiramizu et al [37] described techniques using a Steinman pin and adjustable calliper to achieve intraoperative limb length correction. They also compared their results with a control group of patients who underwent THA without using such devices. Both these techniques describe a cumbersome and expensive device used as an adjunct in routine THA. Also there is a need for a larger or a separate incision to accommodate these devices for their pelvic reference.

The major limitation in all these studies is that the accuracy of measurement technique was not discussed and the correlation between the predicted lengthening with the actual lengthening was not noted.

Hence, to overcome these limitations Ranawat et al [1], reported a new technique using vertical Steinman pin at the infracotyloid groove of the acetabulum. They alluded that the points of reference are close to center of rotation of hip, making variations in measurements resulting from limb positions less likely to occur. The main limitation of this technique making it unreliable is the difficulty in accurate positioning of the pin due to large osteophytes at the posterior lip of acetabulum.

Mihalko et al [11] described a technique using a large screw in the superior part of acetabulum along with screw driver to achieve limb length correction. Another simple technique described by Cuckler [38]—by using an umbilical tape and knots to reference the bony landmarks like ASIS—is very unreliable as often it is very difficult to identify the bony prominence under surgical drapes especially in obese patients. Furthermore, this method of limb length assessment is not substantiated by any clinical data to determine its accuracy.

Matsuda et al [39] used a ruler intraoperatively in their study group and compared it with a control group using modular head to overcome LLD. The main disadvantage of this method as admitted by the authors is the difficulty in evaluation of acetabular component position, which is a key step in the technique. Similar technique was described by Gonzalez et al [40] using cemented components but the same limitations apply to this study as well.

Another simple technique using a skin suture below the iliac crest has been described without any clinical or radiological correlation [41]. This technique is unlikely to be reliable as the skin is not a fixed point and differential tension on the suture between length assessments will lead to significant error.

Takigami et al [42] described another technique using a dual pin retractor for measuring the LLD. Though this is well validated by radiological and functional outcome, the technique itself has some limitations. The device is expensive

and is an additional instrument during the surgery. Similarly, Lakshmanan et al [43] described another technique of achieving medial offset and leg length by using only femoral references. This technique largely relies on the prominent tubercle on the greater trochanter, which can be difficult to assess. Often in deformed head or proximal femur, this technique becomes unreliable.

Finally, some studies look into the effect of computer navigation in achieving leg length correction [44]. The navigation technique has several limitations of not only being cumbersome and expensive [24] but also has a steep learning curve. Though the measurements are calculated precisely, the precision largely depends upon mapping and referencing points, which are surgeon controlled, hence the possibility of LLD remains.

We have earlier published a simple technique to overcome LLD during primary THA by the standard posterior approach [45]. This involved placing a Judd pin (Judd Medical, Braintree, Essex, UK) or any stout pin into the ileum just superior to the acetabulum, to provide a stable pelvic reference point. A thread/suture (normally no. 5 ethibond, but any stout braided material can be used) is then securely tied to this pin, and a knot tied in the suture and a reference mark made with diathermy on the greater trochanter at the level of the knot, which is then used as a guide to either lengthen or maintain the same length based on preoperative templating/planning. This technique is dependent on 2 factors: the Judd pin stays in its original point in the pelvis and is stable; and the attitude of the leg when measuring stays in the same position (Fig. 1).

Based on the current literature available it can be concluded that use of a stable pelvic reference with accurately positioning the leg during measurements will provide the surgeon with a practical method for measuring leg length during THA [3]. Such a method helps the surgeon to select appropriate implants and to adjust final leg lengths without compromising on the stability.

Fig. 1 Picture illustrating intraoperative assessment of limb length by pin and thread technique

Limitation of techniques

Techniques that compare 2 linear measurements are basically based on accurate repositioning of the leg in abduction, flexion, and rotation. Hence small errors in femur repositioning can lead to substantial errors in assessing the leg length and offset, as the fixed reference points used is away from center of rotation of the hip joint [1].

According to Sarin et al [46] inaccurate femur repositioning in terms of abduction / adduction caused substantially greater errors than flexion / extension repositioning. A 5° – 10° of abduction / adduction error lead to LLD of 8–17 mm.

Similarly, a less pronounced effect was noted on femoral offset restoration secondary to inaccurate femur repositioning.

DiGioia et al [47] studied motion of pelvis during THA by using navigation system and reported an average of 23° rotation of pelvis in abduction/adduction and 16° of rotation of the pelvis in flexion/extension and 40° of rotation of pelvis in version.

