COMPARISON OF GAIT PARAMETERS IN PATIENTS WITH TOTAL HIP ARTHROPLASTY FOLLOWING DIRECT LATERAL AND ANTEROLATERAL SURGICAL APPROACH

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ABSTRACT
In 20 patients with unilateral osteoarthris, who underwent total hip arthroplasty (THA) using a direct-lateral approach and in 19 patients with unilateral hip osteoarthritis, who underwent THA using an antero-lateral approach, the gait was analyzed using a zebris ultrasound-based three-dimensional motion analysis system. The constant gait speed was 2.5 km/h. The spatial-temporal angular and kinetics parameters determined preoperatively and 3, 6, and 12 months after THA are compared to each other and to the gait parameters of 20 healthy, elderly subjects. The aim of this study is to determine how selected gait parameters change as a result of total hip arthroplasty at constant gait speed, to examine the effects of the surgical procedure on the biomechanics of gait twelve months postoperatively and to perform comparisons between gait parameters determined 3, 6, 12 months after THA and those of healthy persons, before THA asymmetry was observed in spatial-temporal parameters, in hip motion, in knee motion, as well as in kinetical parameters. The study showed that increased pelvic obliquity and flexion-extension worked as compensation. It seems that the range of pelvic rotation was not involved, even in our patients with unilateral osteoarthritis of the hip joint. Almost all of the patients who underwent THA using a DL approach have limitation of hip motion, increasing of pelvic rotation, and asymmetry of loading. In contrast, most of AL patients exhibited gait patterns that most resembled the control group, indicating a better outcome when using the AL approach. These findings are based on gait parameters at twelve months postoperatively. The greatest improvements have been shown to occur during the first year after operation, but improvement in gait ability continues over one or two years postoperatively. Therefore, with monitored rehabilitation, with strengthening hip extensors and with stretching hip joints could improve the provision of a more normal gait.

KEY WORDS
Biomechanics, gait analysis, osteoarthritis, total hip arthroplasty (THA)

1. Introduction
Total hip arthroplasty (THA) is a surgical procedure that usually results in a marked decrease in pain and in a concomitant improvement of the functional capacity of patients [31, 32]. It is widely acknowledged that nearly complete pain relief is achieved early after THA. Following THA, functional recovery takes place early and patients can usually walk unassisted after three months. Thereafter, however, functional improvement is slower and full recovery is never likely to be achieved. Despite the success of the operation, the gait characteristics may not return to normal up two [29, 30, 31, 37] and even four [4, 22] years after operations. Post-operative gait is not a level that would be considered normal, because it seems that there is a loss of terminal extension of the operated hip during the late stance [10, 21, 29, 30, 31, 37, 38], of hip flexor and extensor moments and of hip abductor moment of force [38], as well as a decrease in the energy developed at the hip in the sagittal plane [22, 35]. In addition, total hip arthroplasty modifies the motion of neighboring joints. Several studies established an associated increase in the sagittal motion of the pelvis and the ipsilateral knee and ankle from 6 to 18 months after surgery, but the differences are not significant [10, 21, 31, 33, 41]. Miki et al. [26] established that the compensatory mechanism greatly involved the pelvic joint.

Two common surgical approaches are used in THA. The direct-lateral (DL) approach used in this study was a Hardinge-Bauer approach, that is a straight longitudinal incision above the greater trochanter [6]. The antero-lateral (AL) approach used in this study was a Watson-Jones approach, that is a curved incision starting distally
and behind the spina iliaca anterior superior, above the gluteus medius to the greater trochanter and the femur.

Most of previous studies analyzed in case of one approach the effects of total hip arthroplasty on the biomechanical parameters of gait [3, 4, 9, 10, 14, 15, 21, 22, 25, 26, 29, 30, 35, 36, 37, 38]. Only few studies [8, 11, 23, 34, 40] have addressed how the different surgical approaches affect the biomechanical parameters on gait. The AL approach has been shown to produce more positive results in static Trendelenburg tests, an indication of hip abductor dysfunction, then the DL approach [40]. Ritter et al. [34] found no difference in post-operative limp between the antero-lateral and posterior-lateral approaches. Madsen et al. [23] established that the gait parameters of patients who underwent THA using the AL approach were better after six months after operations, compared to the parameters of patients who underwent THA using the posterior-lateral approach.

