Section: Surgical Procedures

Use of the tip - implant distance reduces variability in leg length discrepancy following hip replacement surgery

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</table>
Abstract

A minority of patients does suffer from symptomatic leg length discrepancy (LLD) following hip replacement surgery (THR). We report the success of a simple method of reducing variability in LLD using a single measurement of length made from a templated preoperative plan. A radiographic comparative study was conducted on consecutive patients undergoing THR surgery. The patients were separated into two groups dependent on the use of preoperative templating. The Tip-Implant distance was measured in the templated group, and this was reproduced intraoperatively. This is a measurement of the distance from the shoulder of the femoral implant to the tip of the greater trochanter. There were 27 templated and 20 non-templated hips that met the study criteria. The mean LLD (inter-teardrop to lesser trochanter) in the hips was not significantly different at +1.1mm(SD 3.9) and +2.9mm(SD 8.1) in the templated and non-templated hips respectively. The range of leg length discrepancy observed in the templated hips was -6mm to 11mm and in the non-templated hips was -6mm to 21mm. The pre and post operative mean Tip-Implant measurement was 16.1mm(SD 4.5mm) and 16.5mm(SD 5.2mm) respectively, which correlated strongly with paired t testing 0.749(p=.0001). There was a significant difference in variances with a Levene's test for equality F value of 12.0(p=0.01) suggesting a far narrower spread of LLD in the templated group. The Tip-Implant measurement determined preoperatively is reproducible intraoperatively and reduces the likelihood of LLD outliers in THR surgery.
Introduction

Total hip replacement remains a successful procedure, survivorship analysis and functional assessments continue to suggest that outcomes are very good(1). Despite these reported high satisfaction rates there are a number of well recognised complications. Technical error in the placement of the implants remains a significant concern. A minority of patients do suffer from symptomatic leg length discrepancy that can lead to claims of negligence(2), back pain(3), dislocation(4), poor patient satisfaction(5) and even revision surgery(6). Surgeons have tried a number of techniques to try and reduce this risk. Variable degrees of success have been been reported with strategies that employ preoperative templating(7–9), the use of intraoperative anatomical cues(10), jigs(11), and implant navigation systems(12).

The advent of Picture Archiving and Communication Systems(PACS) in general use and associated digital templating systems has added a further tool to the armamentarium of orthopaedic surgeons trying to achieve a successful outcome. We report the success of a simple method of reducing variability in leg length discrepancy utilising a single measurement of length made off a templated preoperative plan.

We hypothesised that use of the Tip–Implant distance would reduce the variance in leg length discrepancy seen in a series of patients that undergo hip replacement surgery. This narrower spread should reduce the likelihood of a leg length discrepancy ‘outlier’ as shown in figure 1.

Materials and methods

A retrospective radiographic comparative study was conducted on consecutive patients undergoing total hip replacement surgery at our institution. The procedures were carried out by three surgeons (WR, CG, JD).
Inclusion criteria for the study included patients with a diagnosis of primary osteoarthritis of the hip requiring arthroplasty surgery, in whom adequate pre- and postoperative AP radiographs centred on both hips were available. We excluded patients that had a significant radiographic preoperative leg length discrepancy (>10mm), acetabular bone erosion or fixed contractures. The patients were stratified into two groups dependent on the use of preoperative templating, into a Templated and a Contemporary group. Where templating was not used the surgeons used contemporary measures of establishing adequate leg length by using clinical assessments intraoperatively. These included an assessment of the relationship of the flexed knees to one another whilst in the lateral decubitus position, soft tissue cues of anterior capsular and abductor musculature tension. Radiographic cues included an estimate of the position of the centre of femoral head in relation to the tip of the greater trochanter.

