Position of the Centre of the Hip Joint and the Greater Trochanter after Total Hip Replacement Surgery and its Influence to Limping

Marinko Erceg1*, Ivica Grković2, Mihajlo Lojpur3 and Stjepan Jagić4
1Private Orthopaedic Surgery Clinic, Marinko Erceg Pty. Ltd., Croatia
2Department of Anatomy, Histology and Embryology, University of Split, Croatia
3Department of Anaesthesiology and Intensive Care, University of Split, Croatia
4Department of Pedagogy, University of Zadar, Croatia

Aim: Most patients are pain-free and do not limp following the total hip replacement (THR) surgery. However, a percentage of patients still continue to limp despite not being in pain. Using a new approach to demonstrate biomechanical properties of the hip joint, we wish to offer an explanation for persistent limping following the surgery and how to prevent it or minimise it.

Methods: Among numerous patients that had undergone a total hip replacement surgery, 12 patients were included into our study. All of them had developmental dysplasia and secondary arthritis in one hip joint, while the other joint was normal.

All of them were limping and were in pain before the surgery. Following the THR surgery, all patients included in our study were pain-free but limping did not disappear. Limping was confirmed on examination at least 6 months after the surgery.

Radiographs of the pelvis (with both hip joint visible) were taken before and after the surgery so that biomechanical properties could be calculated.

Results: Developmental dysplasia led to significant lateral and cranial shifts of the hip joint centre. THR surgery annulled lateral shift but neither the centre of the hip nor the tip of greater trochanter could be 'lowered' to the level of the normal side. Centre of the hip and greater trochanter were on average still 10% and 9% higher than on the normal side, consecutively.

Conclusion: Higher position of the hip joint centre and of the greater trochanter are reasons for shortening of vertical lever \( k_2 \) and for relative insufficiency of the hip abductor muscles affecting hip biomechanics ultimately leading to limping. It appears that in some cases a complete ‘lowering’ of features on the femoral proximal ending cannot be achieved by THR surgery and this is the cause for persistent limping.

INTRODUCTION

Normal functioning of the hip joint requires good condition (and matching) of articular facets, optimal angle alignment (of the neck-shaft and anteversion angles) and normal functioning of associated muscles, particularly abductors. These parameters should also be taken into consideration when a total hip replacement (THR) surgery is performed with the aim of achieving a pain-free walk without limping.

In adult, the tip of the greater trochanter is at the same (horizontal) level as the centre of the hip joint. According to Pauwels’ theory of hip biomechanics, the balance in the hip can be compared with a scale whose fulcrum is in the centre of the hip while levers are not equidistant. The equilibrium (\( M_1 = M_2 \)) is expressed as \( M_1 = k_1 \cdot G \) (G=body weight), while \( M_2 = k_2 \cdot F \) (F=muscle force of the hip abductors). Since lever \( k_1 \) is about three times longer than lever \( k_2 \), the muscle force of abductors (F)
should be three times greater than the body weight (G). Hence, while standing on one leg, the weight bearing on that hip (force \( R \)) is about four times greater than the body weight. According to Pauwels, the force \( R \) in adults has a 16° inclination angle in the frontal plane [1]. In \( \text{coxa valga/vara} \) and in hip dislocation (lateral shift of the femoral head), the above mentioned levers change and hip biomechanics can be explained using this approach. However, in hip dislocation, not only that the head of the femur moves laterally (causing lengthening of \( k_1 \)) but it also shifts cranially, which additionally affects the hip balance and causes limping. Pauwels’ method does not take this cranial shift into consideration and it seems reasonable that a vertical lever \( k_2 \) causes limping. Pauwels’ method does not take this cranial shift into consideration and it seems reasonable that a vertical lever \( k_2 \) causes limping.

