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Independent restoration of femoral and acetabular height reduces limb length discrepancy and improves reported outcome following total hip arthroplasty*

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ABSTRACT

Background: Restoration of native hip biomechanics is viewed as a key intra-operative goal in total hip arthroplasty (THA). The transverse acetabular ligament (TAL) can aid in the restoration of acetabular height and offset, and a calliper can be utilised to restore femoral height and offset. This study aimed to determine how these techniques affected the incidence of patient perception of limb length discrepancy (LLD), and if restoration of native biomechanics correlated with improved patient outcomes.

Methods: 123 patients were questioned regarding perception of LLD at 6 weeks and 1 year following THA. Oxford hip score (OHS) and pain scores were recorded. Radiographs were analysed by a blinded clinician who measured three variables; Global hip height (surrogate for limb length), global offset and the combination of both. These measurements were then compared to the unaffected contralateral hip. Data were analysed based on hips that were restored to within $\leq \pm 10$ mm of native values, and those $> \pm 10$ mm. Spearman's rank test was used to assess correlation with outcome.

Results: 8 (6.5%) patients perceived a LLD at 6 weeks, reducing to 3 (2.4%) at 1 year-lower than generally reported. Those patients not restored within ± 10 mm of native global height had increased pain at 1 year ($r = 0.558$, $p = 0.047$). Those not restored within ± 10 mm native global offset had a poorer OHS at 1 year ($r = -0.586$, $p = 0.035$) and those patients with combined height and offset discrepancy $> \pm 10$ mm had both a worse OHS ($r = -0.581$, $p = 0.037$) and increased pain ($r = 0.783$, $p = 0.002$).

Conclusion: Patient perception of LLD is complex and relates poorly to radiographic measurement, however, patients not restored to within 10 mm of native hip height and offset have demonstrated poorer outcomes.

1. Introduction

Increasing numbers of Total hip arthroplasties (THAs) are being performed each year.[1] It is a highly successful procedure with well-established mid-to long term clinical outcomes and implant survivorships.[2] Restoration of native hip biomechanics is a key intra-operative goal. Limb length discrepancy (LLD) is a well-recognised complication, yet the incidence (1–27%) and magnitude (3–70 mm) varies widely within the literature.[3,4] LLD can lead to gait disturbance, back pain, early component loosening and dislocation.[5–7] It also remains a common cause of litigation for hip surgeons.[8]

Reported patient perception of LLD is variable, together with what constitutes an acceptable radiological discrepancy.[9] Increased offset can contribute to a patient's perception of LLD due to increased abductor tension and pelvic obliquity.[10] Reconstruction of global offset also contributes to stability, range of movement, abductor muscle lever arm and minimises wear.[11,12]

Placement of both the acetabular cup and femoral stem impacts on limb length.[13,14] The transverse acetabular ligament (TAL) is an effective intra-operative marker to aid in the restoration of acetabular height and offset, thus recreating the acetabular centre (AC) or the centre of rotation of the hip (COR).[15,16] To restore femoral height, an intra-operative calliper has been shown to be a reliable and reproducible method.[13] As robotic and navigation techniques are expensive and as

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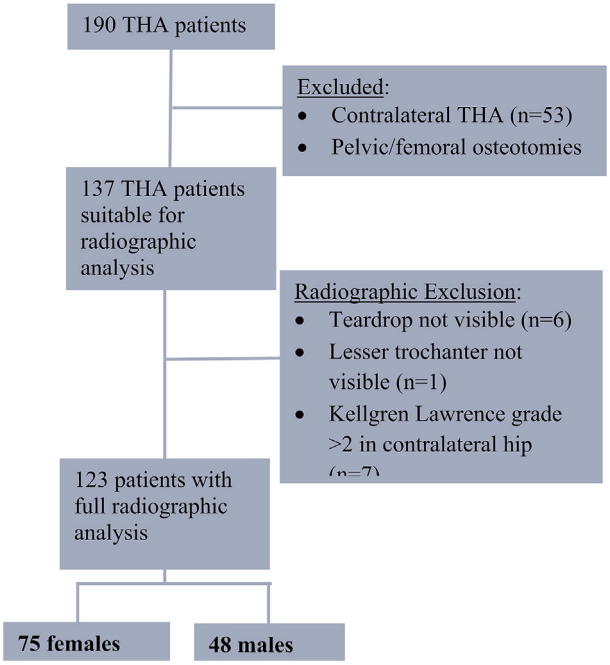

Fig. 1. Consort diagram.

yet, unproven to improve post-operative outcomes,[17] it remains essential all surgeons have access to simple and effective alternatives.

