Influence of leg length discrepancy on clinical results after total hip arthroplasty - A prospective clinical trial

Christian Plaass 1, 2, Martin Clauss 1, Peter E. Ochsner 1, Thomas Ilchmann 1

1 Department for Orthopaedic Surgery, Kantonsspital Liestal, Liestal - Switzerland
2 Department of Orthopaedic Surgery, Hannover Medical School, Hannover - Germany

ABSTRACT: The effect of leg length differences on early clinical outcome after total hip arthroplasty remains uncertain. We performed a prospective study on 94 patients who were evaluated preoperatively and one year after surgery for clinical leg length differences, which were then compared with radiological measurements. The effect of leg length differences on walking ability, limp, pain and patient satisfaction was studied.

The mean clinical leg length difference after operation was 0.05 cm (-1.5 to 1.5, SD 0.5). Clinical and radiological measurements correlated poorly ($\omega=0.36$ pre- and $\omega=0.186$ postoperatively). Patients with a shorter operated leg on clinical assessment were more prone to limping (p<0.05), and patients with a longer leg had more pain compared to patients with equal leg lengths (p<0.05). Walking ability, Harris Hip Score and patient satisfaction were only marginally affected by leg length differences.

Virtually equal leg length was achieved for most patients but small differences had a negative influence in relation to limping and pain. Patients should be counselled pre-operatively about possible leg length differences and associated symptoms.

KEY WORDS: Leg length, Total hip arthroplasty, Limb length, Clinical outcome, Leg length measurement

INTRODUCTION

Leg Length Discrepancy (LLD) is one of the main reasons for patient’s dissatisfaction after total hip arthroplasty (THA) (1-5). The Joint Commission on Accreditation on Healthcare Organizations reported leg length discrepancies as one of the most important adverse effects for orthopaedic surgery, accounting for 4.7% of medical errors (6). LLD can be associated with limping, abnormal gait, low back pain, aseptic loosening and further discomfort (6-8) and has become one of the most common reasons for litigation against orthopaedic surgeons in the USA (1, 4, 9).

LLD can result from structural skeletal differences or from functional factors such as contractures. A sudden change of leg length (LL) following a THA may be more noticeable for a patient than a congenital or slowly developing degenerative LLD. In the early postoperative period after THA subjective awareness of LLD is frequently due to functional factors and may resolve with time (3, 6, 5) but some patients continue to be aware of LLD. The influence of LLD on clinical outcome after THA has been reported, but with conflicting results (4, 10).

There is no clear consensus on definition and measurement of LLD. Various clinical (11) and radiological (12-14) methods have been described with different degrees of agreement between clinical and radiological measurements (11, 15-17).
Radiological methods might be expected to provide precision, but in practice they are not always reliable (2, 13, 18). Most radiological methods do not adequately address functional factors such as flexion, adduction or abduction contractures, and this can lead to errors in determining leg length (19). In addition, some radiological methods require special radiographs or are difficult to perform and therefore impractical. As a result, most surgeons rely on clinical measurements, which are easily performed and cost-effective. From the clinical methods, palpating the iliac crest has the best reproducibility as a proximal landmark (11, 17).

In our prospective study we analysed LLD before and after THA. We hypothesized that affected legs would be shorter before operation and LLD reduced after primary THA. We addressed possible correlation between clinical and radiological leg-length assessment, and the effect of postoperative LLD on walking ability, limping, pain, Harris Hip Score (HHS) and patient satisfaction.

METHODS AND PATIENTS

248 primary THA were implanted from April 2002 to July 2004 at our institution. All patients have standardized preoperative and at 3 month, 1, 2, 5 years and every 5 years thereafter postoperative clinical and radiological follow-up employing the International Documentation and Evaluation System (IDES) and a standardized supine radiograph of the pelvis, centered on the symphysis.

Only unilateral THA was included. Exclusion criteria included further planned surgery on the lower limbs such as contralateral THA or knee replacement, and factors other than LLD influencing gait such as implant revision due to infection or loss of mobility for other reasons. Preoperative patient recruitment depended on the working shifts of two physiotherapists (PTs), who performed all clinical examinations. They selected patients the day before operation according to the inclusion criteria. Informed consent was obtained from all patients before surgery, and none rejected participation.

94 patients were recruited on this basis and examined by the physiotherapists preoperatively and one year postoperatively for LLD and limp independently from the operating surgeon. The mean age at operation was 68.5 yrs (40 to 86, SD 10.4), and 38% of the patients were female. The preoperative diagnosis was primary osteoarthritis in 89%, developmental dysplasia in 3%, posttraumatic osteoarthritis in 3%, femoral head necrosis in 4% and chondromatosis in 1%.