Lengthening of horizontal lever \( k_1 \) and shortening of vertical lever \( k_2 \) have a negative effect on the biomechanical properties of the hip joint resulting with an increase of its loading. That is demonstrated in following formula:

\[
R = \frac{G \cdot k_1}{k_2 \cdot \sin \gamma}
\]

(1)

(\text{where } \gamma \text{ is an angle of 'bending' of force } \textbf{R})

Hip dislocation affects joint biomechanics and causes limping which is often ignored by a child, tolerated by an adolescent and of most concern to an adult. Hip dislocation leads (sooner or later) to the secondary arthritis and that is when limping becomes associated with the pain. The degree of dislocation can be graded as dysplasia, subluxation or luxation and it always leads to the secondary arthritis. According to Hartofilakidis et al., there are 3 types of dislocation with secondary arthritis: type I - acetabulum is shallow but femoral head is still located in it; type II - femoral head is shifted to the false acetabulum (neoacetabulum), but inferior part of femoral head is still in contact with true (natural) acetabulum and type III - total dislocation, femoral head has no contact with true (natural) acetabulum [4].

In all cases of dislocation, both head of the femur and greater trochanter are shifted laterally and cranially, and limping is constant. The limping is worse as the degree of dislocation is greater.

As we do a surgical procedure for open reduction of the dislocated hip joint in child to restore normal biomechanics, on the same way we must think about hip biomechanics when we do the total hip replacement surgery (THR) in patients with secondary arthritis after developmental dysplasia of the hip (DDH). It means that after surgery the horizontal lever \( k_1 \) must be shorter (\( k_1 \) is longer because of lateral femoral head shift) and the vertical lever \( k_2 \) must be longer (\( k_2 \) is shorter because of cranial femoral head shift on dislocated side). If we did not achieve this after THR surgery, we did not restore hip biomechanics and limping exists. Particularly it is important how “high” is the top of greater trochanter and the center of hip prosthesis in relation to the normal hip. We analysed these parameters in our patients, because of limping after THR surgery.

**MATERIALS AND METHODS**

Among numerous patients that had undergone a THR surgery at the University hospital in Split in last five years, 12 patients that fulfilled listed inclusion criteria were chosen for our investigation:

- they had to have a DDH of one hip joint, the other hip had to be normal,

- on the affected side, a secondary arthritis had to be diagnosed and pain together with an associated limping was an indication for the THR surgery,

- on postoperative clinical examination at least six months after the surgery, the limping (although less obvious) had to be noticeable.

It means that the patients with DDH and secondary arthritis on both sides were not included, as were not included the patients who had problems with one hip, but they did not limp after surgery.

Radiographs of the pelvis taken so that both hip joints could be precisely assessed were taken before and after the operation and the distances between the ‘trans-ischial’ line and (a) the tip of greater trochanter and (b) the centre of the hip joint were measured on both normal and affected sides (Figure 2.3). Also, the distance between the centre of the hip and the most medial edge of the contralateral obturator foramen was measured bilaterally before and after the THR surgery and presented as the \( k_1 \) lever (Figure 2.3). The size of the vertical lever \( k_2 \) could not be measured because the attachment of abductor muscles could not be localised since the iliac crest was not visible on some radiographs. Hence, its postoperative shortening rather than its total length could only be determined.
Since pre- and post-operative radiographs were not identical (there were slight magnification differences), data were expressed as 'affected over normal' ratios before and after the THR surgery, percent changes before and after surgery as well as means and standard deviations were calculated and compared.

**RESULTS**

All patients included in our study could walk pain-free but were still limping, although as they all claimed, significantly less than before the surgery. Results of all calculations are presented in Table 1.

The average distance between the greater trochanter and transischial line before the operation was 30% longer on dislocated side. After the THR surgery, this distance was reduced for 21%. This means that the tip of the greater trochanter was still higher on the operated side for an average of 9%.

