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# Rehabilitation of gait in patients after total hip arthroplasty: Comparison of the minimal invasive Yale 2-incision technique and the conventional lateral approach

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ABSTRACT

The minimal invasive anterolateral Yale 2-incision approach for total hip arthroplasty aims minimizing damage to the muscles for faster recovery of function. Therefore the hypothesis was investigated, that during the rehabilitation process the Yale approach shows a faster return to natural gait than a conventional lateral approach.

Nineteen patients had the Yale, 16 the conventional Bauer approach. Instrumented gait analysis was performed 3 days, 3 and 12 month post operatively. Velocity, cadence, step length, weight bearing, thorax lean, Trendelenburg limp, hip abduction moments, and hip muscle activation times were evaluated.

Three days post-surgery a significantly greater loading of the treated limb and increased hip abduction moment were observed in the Yale group. In addition, the Yale group showed its greatest improvement in walking speed and step length between at 3 days and 3 months, whereas the conventional group showed an additional significant gain between 3 and 12 month to reach a similar walking speed as the Yale group. For all hip muscles investigated, only muscle tensor fasciae latae in the conventional group showed a significant increase in activation time between 3 days and 3 months.

This study showed significantly faster return to natural gait in the Yale compared to the conventional approach, which could be biomechanically related to less impairment of abductor muscles in the Yale approach.



## 1. Introduction

Osteoarthritis or inflammatory arthritis of the hip is the highest-ranking disease among the musculoskeletal diseases [1]. It is caused by the wear and tear of aging that degenerate the cartilage covering the joint surfaces, resulting in pain and stiffness. Total hip arthroplasty (THA) is one of the most successful and cost effective interventions [2–4]. THA offers reliable relief of pain and considerable improvement in mobility and function [5–7]. In recent decades there has been a considerable effort to improve the surgical techniques for THA. Classically a lateral approach (CON) allowed for good visibility of anatomical landmarks and vital structures [8]. However it has the drawback of increased soft tissue trauma of the abductors that stabilizes the pelvis during stance phase of gait. Therefore minimally invasive surgery (MIS) was introduced that aims at decreasing the surgical incision and minimizing damage to the underlying soft tissues to accelerate postoperative recovery (less pain shorter hospital stay and quicker return to function). Based on a literature review [9] it has been shown that conflicting evidence exist for the effect on MIS THA on pain in the early postoperative period and moderate evidence exists for shorter hospital stay. In order to evaluate physical functioning after THA subjective physician-based or self-reported questionnaires are frequently in use. An objective assessment of function can be done by instrumented gait analysis [10–17]. Contrary to what the supporters of MIS THA stated, it was reviewed [9] that MIS THA has no effect on physical

*Abbreviations:* THA, Total hip Arthroplasty; HC, Healthy controls; MIS, Minimal invasive surgery; CON, Conventional surgery.

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functioning, as measured by questionnaires, scores and instrumented gait analysis. However, one of the main purported benefits of the new technique of minimally invasive hip replacement surgery is that it provides for improved ambulation in the immediate post-operative period and allows for early hospital discharge by the second postoperative day [11,18]. However, most of the quantitative gait studies have provided six weeks up to 12 months post-operative data [10–19]. Only two studies measured gait in addition shortly after surgery, which was 2 days [10] and 10 days [13] post-operatively. However none of the studies shortly or longer postoperatively found a significant difference in function of MIS THA compared to conventional methods. However both of the shortly postoperative studies were using a MIS single incision approach. The advantage of any minimally invasive surgery is less injury to the body. However with more radical approaches, such as MIS-2 incision, that use an anterior incision for acetabula cup placement and a posterior incision for femoral stem insertion there is reduced trauma to the deep muscle tissues and underlying structure of the hip [20,21]. The anterior incision may lead to a better functional outcome in the long term than the lateral incision [19], and it may in particular improve hip abduction moments shortly after surgery, that was one of the main impairments of gait following THA, reported in a recent review [22].