The aim of this paper was to assess how achieving independent reconstruction of acetabular height and offset using the TAL; and for femoral height and offset, using a calliper, impacted upon the incidence of patient perception of LLD, and if radiological measurements correlated with patient reported outcomes.

2. Material and methods

This prospective series was registered with the Hospital Standards, Quality and Audit department (reference number: 4813). 190 consecutive THAs were performed under the care of a single surgeon from October 2014 until May 2015. To allow comparison of the replaced hip with the anatomy of the native hip, patients were excluded if the contra-lateral hip had either been replaced, had undergone previous surgery, or exhibited loss of joint space (defined as Kellgren-Lawrence grade > 2).[18] Additional exclusion criteria were based on the quality of radiographs available (Fig. 1).

2.1. Operative technique

All procedures were performed via the posterior approach, using cementless implants (Pinnacle® cup, Corail®Stem, Depuy Synthes, Leeds, UK). Acetabular Centre (AC) and Femoral Head Centre (FHC) were restored separately. For the acetabulum, TAL was utilised to control both version, (cup face placed parallel to TAL) and to restore AC, (cup cradled by TAL).[15,16] The acetabular component was ideally no more than 4 mm bigger than the original head diameter. FHC was determined using a calliper technique, this technique has been described in detail previously.[13]

2.2. Patient follow up

Patients were questioned by an independent physiotherapist at 6-week review and specifically asked if they perceived a LLD. Those patients who did perceive a LLD were questioned again at their 1-year review. Any perceived LLD pre-operatively was also recorded. Those still perceiving a LLD at 1 year were then measured clinically using the standardised blocks method[19] with 0.5 cm blocks being placed under the shorter leg until the patient felt that their limb length had been corrected. Oxford hip scores (OHS) and pain scores (1 no pain, 5 severe pain) were noted at 1 year review for all patients.

2.3. Radiographic analysis

The post-operative digital AP pelvic radiographs were measured by an independent clinician (JW), who was blinded to the patients' outcome, using image software (PACS, SECTRA, Sweden). Radiographic magnification was calculated based on the known prosthetic head diameter. Global height and offset were measured on the replaced hip, with the contralateral hip considered a reference of AC and FHC (Fig. 2).

2.4. Measuring global hip height and offset (Fig. 2)

AC and FHC were defined on both sides using Moses circles. On the operative side, a greater value of acetabular height as compared to the contra lateral side, was given a negative value as this results in a