Leg length was measured with the patients standing by palpating the iliac crest and the posterior superior iliac spine. Spacers were placed under the foot until the pelvis was judged to be horizontal and LL was measured in mm (Fig. 1). LLD below 0.3 cm were considered to be equal leg lengths. To compensate for functional deformities such as hip or knee flexion contractures, the opposite site was flexed to the same degree (17).

LLD referred to the operated side with negative values for shorter legs. Change of length was documented, and negative values indicated shortening due to THA.

To assess interobserver reliability of the clinical LLD measurements, 25 patients planned for primary THA and not related to the study, were measured twice by the two physiotherapists. This showed a good interobserver correlation (Spearman r=0.85, p<0.001). The mean difference between the measurements was 0.3 cm (-0.7 to 1.6, SD 0.51).

Radiographic LLD were measured using the perpendicular distance between the inter tear-drop line or (if more appropriate) the most inferior portion of the ischial tuberosity, and the most prominent part of the lesser trochanter (20).

Limping was categorized as absent (=4), little (=3), mild (=2) or severe (=1). A little limping was identified only by the physiotherapists, mild limping was identified by the patient, but did not cause any inconvenience. Severe limping compromised the patient in daily mobility.

Walking ability, pain and patient satisfaction were evaluated by the treating doctor according to the IDES sheet. Walking ability was documented using a five-grade scale: unrestricted walking ability (=5), walking ability 30 to 60min (=4), 10 to 30min (=3), 0 to 10min (=2) and unable to walk (=1). Pain was documented using a five-grade scale, ranging from no pain (=5) to unbearable pain (=1). Patient satisfaction was rated ranging from excellent (=4) to poor (=1).

Detailed preoperative planning (21, 22) of surgery took place. Equalisation of leg lengths was an objective, and operative shortening was avoided to reduce the risk of dislocation. In patients with severe shortening preoperatively (> 3cm), some residual LLD was accepted to avoid damage to neural structures. During preoperative planning LL was referenced to the lesser trochanter (23). The objective was to restore the centre of rotation, not to increase femoral offset and to achieve equal leg lengths. The contralateral side was generally used for reference. After templating the size, position and orientation of the implant, the distance of the lesser trochanter and greater trochanter from the lower edge of the femoral cone was measured.
All patients underwent surgery in the supine position through a lateral transgluteal approach. After inserting the cup and reaming the femur, a trial femoral component was inserted and the distance between the lesser trochanter and the prosthetic cone was measured. In cases of discrepancy with preoperative planning further reaming was performed or a larger implant chosen. A trial reduction was then performed and the hip was examined using fluoroscopy to determine if the planned insertion position had been achieved.

87 cemented stems (55 Mueller straight, 30 Virtec, 2 CDH) and 7 uncemented stems (CLS), combined with 69 uncemented SL2-cups, 19 acetabular reinforcement rings and 6 cemented PE cups were implanted (all Zimmer Inc., Winterthur, Switzerland). A 28 mm ceramic head and a polyethylene inlay was used in all patients, and all femora had the same shape of cone.

57% (54/94) of the operations were done by residents supervised by a consultant, and the remainder by consultants. 18 different surgeons were involved.

**Statistical analysis**

Statistical analyses were performed using SPSS-Software V13 (Chicago, Illinois, USA). Sample size was based on an a priori power analysis for the correlations with a power of 0.8, a significance level of (alpha) 0.05 and a medium effect size of 0.3. A sample size of 82 was required. By assuming a drop out rate of 15%, 12 patients were additionally included. Normal distribution was tested where necessary using the one-sample Kolmogorov-Smirnov Test. Correlation of clinical parameters and LLD were evaluated using Spearman’s r-Test. Non-parametrical data was analyzed using the Mann-Whitney U-Test. The level of significance was set to α<0.05.

**RESULTS**

All 94 preoperatively assessed patients were examined by the two physiotherapists at one year. There were no dislocations, no infections and no other relevant complications that might have affected the clinical outcome.
Clinical measurements

The mean shortening of the operated side before surgery was 0.4 cm (-4.0 to +2.5, SD 0.8). There was no detectable LLD before surgery in 37 (39%) patients. In 13 (14%) patients the affected leg was longer and in 44 (47%) shorter (Tab. I). The LLD exceeded 1 cm in 30 (32%) patients. Comparing pre- and postoperative leg lengths, there was a mean lengthening of 0.4 cm (-1.5 to 3.5, SD 0.7). 36 (38%) patients had no detectable change in leg length after surgery, 49 (52%) lengthening and 9 (10%) shortening. Postoperatively the mean LLD was 0.05 cm (-1.5 to 1.5, SD 0.5). 57 (61%) patients had no LLD, 21 (22%) had a longer and 16 (17%) a shorter operated leg (Tab. I). Three patients had a postoperative LLD of more than 1 cm.