The use of templating was variable in the patient group as this was only performed on an AP radiograph of the hips if a calibration marker ball had been used on the preoperative radiograph and was adequately located to minimise error (13). An acetabular and femoral component were templated using Traumacad, (Brainlab AG, Felkirchen, Germany) to best fit the patients anatomical morphology in a position that corrected any preoperative leg length discrepancy. The Tip-Implant distance was measured. This is a measurement of the distance from the shoulder of the implant to the tip of the greater trochanter measured parallel to the anatomical axis of the femur. (Figure 2)

The operative technique of all the surgeons was identical. The hip is approached posteriorly. The femoral neck is osteotomised. After adequate retraction and preparation, the acetabular component is seated. The aim of preparation of the acetabulum is to remove the remaining cartilaginous tissue and present cancellous bone to allow the use of a pressfit component.

The femur is broached sequentially until an adequate interference fit is achieved. In the
Contemporary group once the surgeon felt that the broach was in an appropriate position it was trialled and clinical leg length assessed. Alterations were made thereafter as required. In the Templated group the surgeon had an additional cue in the pre measured Tip-Implant distance to try and reproduce, prior to trial reduction (Figure 3). Thereafter the technique was the same with clinical leg lengths being assessed and adjustments made accordingly.

Over a 12 month period we reviewed radiographs for patients that conformed to our inclusion and exclusion criteria.

The radiographs were assessed for adequacy and measurements were taken after calibration, using a marker ball preoperatively or the femoral head component postoperatively. The diameter of a best fit circle in the contralateral head of the femur allowed all radiographs for each patient to be calibrated to allow comparable measurements to be taken.

The measurements recorded on all the radiographs included the perpendicular distance from the interteardrop line to the lesser trochanter as validated previously (14). The Tip-Implant distance was measured pre- and postoperatively in the Templated group. An assessment of the leg length discrepancy was performed in all hips and we compared this value between both Contemporary and Templated groups.

We tested the hypotheses that the group in which the surgeon had a preoperatively determined the greater trochanter Tip-Implant distance should have a reduced variance and range of values of leg length discrepancy

Statistical analysis

A power analysis was performed on the basis of a pilot study on ten previously performed
total hip replacements. With an alpha value of 0.05 and power of 0.8, a sample size of 20 in each arm would be adequate to detect a difference of 50% in variance between the groups.

Descriptive statistics were reported as a mean and range or standard deviation. Comparison of the mean leg length discrepancy was assessed using the Student’s t test and variance was assessed using Levene’s test for equality of variances. SPSS v 21.0 (IBM, Armonk, USA) was used for statistical analysis and PASS 12 (NCSS, Kaysville, USA) for the power analysis required.

Results
We reviewed the radiographs of 50 consecutive total hip replacements performed at our institution. An adequate preoperative templated plan was recorded in 27 cases. In 20 cases adequate radiographs were available for review and the there had not been any attempt to template the hip replacements preoperatively. In 2 cases the radiographs were inadequate and 2 further cases were excluded for the presence of significant preoperative deformity. The hip replacements used in the study included the Accolade and the Exeter stems and the Trident acetabular system (Stryker, Kalamazoo, USA). There were 24 Accolade/Trident and 23 Exeter/Trident hip replacements.

There was no significant difference in the Contemporary and Templated groups when assessed for age, sex, surgeon or type of implant used.

The mean age of the patients was 67.3 (range 54 to 85). The mean preoperative leg length discrepancy was – 2.0mm(SD 5.8) and -3.7mm(SD 6.6) in the Templated and Contemporary groups respectively (p=0.395), the corresponding postoperative leg length discrepancy in the hips was + 1.1mm(SD 3.9) and +2.9mm(SD 8.1). This was not significantly different between groups (Students t test p=0.326). The postoperative range of leg length discrepancy observed in the Templated group was -6mm to 11mm and in the Contemporary group was -6mm to 21mm.
The mean templated Tip - Implant measurement was 16.1mm (SD 4.5mm) and the achieved mean was 16.5mm (SD 5.2mm). A paired t test suggested a strong correlation in the templated and actual values achieved of 0.749 (p=.0001). There was no significant difference in the mean values (p=0.535, paired t test).