In previous studies, patients walked at a self-selected walking speed on level ground or on treadmill [3, 4, 8, 9, 10, 13, 14, 15, 21, 22, 23, 25, 26, 28, 29, 30, 34, 35, 36, 37, 38, 40]. The gait parameters are speed-dependent [2, 27]. For these reasons, in the present study, gait parameters were determined using a three-dimensional gait analysis at constant gait speed.

The purpose of this study was (1) to examine the effects of the surgical procedure on the biomechanics of gait twelve months postoperatively at a constant gait speed; (2) to perform comparisons between gait parameters determined 3, 6, 12 months after THA and those of healthy persons.

2. Materials and methods

2.1 Patients

The gait patterns of three groups of adults were evaluated. The population of the healthy group consisted of 9 women and 12 men. Their mean age was 61.15 years (SD ± 9.14 years), the mean weight 77.23 kg (SD ± 13.12 kg), and the mean height 1.74 m (SD ± 0.22 m). These subjects had no history of osteoarthritis of the knee joint and the hip joint, knee instability or major lower extremity joint surgery. These individuals had normal strength, full range of motion of lower extremities and no neurological deficiencies.

The population of patients, who underwent THA using a direct-lateral approach consisted of 10 women and 10 men. Their mean age was 71.8 years (SD ± 7.51 years), the mean body weight was 72.3 kg (SD ± 8.34 kg), and the mean height was 1.68 m (SD ± 0.23m) at the time of surgery. All patients were seriously limited in their activities due to the pain. The severity of osteoarthritis of the hip joint was determined by the Kellgren and Lawrence radiographic index [17], a 5-point scale (0-4) on the basis of anteroposterior and Laustein X-ray projections. The Kellgren and Lawrence radiographic index of 18 patients with hip osteoarthritis was 4, the Kellgren and Lawrence radiographic index of 2 patients with hip osteoarthritis was 3. The population of patients who underwent THA using the antero-lateral approach consisted of 11 women and 8 men. Their mean age was 73.5 years (SD ± 75.3 kg (SD ± 1.1 kg), and the mean height was 170.6 cm (SD ± 1.16 cm) at the time of surgery. All patients were seriously limited in their activities due to the pain. The Kellgren and Lawrence radiographic index of 16 patients with hip osteoarthritis was 4, the Kellgren and Lawrence radiographic index of 3 patients with hip osteoarthritis was 3.

All patients were classified as having severe osteoarthritis of the hip joint. It means they have large osteophytes, marked joint space narrowing, severe sclerosis and definite bone contour deformity. None of the patients had any symptoms involving the contralateral hip, lumbar vertebrae, knees or ankles.

Subjects in the DL and AL groups had the THA performed at Orthopaedics Clinic of Semmelweis University (Budapest, Hungary) by one of two experienced surgeons. All patients received a cemented Müller-type hip endoprosthesis with an all-polyethylene socket. No significant differences in construct offset and leg length were noted. Full weight bearing was started on the third day postoperatively, and all patients were discharged without a walking aid within 2 weeks after surgery. We did not impose special rehabilitation requirements on any of the patients after they were discharged from our department. Thus, all subjects received only standard rehabilitation care.

2.2 Methods

Spatial coordinates for the determination of kinematic data were collected using an ultrasound-based Zebris CMS-HS system (ZEBRIS, Medizintechnik GmbH, Germany) at the Biomechanical Laboratory of the Department of Applied Mechanics at the Budapest University of Technology and Economics. The measuring head with three sensors is positioned behind the individual and the five ultrasound triplets with three active markers on each are placed on the sacrum, the left and right thighs, and the left and right calves (Figure 1). The data, obtained from the measuring system recording the active markers, allowed for the determination of coordinates of optional anatomical points of the lower limb, (e.g. medial and lateral malleolus, the heel, the head of fibula, the tibial tubercle, the medial and lateral femoral epicondyle, greater trochanter the left and right anterior superior iliac spine and sacrum) [19]. The spatial coordinates were recorded at a frequency of 100Hz. The absolute error of our ultrasound-based system is less than 1mm [18]. The measuring method was developed by Kocsis [20].