Radiological measurements

The mean LLD was -0.5 cm (-4.1 to 1.4; SD 1.0 cm) preoperatively and 0.02 cm (-2.1 to 1.4; SD 0.7 cm) postoperatively. The mean difference between clinical and radiological measurement was 0.2 cm (-2.8 to 2.0; SD 0.9 cm) preoperatively and 0.03 cm (-2.6 to 1.7; SD 0.8 cm) postoperatively. There was a poor correlation between radiologic and clinical measurements pre- (ω=0.36) and postoperatively (ω=0.186).

Clinical outcome

Preoperative leg length differences had no effect on pre- (p=0.8) and postoperative (p=0.2) walking ability. The change in leg length (p=0.9) and postoperative LLD (p=0.1) did not influence walking ability either (Tabs. II and III).

Patients with shorter affected legs before surgery experienced more limping pre- (p<0.01) and postoperatively (p=0.05). The intraoperative change in LL did not affect residual limping (p=0.6). Postoperatively, patients with shorter operated legs experienced more limping than patients with equal (p<0.01) or longer (p=0.04) operated legs (Tabs. II and III).

Preoperative LLD did not correlate with pain pre- (0=0.8) or postoperatively (p=0.8). The change in LL did not influence postoperative pain levels (p=0.1), but patients with longer operated legs had more pain than patients with equal LL (p=0.002) (Tabs. II and III).

The preoperative LL (p=0.3) and change in LL (p=0.9) did not affect the postoperative HHS. Patients with an equal postoperative LL had a better HHS than patients with shorter operated legs (p=0.04) (Tabs. II and III).

Preoperative LL (p=0.7) and intraoperative change in LL (p=0.2) did not influence patient satisfaction (Tabs. II and III). One year postoperative patient satisfaction was excellent or good in 90 (95%) of the patients (Tab. IV). Only patients with a LLD rated the result as fair, all patients with equal LL rated the operation as excellent or good.

DISCUSSION

Leg length discrepancy after THA has been widely discussed (1-5, 9, 10, 24) but there is no consensus on how to assess it and no threshold value of clinical relevance. In our patients we observed small postoperative leg length discrepancies comparable to other published series (20, 25, 26). Nevertheless, these small discrepancies influenced the clinical outcome one year after THA. Patients with lon-

### TABLE I - DEVELOPMENT OF LEG LENGTH DUE TO OPERATION IN THE PATIENTS AFTER THA

<table>
<thead>
<tr>
<th>preoperative LLD</th>
<th>equal n=57</th>
<th>shorter n=16</th>
<th>longer n=21</th>
</tr>
</thead>
<tbody>
<tr>
<td>equal n=37</td>
<td>29</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>longer n=13</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>shorter n=44</td>
<td>23</td>
<td>15</td>
<td>6</td>
</tr>
</tbody>
</table>

© 2011 Wichtig Editore - ISSN 1120-7000
### TABLE II - PREOPERATIVE LLD COMPARED TO PREOPERATIVE CLINICAL FINDINGS AND POSTOPERATIVE LLD COMPARED TO POSTOPERATIVE RESULT. ALL VALUES ARE EXPRESSED AS MEANS WITH STANDARD DEVIATION IN PARENTHESES. THE P-VALUES WERE CALCULATED USING THE SPEARMAN-RHO-TEST

<table>
<thead>
<tr>
<th></th>
<th>equal</th>
<th>shorter</th>
<th>longer</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preoperative LLD vs. preoperative findings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking ability (/5)</td>
<td>2.9 (1.3)</td>
<td>3.0 (1.3)</td>
<td>3.1 (1.3)</td>
<td>0.8</td>
</tr>
<tr>
<td>Limp (/4)</td>
<td>2.4 (1.0)</td>
<td>2.0 (0.8)</td>
<td>2.4 (0.8)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Pain (/5)</td>
<td>2.1 (1.0)</td>
<td>2.3 (1.1)</td>
<td>2.2 (0.7)</td>
<td>0.8</td>
</tr>
</tbody>
</table>

| **Postoperative LLD vs. postoperative findings** |       |         |        |         |
| n=58                 |       |         |        |         |
| Walking ability (/5) | 4.3 (1.1) | 4.2 (1.3) | 4.2 (0.9) | 0.1     |
| Limp (/4)            | 3.7 (0.7) | 3.1 (0.9) | 3.6 (0.5) | 0.05    |
| Pain (/5)            | 4.7 (0.6) | 4.6 (0.6) | 4.3 (0.7) | 0.05    |
| HHS (/100)           | 88 (12)  | 83 (12)  | 85 (12)  | 0.4     |
| Satisfaction (/4)    | 3.6 (0.5) | 3.3 (0.7) | 3.3 (0.7) | 0.8     |