The average distance between the centre of the hip joint and transischial line before the operation was 29% longer on the normal side. After the THR surgery, this distance was reduced for 20%. This means that the centre of the prosthetic hip was still higher on the operated side for an average of 9%.
Central

surgery. Affected over normal ratios of k1 lever before and after surgery. Affected over normal ratios of distances between the transischial line and (1) greater trochanter and (2) centre of the hip joint before and after surgery. Table 1: cranial shift of the hip on operated side.

After the THR surgery, this lever was lengthened, but it was still shorter than contralateral lever for the amount of (still existing) still existing cranial shift. After the THR surgery, this difference disappeared meaning that there was no difference between dislocated and normal side.

Vertical lever k2 on dislocated side was shorter (when compared to the normal side) for the value of hip's cranial shift. After the surgery, this lever was lengthened, but it was still shorter than contralateral lever for the amount of (still existing) cranial shift of the hip on operated side.

DISCUSSION

Because of developmental abnormalities and abnormal biomechanics of the hip joint, our patients were limping from the time they started to walk. As they aged, limping was more pronounced because of the pain caused by the secondary arthritic changes. A THR surgery was recommended to these patients as the treatment of choice. What did these patients expect from the surgery? Were their expectations fulfilled? They were happy with the fact that they could walk pain-free, but limping, although smaller than before the surgery was still a major concern for many of them. Why were the patients still limping?

Let’s analyze the mechanics (and reasons) of limping before the surgery and see what was achieved with the surgery.

On dislocated site the horizontal lever k1 was on average 8% longer because the femoral head ‘escaped’ laterally from the acetabulum. Vertical lever k2 was shorter for the length of the femoral head’s cranial shift. Absolute values of k2 levers could not be measured.

A high position of greater trochanter on the affected side as well as shorter k1 lever caused abductor muscles to become insufficient. Abnormal biomechanical balance of affected hip joint is the reason for limping. If abductor muscles could provide sufficient amount of force to correct misbalance, the pressure on the affected hip would be much greater than on the normal side [2].

The aim of the THR surgery is to replace damaged articular components in order to eliminate pain and repair biomechanical properties so that limping is also eliminated. This requires shortening of k1 lever and lengthening of vertical k2 lever. If this is not achieved, the limping will not disappear.

In order to gain proper understanding of the importance of k1 and k2 levers, a normal hip biomechanics (Figure 4) is compared with the biomechanics on operated side (Figure 5) in a case with bigger dislocation than in our 12 patients.

On the normal side, the size of k1 and k2 levers, the body weight G and the muscle force Fm applied at an angle α=22° are presented. The total loading of the normal hip is 3.8 G [2].

When biomechanical properties of the dislocated hip are evaluated, the following is noticed: horizontal k1 lever is longer, vertical krak k2 lever is not only shorter but it is also bent and a muscle force Fm is applied at an angle α=19,7°. To gain the balance under these circumstances, the total loading of this hip would need to be 6.1 G [2].

The tip of the greater trochanter on the affected side is much higher than on the normal side meaning that the distance of proximal and distal insertions of hip abductors is shortened and their strength is weakened and they are simply insufficient.

This is the explanation why limping still persists in this case.

The fact that lengthening of the horizontal lever k1 and shortening of the vertical lever k2 have a negative effect on the biomechanical properties of the hip joint is also demonstrated in following formula:

\[ R = \frac{G \cdot K_1}{k_1 \cdot \sin \gamma} \]  \hspace{1cm} (2)

So let’s look at the results of the THR surgery in our 12 patients.