Therefore the goals of this study are to compare the MIS Yale technique, a 2 incision approach [20,21] to a conventional lateral approach [23] and to investigate the recovery of function immediately 3 days post-operative and follow up to 3 and 12 months. We hypothesized that patients who underwent THA by means of the MIS Yale 2 incision approach would show a faster recovery and a faster return towards normal gait compared to patients with the CON approach.

## 2. Methodology

### 2.1. Participants and surgical procedure

In this controlled prospective study, thirty five patients volunteered to participate. Patients provided written informed consent to participate in this study, as approved by the local ethics committee. Patients underwent THA in the Wolfart - Hospital, Gräfelfing, Germany between February 2008 and September 2009. Exclusion criteria were BMI $> 32$, previous surgeries of the affected hip and inflammatory polyarthritis. Prior to surgery, patients were informed about the benefits and risk of the CON and MIS approaches and could choose between one of both procedures. In the CON group, the transgluteal approach with a single lateral skin incision described by Bauer [23] was used for implantation. In the MIS two incision Yale-approach [20,21], patients were fixed in a lateral position, a small entry incision was made in the vessel free interval between the tensor fasciae latae and the sartorius muscles and the prosthesis socket were put in place. Via a second dorsal incision, after releasing the external rotators (without the m. priformis), the prosthesis stem and ball were implanted and the two parts of the prosthesis were attached. In contrast to the 2-incision approach of Berger [24], fluoroscopy was not required for implant positioning. In this study identical cementless hip implants (Corail shaft und Pinacle Cup, De Puy-Synthes Germany) were implanted by two experienced senior orthopaedic surgeons. Nineteen patients had the MIS, 16 the CON approach.

Preoperatively anthropometric data, Kellgreen Lawrence Score [25] and Merle d'Aubigné-Scores [26] and the American Society of Anaesthesiologists physiological status (ASA) score [27] were not significantly different between patients groups (Table 1). Also there was no significant deviation in BMI and age between the groups. To estimate the recovery towards normal gait, gait of 18 age-matched healthy controls was reported.

Mobilization started on the first day after surgery with use of two forearm crutches. Patients were allowed to dispense with the crutches for full weight-bearing as soon as possible, depending on the individual level of mobilization and pain. During their hospital stay all patients underwent the same physiotherapy routine. After the discharge from the hospital the patients were free to choose between inpatient and outpatient physiotherapy. Both followed similar regime as specified in the guidelines [28,29] depending on the individual progress of the patients.

### 2.2. Gait analysis

Patients had instrumented gait analysis 3 days, 6 month and 12 month postoperatively. Gait was captured with an 8 Camera system (MX, Vicon Inc. Oxford, UK) operating at a sampling rate of 200 Hz and 2 force plates (AMTI, Watertown, MA) collecting data at 1000 Hz. Electromyography (Noraxon, Scottsdale, USA) of m. gluteus medius, gluteus maximus and tensor fasciae latae was measured following the SENIAM guidelines. The Vicon Plug-in-Gait marker set and model was used to generate kinematic and kinetic data [30]. The participants were asked to walk barefoot at a comfortable speed down the 10 m walkway. Kinematics, kinetics and EMG were collected in the course of 10 successful trials. During the gait tests patients were asked to walk without assistive devices. However, in the first gait analysis 3 days postoperative, patients were allowed to use two forearm crutches whenever they did not feel comfortable walking without assistance. Patients that were using crutches were instructed not to put any weight on them. At 3 and 12 months gait analysis no assistive devices were used.

### 2.3. Data analysis

Kinematic and kinetic data were smoothed with Woltring filter and using a smoothing spline [31]. Spatiotemporal parameters that indicated the gait performance were walking speed, step length and cadence in non-dimensional units that corrects for different leg lengths of the participants [32]. Kinetic data included the partial weight bearing towards the involved side, calculated as side difference of the mean ground reaction force during stance phase

**Table 1**
Pre-operative anthropometric data, American Society of Anesthesiologists physiological status (ASA), Kellgren & Lawrence grade of hip Osteoarthritis (K&L) and Merle-Aubigne (MA) score. Mean standard deviation was shown in round bracket, range in square brackets.