### TABLE III - CHANGE IN LEG LENGTH AND POSTOPERATIVE RESULTS. VALUES ARE EXPRESSED AS MEANS WITH STANDARD DEVIATION IN PARENTHESES. THE P-VALUES WERE CALCULATED USING THE SPEARMAN-RHO-TEST

<table>
<thead>
<tr>
<th></th>
<th>equal</th>
<th>shortening</th>
<th>lengthening</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking ability (/5)</td>
<td>4.2 (1.2)</td>
<td>4.2 (1.0)</td>
<td>4.3 (1.1)</td>
<td>0.9</td>
</tr>
<tr>
<td>Limp (/4)</td>
<td>3.7 (0.6)</td>
<td>3.6 (0.5)</td>
<td>3.5 (0.8)</td>
<td>0.6</td>
</tr>
<tr>
<td>Pain (/5)</td>
<td>4.8 (0.5)</td>
<td>4.7 (0.7)</td>
<td>4.5 (0.7)</td>
<td>0.1</td>
</tr>
<tr>
<td>HHS (/100)</td>
<td>88 (10)</td>
<td>85 (11)</td>
<td>85 (14)</td>
<td>0.9</td>
</tr>
<tr>
<td>Satisfaction (/4)</td>
<td>3.4 (0.5)</td>
<td>3.2 (0.7)</td>
<td>3.5 (0.6)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### TABLE IV - PATIENT SATISFACTION VS. LEG LENGTH DIFFERENCE AT THE ONE-YEAR CONTROL. ALL VALUES ARE GIVEN AS PERCENTAGE OF PATIENTS FROM THE CORRESPONDING LLD

<table>
<thead>
<tr>
<th></th>
<th>equal</th>
<th>shorter</th>
<th>longer</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>excellent</td>
<td>55%</td>
<td>37.5%</td>
<td>40%</td>
</tr>
<tr>
<td>good</td>
<td>45%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>fair</td>
<td>0%</td>
<td>12.5%</td>
<td>10%</td>
</tr>
<tr>
<td>poor</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Leg length difference after THA

ger operated legs clinically had more pain, whilst patients with shorter operated legs exhibited more limping. Our study has some limitations. Although none of our selected patients was scheduled for an operation on the lower extremity during the study, and severe skeletal deformities were excluded, unrecognized asymptomatic concomitant diseases such as knee osteoarthritis or pes planovalgus might have influenced the clinical outcome and the measured LL. In addition, not all preoperative deformities around the hip may have been corrected by surgery. These factors were not evaluated in detail, but their effects were probably evenly distributed on all. Tall or short stature might have been expected to influence outcomes in relation to LLD, but we did not observe an effect. However, the effect of LLD may also be influenced by the width of the pelvis, and therefore the distance between the centres of rotation. This aspect should form the basis of further study. Clinical leg length measurements regarding intra- and interobserver reliability, proved to be accurate in our study. Supine pelvic radiographs permit reference only to the lesser trochanter and do not allow an analysis of the whole leg length, which was measured clinical. As deformities and contractures of the hip were expected to improve after operation, we expected better correlation of the radiological and clinical measurements postoperatively than preoperatively (27, 28), but the correlation was still poor after operation. Standing pelvic or full leg length radiographs instead of supine pelvic radiographs might have improved the correlation. Scanograms or computed tomograph scout views may address LL better, but they are less practical to use, they are taken non-weight-bearing and they are still sensitive to functional factors. The value of such methods remains unproven (13, 18, 29). No available radiographic technique allows a comprehensive analysis of the LL. Thus, in daily practice clinical LLD measurement is still most commonly used. Preoperative shortening is frequently caused by degenerative changes (20, 26). The higher incidence of preoperative limping among patients with a shorter leg may be explained by advanced disease and deformity of the hip (30). During clinical evaluation of leg length, palpation of the iliac crest is reliable (11, 16, 17) and correlates better with patients’ perception than radiologic data (29). Therefore a combination of both measurement methods together with evaluation of other factors such as fixed scoliosis needs to