The ground reaction forces were recorded by the multicomponent measuring platform with two force plates (1504 force-cells in each force plate), which are integrated into the motorized and instrumented 330 mm * 1430 mm treadmill (Bonte Zwolle B.V, Austria). The ground forces were measured at 1000 Hz. Walking on the
treadmill can initially be an unfamiliar experience, which in turn may influence the parameters measured. Therefore, measurements are to start after six minutes of familiarization time [1]. The measurement was performed at constant gait speeds of 2.5 km/h. Biomechanical data were collected for six gait cycles.

The assessment parameters are the following:
- Temporal and spatial parameters: stance, swing and double stance phase in percent of gait cycle; step length, step width (in centimetres); cadence (steps per minute)
- Angular parameters: knee, hip and pelvic angles, [2].
- first peak force (F1) in the early stance phase and the second peak force (F2) in the late stance phase (in percent of body weight)

The investigated force parameters are the. The parameters above are calculated by a software package presented first in [16].

Statistical analyses were performed using the computer software named Statistica (version 7, 2004.). For each subject, the average and the standard deviation of parameters were determined from six complete gait cycles, and these data were further processed. Data values are presented as mean ± SD for healthy subjects and for patients. A one-sample t-test was applied when comparing the results of patients preoperative and postoperative and a two-sample t-test when comparing the results for healthy people and patients with osteoarthritis. The overall comparison of gait patterns between the groups was made by multivariate analysis of variance (Wilk’s Λ). Results present statistically significant differences if p < 0.05.

3. Results

All investigated subjects were able to walk on the treadmill at a speed of 2.5 km/h. The spatial-temporal parameters are summarized in Table 1, the angular parameters in Table 2 and the kinetical parameters in Table 3.

4. Discussion

The influence of the type of surgical approach on 12 months postoperative gait was investigated by comparing the data of patients who underwent THA by either the direct-lateral (Harding-Bauere) approach or the anterolateral approach (Watson-Jones) approach. These two approaches affect different structures around the hip, which led to the hypotheses that two groups would have different postoperative gait characteristics. The effects of osteoarthritis of the hip are analysed by Bejek et al. [2] in detail. In this study we analyzed the effects of different approaches.

It was previously reported that the greatest improvements of spatial-temporal parameters (such as cadences, step length, step width, double support phase and time of swing phase) had occurred within the first six months after unilateral THA [26, 31, 41]. The type of approach influences the recovery of spatial-temporal parameters, as the step length, time of double support phase, and of swing phase of patients who underwent THA using the DL approach are similar to healthy subjects at six month postoperatively, and the symmetry of parameters recover only one year after operation (Table 2). However, the step length of patients who underwent THA using the AL approach did not show significant differences at three months after operation, and the symmetry of parameters recover partly three months (step width, swing phase) and partly six months (step length) after operation (Table 1). This may occur when the recoveries of strength of severed muscles and of proprioception are different [8, 11, 21, 40].

Several studies report that the residual limitation of hip extension (compared to normal) persists for one year after THA using the DL approach [21, 41]. The range of hip joint’s motion would reflect differences between the approaches affecting the hip muscles and the joint capsule [11, 12, 23]. The reduction of hip motion range and maximum hip extension on the operated side at the DL group tended to persist even compared with healthy subjects and with the non-operated side at twelve months after surgery (Table 2). Decreased and asymmetrical motion of the hip joint of the AL group did not show at twelve months after THA (Table 2). Reduced hip motion has attributed in the OA to pain inhibition [15, 31], the pain is not a factor following the surgery. It has been postulated that the reduced hip motion at the DL group would be due to the differences in the hip joint capsule and strength of muscles following THA [33]. The reduced hip motion might be a possible cause of asymmetrical loading, as shown by kinetical parameters (Table3). These findings are in line with the results presented by McCrory et al. [25]. These findings strengthen the opinion that the weakness of severed muscles and as a result, the decreased proprioception of the DL group changed the biomechanical parameters of gait. The cause of hip motion difference could be the result of hip contracture after the DL approach [38], because the muscles of
gluteus medius and minimus are severed during the DL approach.