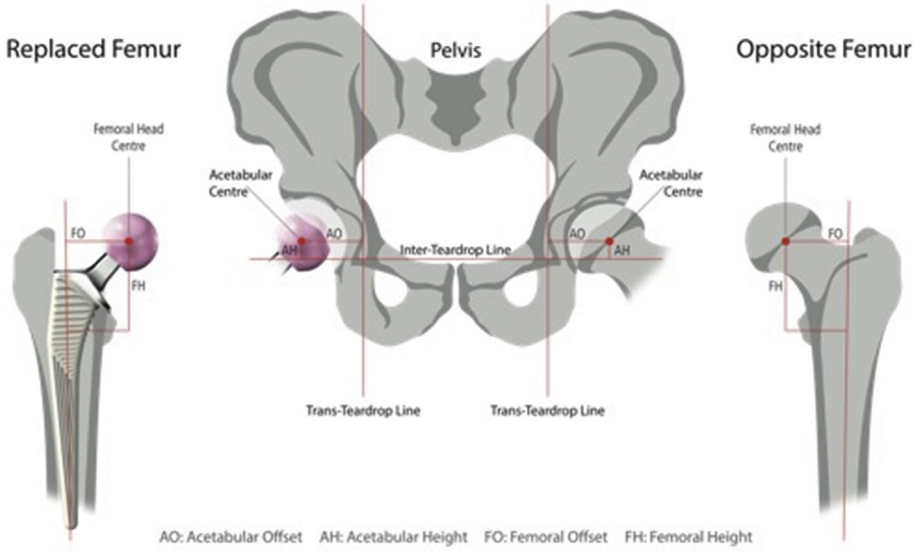

Fig. 2. Defining acetabular and femoral head centres and our measurement technique.

decrease in limb length. On the femoral side, if the femoral height as greater, this was given a positive number as it resulted in lengthening. The addition of acetabular height discrepancy and femoral height discrepancy were added to give the global height discrepancy with a negative number reflecting shortening, and a positive number, lengthening.

For offset, an increase or decrease in acetabular offset and femoral offset on the operative side was given a positive or negative value, respectively, referenced from the opposite side. The acetabular offset discrepancy and femoral offset discrepancy were then added to give global offset discrepancy.

2.5. Combined hip height and offset discrepancy

Global height discrepancy was added to global offset discrepancy to provide combined height and offset discrepancy. Therefore, if a patient had a global height discrepancy of +2 mm and a global offset discrepancy of -2mm their combined height and offset discrepancy would be 0 mm. Similarly, if they had a global height discrepancy of +6 mm and a global offset discrepancy of +6 mm their combined height and offset discrepancy would be +12 mm.

2.6. Lesser trochanter width (LTW)

Femoral rotation can affect projected femoral offset on an AP pelvic radiograph leading to an underestimation of offset. The width of the lesser trochanter has been shown to increase with external rotation, therefore, in this study the LTW of each femur was measured as an indicator of femoral rotation.[20] This was the distance from the midpoint of the lesser trochanter to the postero-medial cortex along a line perpendicular to the anatomical axis of the femur (Fig. 3).

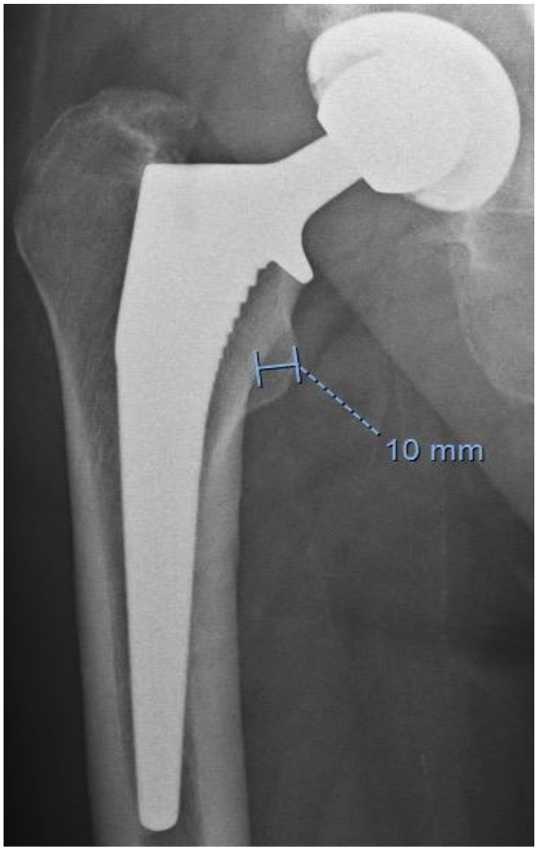

Fig. 3. Lesser Trochanter width (LTW).

2.7. Outcome measures and statistical analysis

Incidence of perceived LLD was recorded at 6 weeks and 1 year. Spearman's rank test was used to assess correlation with OHS and pain scores at 1 year.

Results were analysed based on the three variables; global height discrepancy, global offset discrepancy and combined height and offset discrepancy.

Based on previous studies suggesting up to 10 mm of LLD is well tolerated,[9] we determined that ≤ ± 10 mm represented native restoration for each of the three variables. Therefore, we divided patients into two groups; those ≤ ± 10 mm and those > ± 10 mm, for each variable.