There were 3 hips that were ‘outliers’ in the Contemporary group, seen in figure 4a. There was a significant difference in variances with a Levene’s test for equality F value of 12.0 and p=0.01 when comparing the Contemporary and Templated groups.

Figure 4b reveals the distribution of leg length discrepancy in the Templated group.

Discussion

The mean change in leg length in this study is comparable to previous studies that have reported a range of results for similar measurements from +1mm to +8.2mm (11,14–17). We could not find any study that showed that the spread, variance or range of values was improved with an intervention.

Historically surgeon orientated scoring systems such as the original Harris hip score only acknowledged a discrepancy of greater than 3.2 cm(18). More recent studies have begun to report a discrepancy of greater than 1cm as significant and now quote the percentage of patients that are outside this range as one of their outcome measures(5,12,17,19). There is a recognition that a hip surgeons practice, whether using anatomical cues, intraoperative jigs or computer guided surgery, will produce a normal distribution of leg length discrepancy. The aim we feel should be to have as narrow a spread around the mean value as possible and thereby reduce the likelihood of statistical outliers. The mean change in leg length of a cohort of patients is the most frequently quoted descriptive statistic. We feel the mean value in this situation is not as clinically relevant as a measure of the spread which includes the range of values, the standard deviation or the variance.
Contemporary hip replacement surgical techniques give good results when assessing the mean change in leg length postoperatively as seen in the studies previously published, we feel an emphasis should be placed on reducing the likelihood of outliers that have been reported to have been lengthened by up to 35mm (19).

There are a number of limitations of this type of retrospective study, and the confounding factors such as the type of implant and the surgeon may have an influence on the outcome that failed to reach statistical significance. The intention of the study was however not to determine subtle differences in mean leg length discrepancy, which is not a clinically relevant statistic but to assess the variance of this value, which was achieved.

Conclusion

This study is the first to demonstrate that a simple Tip-Implant measurement taken from a templated radiograph is reproducible intraoperatively and patients that have had it measured as a cohort have a reduced range of leg length difference, and a narrower statistical spread. There is therefore a reduced likelihood of patients having an unacceptably large leg length difference and suffering from the associated morbidity.
References


Figure legends

Figure 1 – The typical distribution of leg length discrepancy in a population of patients following hip replacement surgery, showing ‘outliers’

Figure 2 - An AP radiograph of the hip with digital templating, and blue marker arrow demonstrating the Tip – Implant distance.

Figure 3 – Intraoperative photograph demonstrating measurement of the Tip – Implant distance with the use of a needle and ruler, a white line represents the bone outline

Figure 4a – A graph representing the distribution of leg length discrepancy in the Contemporary group