Table 1: Affected over normal ratios of distances between the transischial line and (1) greater trochanter and (2) centre of the hip joint before and after surgery. Affected over normal ratios of \( k_1 \), lever before and after surgery. Affected over normal ratios of distances between the transischial line and (1) greater trochanter and (2) centre of the hip joint before and after surgery. M = mean, σ = standard deviation.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Distance from trans-ischial line to the tip of greater trochanter</th>
<th>Distance from trans-ischial line to center of the hip</th>
<th>Lever k1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-operative</td>
<td>Post-operative</td>
<td>Diff.</td>
</tr>
<tr>
<td>1.</td>
<td>1.4</td>
<td>1.09</td>
<td>0.31</td>
</tr>
<tr>
<td>2.</td>
<td>1.19</td>
<td>1.03</td>
<td>0.16</td>
</tr>
<tr>
<td>3.</td>
<td>1.47</td>
<td>1.32</td>
<td>0.15</td>
</tr>
<tr>
<td>4.</td>
<td>1.29</td>
<td>1.08</td>
<td>0.21</td>
</tr>
<tr>
<td>5.</td>
<td>1.26</td>
<td>1.06</td>
<td>0.2</td>
</tr>
<tr>
<td>6.</td>
<td>1.33</td>
<td>1.25</td>
<td>0.08</td>
</tr>
<tr>
<td>7.</td>
<td>1.25</td>
<td>1.04</td>
<td>0.21</td>
</tr>
<tr>
<td>8.</td>
<td>1.25</td>
<td>1.06</td>
<td>0.19</td>
</tr>
<tr>
<td>9.</td>
<td>1.38</td>
<td>1.06</td>
<td>0.32</td>
</tr>
<tr>
<td>10.</td>
<td>1.21</td>
<td>1.05</td>
<td>0.16</td>
</tr>
<tr>
<td>11.</td>
<td>1.4</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>12.</td>
<td>1.15</td>
<td>1.04</td>
<td>0.11</td>
</tr>
<tr>
<td>M</td>
<td>1.30</td>
<td>1.09</td>
<td>0.21</td>
</tr>
<tr>
<td>σ</td>
<td>0.09</td>
<td>0.08</td>
<td>0.07</td>
</tr>
</tbody>
</table>
from the point of view of mentioned parameters and their changes. We have managed to decrease the $k_1$ lever size to the size of that lever on the normal side, which is certainly positively affecting biomechanical properties of the joint. However, neither the centre of the hip nor the tip of greater trochanter could be ‘lowered’ to the level of the normal side. After the operation, these parameters were still on average 10% and 9% higher than on the normal side, consecutively (see Table 1). This obviously has a negative effect on the hip joint biomechanics.

Relatively insufficient hip abductors acting through shorter $k_2$ lever cannot keep pelvis horizontally, the limping (although smaller than preoperatively) persists. Complete ‘lowering’ of the proximal ending of the femur in these patients is often impossible, particularly in case of very high (iliacal) hip dislocations. Most common reasons for this are soft tissue changes (adhesions and shortened adductor muscels) and fascia lata, but not hip abductors.

If, during THR surgery, the artificial acetabulum of the prosthesis cannot be implanted in the ‘natural’ acetabulum or near it, and if it is impossible to pull lower the proximal part of the femur sufficiently, the implanted endoprosthetic device will be of the shape and size that still allows reposition of the head of the prosthesis into implanted acetabulum. High level of greater trochanter will decrease the force of hip abductors and postoperative limping will still exist. Endoprosthetic stem with greater “offset” biomechanically is useful but not sufficient. Therefore “distalization” of the greater trochanter is necessary. Some authors suggest immediate osteotomy and distalization of the greater trochanter. However, healing of translocated greater trochanter could create an additional complication in recovery (pseudarthrosis) [5].

Here we present our original ‘distalization’ approach that could avoid pseudarthrosis and help recovering of the abductor strength and decrease limping (Figure 6).

Some authors, in cases of high iliacal dislocations recommend subtrochanteric femoral osteotomy and distalization of the entire proximal part of the femur with or without additional distalization of the greater trochanter. These procedures involve quite a high risk with an unpredictable result, despite recomendations by several authors [6-8].

In conclusion, an orthopaedic surgeon should exercise a caution when informing a patient about the outcome of the surgery, particularly about the limping following the surgery. Apart to fine surgical skills, the knowledge of hip biomechanics is required in order to prevent false expectations and disappointments of the patient.

The patient should be well informed about all possibilities before surgery.

REFERENCES