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Number of patients</th>
<th>Planning technique</th>
<th>LL-measuring method</th>
<th>Preoperative LLD (mm)</th>
<th>Postoperative LLD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manzotti et al., 2009 (31)</td>
<td>48</td>
<td>Computer-assisted Intraoperative level of feet and distance greater trochanter-pin in ilium</td>
<td>Trochanter minor height on pelvic x-ray</td>
<td>12,17* ± 5,93</td>
<td>5,06* ± 2,99</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td></td>
<td>11,94* ± 6,80</td>
<td>11,94* ± 6,80</td>
<td>7,65* ± 4,36</td>
</tr>
<tr>
<td>Unnanuntana et al, 2008 (25)</td>
<td>109</td>
<td>Preoperative planning</td>
<td>Trochanter minor height on pelvic x-ray</td>
<td>- 4,7 ± 7,0mm</td>
<td>0,9 ± 6,8</td>
</tr>
<tr>
<td>Suh et al, 2004 (26)</td>
<td>96</td>
<td>Preoperative planning</td>
<td>Trochanter minor height</td>
<td>- 5,6 (-22 to -2,2)</td>
<td>3,1 (-3,9 to 10,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Trochanter minor height on pelvic x-ray</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woolson et al, 1999 (20)</td>
<td>351</td>
<td>Preoperative planning</td>
<td>Trochanter minor height on pelvic x-rays</td>
<td>-2,9 (-54 to 21)</td>
<td>1,0 (-20 to 22)</td>
</tr>
<tr>
<td>Konyves, Bannister, 2005 (10)</td>
<td>90</td>
<td>n.n.</td>
<td>Trochanter minor height on pelvic x-rays</td>
<td>5,7 (-40 to 16)</td>
<td>3,5 (-22 to 27)</td>
</tr>
<tr>
<td>Plaass et al, 2011</td>
<td>94</td>
<td>Preoperative planning</td>
<td>Clinical leg length measurement</td>
<td>-4 ± 8</td>
<td>0,5 ± 5</td>
</tr>
</tbody>
</table>
be integrated in preoperative planning prior to THA. Good preoperative planning and intraoperative care can result in a reasonable range of postoperative leg length differences (20, 25, 26, 31) (Tab. V). Navigation may reduce variation further (31), but the value of such techniques is not yet proven.

Approximately one third of the patients report LLD after THA, 50% of them being adversely affected (2, 5). Symptomatic patients tend to have a larger LLD (2) or a higher probability of measurable LLD (5) on examination. The threshold of postoperative LLD influencing clinical results is unclear. Minimal differences (32, 33) can be relevant, but some authors accept differences up to 12mm (34, 35). We were not able to demonstrate a clear cut-off value for LLD leading to symptoms. Other factors such as activity level or degenerative changes in the spine or other joints may be of importance.

We observed that clinically equal leg length was associated with the best functional results and highest satisfaction rates. A shorter operated leg was associated with limping, as others have noted (36, 37) and patients with a longer operated leg had more hip pain (28). We cannot be sure whether increased pain related to lower satisfaction, but we believe the detected difference in pain can be attributed to the LLD. Lengthening may cause an over-tensioning of soft tissues and an increased mechanical load, which may explain the discomfort (38). Even small amounts of lengthening appear to lead to symptoms, but do not influence gait (35, 37). Shortening is more likely to affect gait because of reduced tension in the abductors (36, 37), and is an independent risk factor for patient dissatisfaction after THA (39).

A patient centered score (Oxford Hip Score) has been noted to be sensitive to the relationship between outcome and LL (5, 10), whereas the surgeon-based Harris Hip Score (HHS) is not (4). We found no significant differences in the HHS, but differences in specific parameters (pain and limp), when correlated to LL. Differences in sensitivity of these scores and a lack of agreement between surgeon and patient based assessment may be the explanation (40, 41).

CONCLUSION

Both, longer and shorter legs have an impact on clinical outcome and patient satisfaction after THA. LLD can occur after THA for various reasons and patients should be counselled pre-operatively about this potential risk and possible effects on overall outcome.

ACKNOWLEDGMENTS

The authors wish to thank Ruth Bitterli for patient management and examination and Silke Panhorst for her help with statistical analysis.

Financial support: There was no financial support for this study.

Conflict or interest: One or more of the contributing authors (PEO) and their institution have received funding from Zimmer AG®, Winterthur, Switzerland for educational and research purposes not directly related to this study.

Address for correspondence:
Christian Plaass, MD
Hannover Medical School, Department of Orthopaedic Surgery
Anna-von-Borries Str. 1-7
30625 Hannover, Germany
Christian@Plaass.info

REFERENCES

Leg length difference after THA


Plaass et al