Figure 4b – A graph representing the distribution of leg length discrepancy in the Templated group
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Number of hips</th>
<th>Radiological measurement</th>
<th>Mean leg length discrepancy (mm)</th>
<th>Range/(SD)</th>
<th>Further results</th>
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<tr>
<td>Austin et al(20)</td>
<td>2003</td>
<td>105</td>
<td>BI – LT</td>
<td>n/a</td>
<td>n/a</td>
<td>87.6% within +/- 1cm</td>
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<td>Eggli et al(7)</td>
<td>1998</td>
<td>100</td>
<td>IT – LT</td>
<td>2</td>
<td>+/- 1mm (1SD)</td>
<td></td>
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<tr>
<td>Gonzalez Della Valle et al(8)</td>
<td>2005</td>
<td>139</td>
<td>IT – LT</td>
<td>2.8</td>
<td>-6 to 20</td>
<td></td>
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<tr>
<td>Khanduja et al(21)</td>
<td>2006</td>
<td>102</td>
<td>IT – LT</td>
<td>1.1</td>
<td>-20 to 17</td>
<td>93% within +/- 1cm</td>
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<tr>
<td>Konyves and Bannister(16)</td>
<td>2005</td>
<td>90</td>
<td>IT – LT</td>
<td>3.5</td>
<td>-22 to 27</td>
<td>62% long by 9mm</td>
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<td>Maloney and Keeney(15)</td>
<td>2004</td>
<td>50</td>
<td>BI – LT</td>
<td>5.6</td>
<td>-12 to 7</td>
<td>82% within +/- 5mm</td>
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<td>Matsuda et al(9)</td>
<td>2006</td>
<td>45</td>
<td>IT – LT</td>
<td>2</td>
<td>+/- 2mm (1SD)</td>
<td>Study group</td>
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<td></td>
<td></td>
<td>47</td>
<td>IT – LT</td>
<td>7</td>
<td>+/- 4mm (1SD)</td>
<td>Control group</td>
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<tr>
<td>Murphy and Ecker(22)</td>
<td>2007</td>
<td>112</td>
<td>IT – LT</td>
<td>1</td>
<td>+/- 5-2 (-20 to 15)</td>
<td></td>
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<tr>
<td>Ranawat and Rodriguez(23)</td>
<td>1997</td>
<td>100</td>
<td>IT – LT</td>
<td>1.9</td>
<td>-7 to 8</td>
<td>87% &lt;=6mm LLI</td>
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<td>Rand and Listrup(24)</td>
<td>1983</td>
<td>40</td>
<td>BI – LT</td>
<td>0.95</td>
<td>+/- 11 (1SD)</td>
<td>T28 THR group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
<td>BI – LT</td>
<td>2</td>
<td>+/- 7mm</td>
<td>Charnley THR group</td>
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<td>Sathappan et al(25)</td>
<td>2008</td>
<td>132</td>
<td>IT – LT</td>
<td>9.87</td>
<td>+/- 5.05mm (1SD)</td>
<td>Spinal anaesthesia group</td>
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<td></td>
<td></td>
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<td>IT – LT</td>
<td>2.75</td>
<td>+/- 2.59 (1SD)</td>
<td>GA anaesthesia group</td>
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<td>Suh et al(26)</td>
<td>2004</td>
<td>96</td>
<td>BI – LT</td>
<td>3.1</td>
<td>-3.9 to 10.2mm</td>
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<tr>
<td>Unnanuntana et al(27)</td>
<td>2009</td>
<td>109</td>
<td>IT – LT</td>
<td>0.9</td>
<td>+/- 6.8mm (1SD)</td>
<td>93.5% within 10mm</td>
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Table 1 – A summary of the previously published studies regarding leg length discrepancy (Abbreviations BI=bi-ischial, LT=lesser trochanter, IT=inter-teardrop)
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>N</th>
<th>Side</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Notes</th>
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<td>Wedemeyer et al(28)</td>
<td>2008</td>
<td>40</td>
<td>IT - LT</td>
<td>2.55</td>
<td></td>
<td>+/-2.37(SD range - 16.67 to 24.03mm)</td>
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<td>White and Dougall(19)</td>
<td>2002</td>
<td>200</td>
<td>IT - LT</td>
<td>n/a</td>
<td></td>
<td>-20 mm to 35mm</td>
<td>143 within 10mm</td>
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<tr>
<td>Williamson and Reckling(29)</td>
<td>1978</td>
<td>12</td>
<td>BI - LT</td>
<td>16.1</td>
<td></td>
<td>9.51 (1SD)</td>
<td></td>
</tr>
<tr>
<td>Woolsen et al(17)</td>
<td>1999</td>
<td>351</td>
<td>IT - LT</td>
<td>1</td>
<td></td>
<td>-20 to +22(SD 4.7mm)</td>
<td>3% over 1cm LLD</td>
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<td>Meemans et al(14)</td>
<td>2011</td>
<td>52</td>
<td>HC - ankle</td>
<td>3.88</td>
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<td>-8 to 9.1</td>
<td></td>
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<tr>
<td>Manzotti et al (12)</td>
<td>2011</td>
<td>48</td>
<td>BI - LT</td>
<td>5.06</td>
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<td>0-12</td>
<td>Computer assisted group</td>
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<td></td>
<td></td>
<td>48</td>
<td>BI - LT</td>
<td>7.64</td>
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Figure 4: Figure4a.tif
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