The asymmetric motion of knee extension could be observed one year after operation (Table 2) at both patient groups. Our findings supported the results of Foucher et al. [10] that the decreased knee extension at the operated side might result from the defence of operated hip joints. Synchronous motion of the hip joint and pelvic were also reported in normal people previously [7], so it is inadequate to consider this linkage as simply a compensatory mechanism. Preoperative increased pelvic obliquity and flexion-extension (tilt) were detected (Table 2). Unilateral THA could change the compensation mechanism during the postoperative period. The type of approach also influences the motion of the pelvic during the postoperative period. At the DL group the rotation of the pelvic plays a more significant role in compensation mechanisms in the late postoperative period than in the preoperative one and in the early months of the postoperative period (Table 2). The asymmetric movement of hip flexion, range of knee motion and knee flexion observed before surgery showed a recovery by twelve months postoperatively, and the inverse correlation between the hip motion and pelvic obliquity and pelvic tilt (flexion-extension) are not significant, either, by six months (Table 2). At the AL group the rotation of the pelvic plays a more significant role in compensatory mechanisms in the early months of the postoperative period than in the late one (Table 2). The role of pelvic rotation decreases with increases of hip motion of the affected side, the rotation of pelvic at patients is similar at twelve months after operation as that of healthy subjects (Table 2). The inverse correlation between hip motion and pelvic obliquity and pelvic tilt could not show in the postoperative period, because both pelvic motions are decreased after the surgery; however, there is no significant difference in six months after surgery (Table 2). Therefore, this study suggested that unilateral THA could reverse the influence on other joints prior to the symmetrical normalization of hip motion. This study also suggested that the approach of unilateral THA could change the motion of the pelvic.

5. Conclusion

Almost all of the patients who underwent THA using a DL approach have limitations of hip motion, increasing pelvic rotation, and asymmetry of loading. In contrast, most of AL patients exhibited gait patterns that most resembled the control group, indicating a better outcome when using the AL approach. These findings are based on the gait parameters at twelve months postoperatively. The greatest improvements have been shown to occur during the first year after operation, but improvement in gait ability continues over one or two years postoperatively [21, 37, 41]. Therefore, with monitored rehabilitation, with strengthening hip extensors and with stretching hip muscles could improve and provide a more normal gait.

Acknowledgements

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References

[38] R.M. Kiss, L. Kocsis & Zs. Knoll, Joint kinematics and spatial temporal parameters of gait measured by an ultrasound based system, Medical Engineering & Physics, 26, 2004, 611-620.
Table 1 Results of temporal and spatial parameters in healthy subjects and in patients with osteoarthritis of the hip joint preoperative and postoperative 3, 6, and 12 months. 

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Preoperative</th>
<th>Postoperative 3 months</th>
<th>Postoperative 6 months</th>
<th>Postoperative 12 months</th>
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</thead>
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<tr>
<td>Cadence (Step/minute)</td>
<td>94.5 ±20.7</td>
<td>96.8 ±18.9</td>
<td>94.8 ±17.1</td>
<td>95.1 ±15.5</td>
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<td>A 499.9 ±54.9</td>
<td>487.7 ±65.6</td>
<td>498.3 ±55.5</td>
<td>492.1 ±56.3</td>
<td>500.3 ±89.3</td>
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<td>B 477.4 ±55.3</td>
<td>449.3 ±67.7</td>
<td>456.2 ±58.7</td>
<td>475.7 ±68.1</td>
<td>477.1 ±73.3</td>
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<td>Step length (mm)</td>
<td>22.5 ±1.3</td>
<td>36.9 ±1.3</td>
<td>38.4 ±1.5</td>
<td>17.6 ±1.1</td>
</tr>
<tr>
<td>ASV</td>
<td>20.8 ±2.2</td>
<td>39.2 ±16.8</td>
<td>35.6 ±15.7</td>
<td>22.6 ±11.6</td>
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<tr>
<td>Swing phase (percent of gait cycle)</td>
<td>20.9 ±1.9</td>
<td>18.3 ±3.3</td>
<td>15.6 ±1.5</td>
<td>19.9 ±1.9</td>
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<tr>
<td>Double support phase (percent of gait cycle)</td>
<td>35.7 ±5.6</td>
<td>36.7 ±2.7</td>
<td>32.4 ±2.1</td>
<td>35.6 ±1.8</td>
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<td>Swing phase (percent of gait cycle)</td>
<td>32.4 ±5.5</td>
<td>30.6 ±4.5</td>
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<td>33.3 ±2.6</td>
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<td>Step width (mm)</td>
<td>3.2 ±0.4</td>
<td>2.1 ±0.6</td>
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<tr>
<td>ASV</td>
<td>27.9 ±8.7</td>
<td>41.3 ±18.1</td>
<td>39.9 ±14.7</td>
<td>25.7 ±7.6</td>
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<tr>
<td>Swing phase (percent of gait cycle)</td>
<td>3.3 ±0.3</td>
<td>6.1 ±0.6</td>
<td>2.1 ±0.6</td>
<td>1.0 ±0.4</td>
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<tr>
<td>Double support phase (percent of gait cycle)</td>
<td>4.9 ±1.3</td>
<td>4.4 ±0.3</td>
<td>3.6 ±0.3</td>
<td>0.6 ±0.2</td>
</tr>
</tbody>
</table>