| group | Age [years] | Males | BMI [kg/m$^2$] | ASA | K&L grade TEP leg | K&L grade contralateral leg | MA pain | MA mobility | MA ability to walk |
|---|---|---|---|---|---|---|---|---|---|
| MIS | 62.1 (7.8) [46,73] | 9/19 | 27.(3) [23,31] | 1.84 (0.60) [1–3] | 3.7 (0.5) [3,4] | 2.3 (1.2) [1,4] | 2.6(0.5) [2,3] | 2.8(0.7) [2,4] | 3.1(0.1) [3,4] |
| CON | 63.4 (8.1) [47,76] | 9/16 | 28(3) [24,31] | 1.75 (0.58) [1–3] | 3.5 (0.5) [3,4] | 1.9 (1.0) [1,4] | 2.7(0.5) [2,3] | 2.9(0.6) [2,4] | 3.2 (0.2) [3,4] |
| HC | 61.7 (8.9) [45,72] | 10/18 | 24(3) [20,27] | – | – | – | – | – | – |
| *t*-test MIS vs. CON | $p = 0.61$ | – | $p = 0.06$ | $p = 0.51$ | $p = 0.39$ | $p = 0.33$ | $p = 0.41$ | $p = 0.46$ | $p = 0.79$ |

of gait. The function of the abductors was calculated by the mean abduction moment during stance phase of gait. The performance of the hip muscles during propulsion was assessed by the generation energy that was calculated as the integral of the positive hip joint power during stance phase of gait.

Kinematic parameters were the Duchenne and Trendelenburg gait pattern that was described with the frontal plane peak thorax lean and peak pelvis hike respectively. In addition peak hip extension in the sagittal plane was investigated to show the recovery of the gluteal muscles during the rehabilitation period.

EMG data of each muscle was rectified and smoothed following the SENIAM guidelines. The resultant EMG amplitude was then normalized on the respective maximum signal of each subject during all trials. The duration of activity during stance phase was determined as the normalized signal being greater than 15% and lasted at least 5% of the gait cycle.

### 2.4. Statistical analysis

An independent sample t-test was used to test preoperative differences in anthropometrics and scores between patient groups CON and MIS. All gait parameters were tested using a two factor ANOVA with factors group (CON, MIS) and time (3 days, 3 months, 12 months). Post hoc t-tests were used to further analyze significant results. Calculations were carried out using MatLab 7.3 (Mathworks Inc., USA). Significant level was set at $p < .05$.

## 3. Results

In the gait analysis 3 days postoperative, 2/19 in the MIS and 14/16 patients in the CON group requested forearm crutches, because

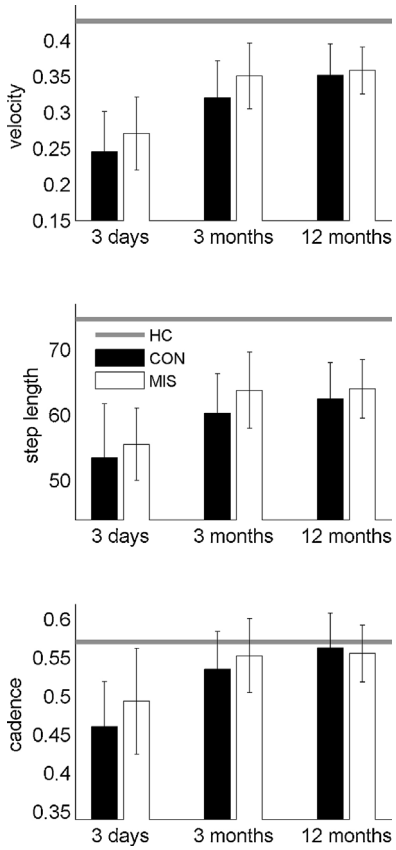


**Fig. 1.** Spatio-temporal parameters in non-dimensional units, corrected for leg length differences between participants. Mean values of healthy controls are show in grey colour.