Spearman's rank test was used to assess correlation between the LTW of each femur. The Mann-Whitney *U* test was used to compare if patients with LTW within 3 mm for each side had reduced discrepancy for each variable, compared to those with LTW > 3 mm difference between each side.

3. Results

After applying the exclusion criteria, the final cohort consisted of 123 patients, 75 (61%) females and 48 males (39%) (Fig. 1).

3.1. Perceived limb length discrepancy

Eight patients (6.5%) perceived a LLD at their 6-week review. Seven felt their operated side was longer and one patient felt their operated side was shorter (Table 1).

Only 3 patients still perceived a LLD at 1 year with two feeling that their operated leg was longer. The first patient (Patient 2, Table 1) had a +10 mm clinical LLD with blocks, they did not perceive a LLD preoperatively. The second patient (Patient 4, Table 1) had a +5 mm clinical LLD and pre-operatively they felt that the same leg was longer.

The third patient (Patient 7, Table 1) who had perceived shortening, did not have a clinically detectable LLD with blocks. This patient did not perceive a pre-operative discrepancy; however, they did have a 20-degree fixed flexion deformity of the ipsilateral knee.

3.2. Radiographic analysis

3.2.1. Global height discrepancy

Acetabular height was negative by a mean of −3.0 mm (range +5.9 to −14.4 mm) which would shorten the limb, but in contrast, femoral height was positive by a mean of +5.0 mm (range −5.2 to +20.6 mm), which led to a net mean increase in global hip height (lengthening) of +2 mm.

One hundred and ten (89.4%) patients were restored within ≤ ± 10 mm native global hip height, with the remaining thirteen (10.6%) > ± 10 mm. The range was −10.4 mm of shortening to +20.4 mm of lengthening.

Patients with ≤ ± 10 mm discrepancy showed no correlation with OHS or pain at 1 year. Patients not restored within 10 mm of native global height discrepancy had increased pain at 1 year ($r = 0.558$, $p = 0.047$).

3.2.2. Global offset discrepancy

Acetabular offset was negative (reduced) by a mean of −0.3 mm (range −10.1 to +5.1 mm) and femoral offset was positive (increased) by a mean of +2.7 mm (range −17.7 to +22.7 mm), which led to a mean increase in global offset of +2.4 mm (range −18.5 to +21.9 mm).

Ninety-eight (79.7%) patients were restored within ± 10 mm of native global offset and the remaining 25 (20.3%) were > ± 10 mm (Fig. 4).

Patients not restored within 10 mm of native global offset had

Table 1
Patients perceiving a LLD.

	6 weeks	1 Year	Clinical LLD	Global height discrepancy (mm)	Global Offset Discrepancy (mm)	Combined Height and Offset Discrepancy (mm)	LTW Opposite hip (mm)	LTW Replaced Hip (mm)
1	LONG	NO		12.6	12.6	25.3	0.8	0
2	LONG	YES	1CM	5.9	8.4	14.3	6.7	6.7
3	LONG	NO		−8.2	14.8	6.6	13.2	12.4
4	LONG	YES	0.5CM	−2.6	8.6	6.1	12.1	9.5
5	LONG	NO		−1.7	−1.7	−3.4	10.2	10.2
6	LONG	NO		0.8	−8.4	−7.6	6.7	3.4
7	SHORT	YES	0CM	1.6	−9.9	−8.2	13.2	13.2
8	LONG	NO		−4.2	7.6	3.4	0	0

poorer OHS at 1 year ($r = -0.586$, $p = 0.035$).

3.2.3. Combined height and offset discrepancy

Eighty-four patients (68.3%) were restored within ≤ ± 10 mm of native combined height and offset and the remaining 39 (31.7%) were > ± 10 mm (Fig. 4). Patients not restored within 10 mm of native combined height and offset had increased pain ($r = 0.783$, $p = 0.002$) and a poorer OHS ($r = -0.581$, $p = 0.037$).