A: non-dominant side at healthy people, OA side at patients with osteoarthritis and THA side at patients after the operation. 
B: non-dominant side at healthy people, OA side at patients with osteoarthritis and THA side at patients after the operation. 

ASV: asymmetry value; 
1 significant difference comparing to healthy subjects; 
2 significant difference comparing to patients with hip osteoarthritis preoperative; 
3 significant difference comparing the healthy side (contralateral side) to the OA side or to the THA side 
4 significant difference comparing the both patients groups each to other (patients with DL approach to patients with AL approach)
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<th>Parameters</th>
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<th>Postoperative</th>
<th>Patients with AL approach</th>
<th>Postoperative 3 months</th>
<th>Postoperative 6 months</th>
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<td>Hip angle (degree)</td>
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<td>23.5 ±9.8</td>
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<td>35.9 ± 5.6</td>
<td>39.9 ± 9.3</td>
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<td>36.1 ±7.5</td>
<td>42.9 ± 11.3</td>
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<td>B</td>
<td>40.9 ±7.1</td>
<td>4.3 ±5.6</td>
<td>9.3 ± 4.5</td>
<td>22.4 ±7.6</td>
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<td>41.2 ± 7.3</td>
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<td>80.1 ± 16.5</td>
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<td>44.2 ±12.4</td>
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<tr>
<td></td>
<td>B</td>
<td>8.9 ± 3.0</td>
<td>1.9 ± 0.9</td>
<td>3.4 ±4.1</td>
<td>7.6 ±3.9</td>
<td>8.4 ± 5.8</td>
<td>10.2 ±4.1</td>
<td>10.6 ±3.9</td>
<td>8.5 ± 3.9</td>
</tr>
</tbody>
</table>

Table 2 Results of angular parameters in healthy subjects and in patients with osteoarthritis of the hip joint preoperative and postoperative 3, 6, and 12 months.
Table 3: Results of kinetical parameters in healthy subjects and in patients with osteoarthritis of the hip joint preoperative and postoperative 3, 6, and 12 months.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Preoperative</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: dominant side at healthy people, contralateral (healthy) side at patients</td>
<td>118.5 ±13.4</td>
<td>107.6±20.6</td>
<td>108.9±16.6</td>
<td>114.3 ±5.6</td>
</tr>
<tr>
<td>B: non-dominant side at healthy people, OA side at patients with osteoarthritis and THA side at patients after the operation</td>
<td>116.5 ±14.8</td>
<td>103.6±20.3</td>
<td>105.1 ±3.2</td>
<td>108.4±19.4</td>
</tr>
</tbody>
</table>

Significant difference comparing the healthy side (contralateral side) to the OA side or to the THA side:

- Significant difference comparing healthy subjects:
- Significant difference comparing to patients with hip osteoarthritis preoperative:
- Significant difference comparing to patients with AL approach versus DL approach:
- Significant difference comparing the both patients groups each to other (patients with DL approach to patients with AL approach)