Therefore great care must be taken when there is significant stiffness of the operated hip. Prior to dislocation the weight of the leg can alter the position of the pelvis giving rise to erroneous reading when the hip has been reconstructed and the pelvis can 'spring' back to its natural position. In this way the following problems can occur:

Abduction deformity will adduct the pelvis and the hip will be measured as too long when it is actually the correct length; adduction deformity will abduct the pelvis and the hip will be measured as too short when reconstructed to the correct length.

Lengthening of a short leg can lead to nerve impairment. This can be an issue particularly in patients with either a congenital short leg or in adults with an acquired deformity, which has led to a short leg. It is important to document this baseline LLD preoperatively. Edwards et al [48] noted peroneal nerve palsy with an average lengthening of 2.7 cm (range, 1.9–3.7 cm) and sciatic nerve palsy with an average lengthening of 4.4 cm (range, 4.0–5.1 cm). Mihalko et al [11] noted acute sciatic and femoral nerve neuritis without motor or sensory deficit following a leg lengthening of 2.5 cm after THA. Finally, Pritchett [49] also reported on 19 patients who had severe neurologic deficit and persistent dysesthetic pain following THAs with lengthening of 1.3–4.1 cm.

Discussion

Restoration of LLD is an important goal of any hip arthroplasty procedure as it affects functional outcome. According to Jasty et al [23] preoperative LLD of more than 2 cm presents social problems. They also allude that if shortening occurred in adult life, lengthening of more than 2 cm may be attempted.

LLD has been perceived by 6 %–32 % [22] of patients and universally perceived when shortening exceeds 10 mm and lengthening 6 mm [50]. Edeen et al [22] allude that 32 % of patients in their series were aware of LLD with an average LLD of 15 mm.

In another study by Knoyves and Bannister [51], 33 % of patients perceived lengthening and 18 % of patients had worst Oxford Hip Score (OHS) who perceived true lengthening at the end of 12 months after THA. Wyld et al [52] also concluded that patients with LLD had significantly poorer OHS and limped more frequently. In contrast to all these studies, White and Dougall [21], concluded that radiological lengthening up to 35 mm and shortening up to 21 mm during THA do not correlate with functional outcome of the patients (the authors used OHS and Harris Hip Scoring outcomes). However, the lack of correlation between LLD and functional outcome by using such surgeon based and generic tool, which lacks sensitivity and specificity of other disease-specific or joint-specific questionnaires has been well criticized [52].

Various techniques have been described in the literature, which aims to avoid any LLD following THA. Preoperative templating seems an unreliable option as a study by Woolson et al [27] after reviewing 408 THA cases done by using templating and a calliper device to overcome LLD, concluded that their technique is more accurate for patients with small preoperative LLD.

Intraoperative technique is more reliable

In the literature, the mean postoperative LLD varies from 1 to 17 mm [9, 27]. Love and Wright [17] reported 18 % incidence of LLD of greater than 15 mm after THA. Turula et al [8] found a mean LLD of 8.7 mm in unilateral and 11.5 mm in bilateral THA. In prior reports, in which no intraoperative measurements were performed by using any technique, the mean clinical and radiological LLD after THA was more than 5 mm [8, 53].

The methods described earlier using pins, callipers, and rulers have also been described for intraoperative correction of LLD [42], but little has been reported on the accuracy of these devices [36]. Careful planning and application of these intraoperative measuring systems seem to decrease the percentage of leg length inequalities [54]. Mean LLD postoperatively after using such techniques is reported between 1 and 4.2 mm [42]. LLD after using an intraoperative technique is seen in up to 13 % of patients with a great deviation of 10 mm ranging from 2.6 to 9 mm [23].

When one such simple intraoperative technique was used, it has further demonstrated a significant better clinical and radiological outcome compared with control group using no such technique to avoid LLD [55•].

According to Bose [36], it is essential not only to have a stable reference point both in pelvis and femur but also to have exact reproduction of the abduction/adduction position of the femur in space before and after trial component placement to overcome LLD intraoperatively.

Conclusions

Selection of an appropriate intraoperative technique to overcome LLD from the numerous methods described can be overwhelming. From a review of the literature, we can conclude that LLD is a common and recognized complication following THA. Therefore, it is paramount that surgeons maintain their focus on avoiding LLD as one of the primary goals of THA. Based on the current literature available it can be concluded that the combined use of templating to predict the necessary length correction and plan femoral neck osteotomy level and the intraoperative use of a simple pelvic reference pin with accuratere-positioning of the leg during measurements will provide the surgeon with a practical method for measuring leg length during THA. Such a method helps the surgeon to select appropriate implants and to adjust final leg lengths without compromising the stability of the hip.

Compliance with Ethics Guidelines

Conflict of Interest Aravind S. Desai, Asterios Dramis, and Tim N. Board declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies on animal subjects performed by any of the authors.

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