3.3. Comparison of radiographic femoral rotation

The LTWs on each side showed a strong positive Spearman's correlation coefficient ($r = 0.64$, $p < 0.001$), (Fig. 5).

Patients with LTW within 3 mm of each other had reduced Global Offset Discrepancy compared to patients with over 3 mm difference ($p = 0.007$). LTW did not impact upon global height discrepancy ($p = 0.669$) or combined height and offset discrepancy ($p = 0.114$).

4. Discussion

Limb length discrepancy remains a feared complication for orthopaedic surgeons with potentially significant medico-legal implications.[8] By considering the independent contributions of the acetabulum and femur to both hip height and offset, this series has shown a lower than generally reported incidence of perceived LLD of 2.4% at 1 year.[3,4,21,22]

As previously described, patient perception of LLD reduces over time[22] with lengthening more commonly reported than shortening. Of the three patients still perceiving a LLD at 1 year, two had a pre-operative LLD perception, and one patient had a fixed flexion deformity of the knee. Only two (1.6%) patients had both a perception of LLD and clinically measurable discrepancy. This is despite our cohort containing radiographic outliers. From a technical perspective, such outliers are disappointing, however, all patients at the extremes of the cohort were asymptomatic and other authors have also found little correlation between radiographic global height discrepancy and patient perception. Kersic et al. found no radiographic measurement that correlated with patient perception, but did identify a correlation between a clinical measurement from the umbilicus to the medial malleolus and patient perception. Importantly, this clinical method cannot account for pelvic obliquity, providing a functional rather than an anatomical measurement.[21] Similarly, Lazennec at al. found that patients were more likely to perceive a LLD with altered sagittal knee alignment or pelvic obliquity, than anatomical discrepancy in the length of their femur.[23]

In this series, patients not restored to within 10 mm of native global height and global offset reported increased pain and a poorer OHS respectively. Those patients with over 10 mm combined height and offset discrepancy had both a poorer OHS and increased pain at 1 year. Innmann et al. showed that patients with lower combined discrepancy of limb length and offset restoration had a significantly better improvement in Harris Hip score post-operatively.[24] They used intra-operative imaging to guide implant placement in 113 consecutive patients. Their mean global offset discrepancy was −3.5 mm, compared to the current study (+2.4 mm), and they lengthened patients by +2.8 mm (current study +2 mm), however, they did not comment on the independent contribution of the acetabulum and stem to height and offset. Although not mentioned in their technique, reaming to the true

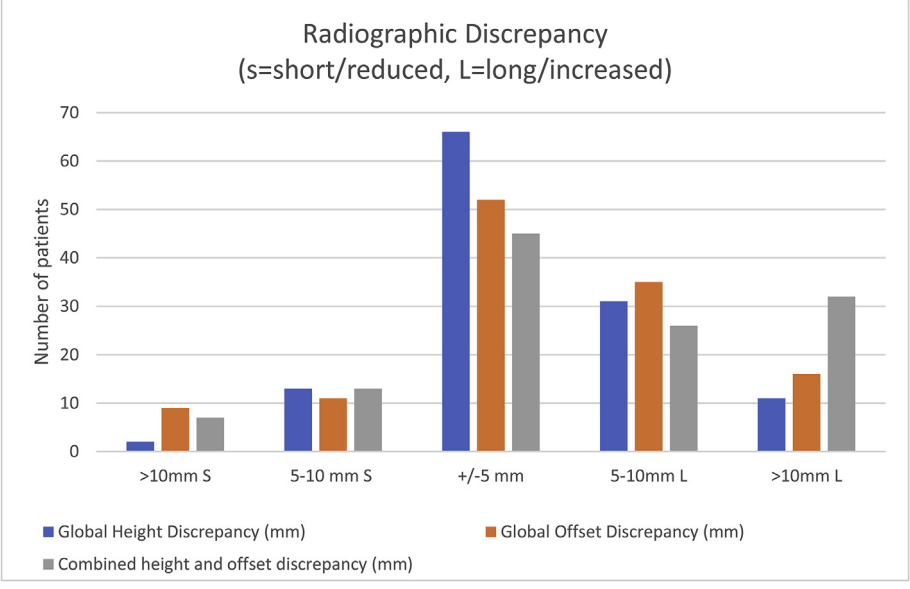

Fig. 4. Radiographic discrepancy. (L) lengthening/increased, (S) Shortened/decreased.

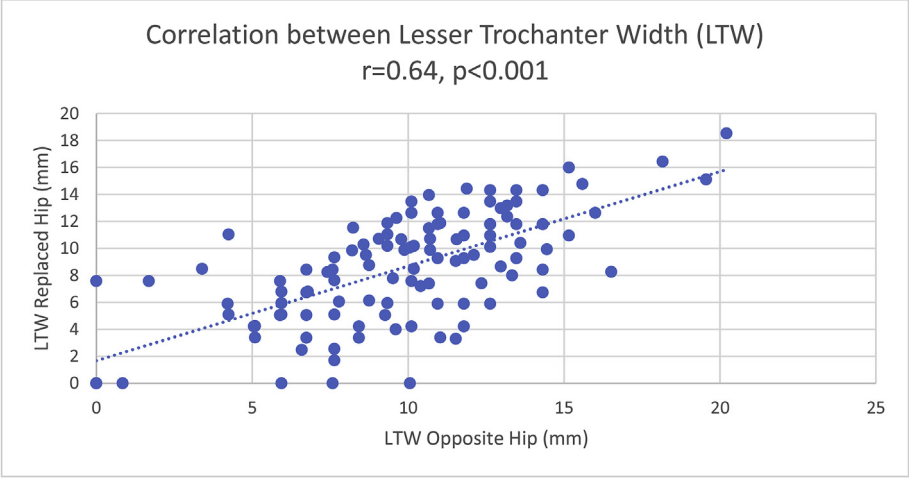

Fig. 5. Comparison of width of lesser trochanters as a marker of Femoral rotation.

floor may account for the difference in global offset. Bonin et al. demonstrated that in 18% of males, reaming to the true floor can lose as much as 10 mm of acetabular offset.[25] In such a patient, to ensure global offset is within the 10 mm target, the surgeon will have to compensate by increasing femoral offset, which can accelerate wear.[10]

The limitations of this study include the challenges of undertaking radiographic analysis. Projectional error of a 3-dimensional structure to a 2D radiograph can potentially lead to under projection of femoral offset with increasing femoral rotation.[21] In this study, a correlation of 0.64 between the LTWs suggest the rotation of both femurs was generally comparable, implying femoral offset was generally comparable. However, if the LTWs are different by over 3 mm then global offset discrepancy is significantly greater. In this situation surgeons should consider femoral rotation and interpret femoral offset projection with caution. AP Pelvic radiographs also only image the hip and not the entire limb-we suggest hip height is a more appropriate terminology when discussing limb length from Pelvic radiographs only. For assessing true lower limb length, the CT scanogram is considered more accurate,[19] however, this has greater cost, does not reflect routine practice, and has a higher radiation dose for patients. Finally, as patient *perception* was considered the most important outcome, clinical measurements from all patients within the cohort were not performed. By measuring limb length in those patients not perceiving a LLD, it may have introduced a perception bias.

5. Conclusion

This study has identified an incidence of perceived LLD of 2.4% at 1 year. Accurate reconstruction of native hip biomechanics within 10 mm improves outcome post-operatively. Using the TAL to restore acetabular height and offset, and using a calliper to restore femoral head centre are reliable and reproducible methods leading to predictable results. LLD perception, however, is a complex sensation and combines patient and surgical factors.

Patients complaining of post-operative LLD should undergo examination of the spine, pelvis and knee, and have further imaging, the gold standard being a CT scanogram. From a medico-legal perspective, to suggest that global height discrepancy alone, as measured from an AP pelvic X-ray with its limitations, is responsible for perception of LLD, appears to be incorrect.

Study design

Prospective consecutive cohort series.

Location of study

Primary Joint Unit, Musgrave Park Hospital, Stockman's Lane, Belfast, BT9 7JB, Northern Ireland.

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