**Table 2**
Mean and confidence intervals in square brackets for MIS and CON patients groups for all 3 sessions and healthy age matched controls (HC).

| Parameters | Session 1 | | Session 2 | | Session 3 | | |
|---|---|---|---|---|---|---|---|
| Spatio temporal (non-dimensional) | MIS | CON | MIS | CON | MIS | CON | HC |
| velocity | 0.27 [0.25,0.30] | 0.25 [0.19,0.30] | 0.35 [0.33,0.37] | 0.32 [0.29,0.35] | 0.36 [0.34,0.37] | 0.35 [0.33,0.38] | 0.43 [0.40,0.45] |
| step length | 55.54 [52.87,58.22] | 53.51 [45.90,61.11] | 63.82 [61.00,66.65] | 60.29 [57.05,63.53] | 64.04 [61.88,66.21] | 62.50 [59.54,65.47] | 74.68 [72.09,77.27] |
| cadence | 0.49 [0.46,0.53] | 0.46 [0.41,0.51] | 0.55 [0.53,0.58] | 0.54 [0.51,0.56] | 0.56 [0.54,0.57] | 0.56 [0.54,0.59] | 0.57 [0.55,0.59] |
| Kinematics [°] | | | | | | | |
| peak thorax lean stance | −2.05 [−3.14, −0.96] | −2.23 [−4.19, −0.28] | −1.15 [−1.90, −0.40] | −3.70 [−5.04, −2.36] | −1.42 [−2.37, −0.48] | −3.66 [−5.17, −2.15] | −2.19 [−3.45, −0.92] |
| peak hip extension | 2.08 [−1.59,5.76] | 6.91 [2.83,10.98] | −4.60 [−8.08, −1.12] | 0.35 [−3.11,3.82] | −6.28 [−10.02, −2.54] | −0.60 [−6.65,5.45] | −12.40 [−15.74, −9.06] |
| peak pelvis hike stance | 1.08 [0.21,1.94] | 3.44 [1.59,5.29] | 2.14 [1.16,3.12] | 2.31 [1.32,3.31] | 2.54 [1.51,3.57] | 2.78 [1.78,3.79] | 4.98 [3.78,6.18] |
| Kinetics | | | | | | | |
| mean GRF side difference (surg - nosurg) [%] | −2.29 [−3.26, −1.32] | −5.85 [−11.22, −0.47] | −1.02 [−1.89, −0.16] | −0.68 [−1.84,0.49] | −0.09 [−1.31,1.13] | −1.47 [−2.59, −0.35] | 0.00 [−3.08,3.09] |
| mean hip abduction moment in stance [Nm/kg] | 0.47 [0.42,0.53] | 0.27 [0.15,0.38] | 0.51 [0.46,0.55] | 0.47 [0.40,0.54] | 0.55 [0.50,0.59] | 0.53 [0.48,0.57] | 0.50 [0.44,0.55] |
| hip generation energy in stance [J/kg] | 0.08 [0.06,0.10] | 0.07 [0.02,0.12] | 0.11 [0.09,0.12] | 0.12 [0.10,0.14] | 0.13 [0.11,0.15] | 0.15 [0.12,0.18] | 0.15 [0.12,0.18] |
| EMG activity duration [% stance phase] | | | | | | | |
| gluteus medius | 37.8 [24.4,51.2] | 23.2 [−1.8,48.3] | 21.4 [11.5,31.3] | 38.9 [30.5,47.2] | 18.8 [10.3,27.3] | 32.9 [23.9,41.8] | 27.1 [19.4,34.8] |
| gluteus maximus | 23.8 [10.8,36.7] | 14.1 [−8.2,36.6] | 23.3 [13.0,33.5] | 31.6 [21.2,42.0] | 20.0 [11.1,29.0] | 26.9 [19.8,34.1] | 17.8 [9.2,26.6] |
| tensor fasciae latae | 27.7 [14.9,40.4] | 11.9 [−7.3,31.1] | 29.1 [18.1,40.1] | 44.9 [39.0,50.8] | 29.2 [19.4,39.0] | 46.2 [44.0,48.5] | 38.4 [31.8,45.0] |

**Table 3**
ANOVA results for two factors and 3 sessions. Post hoc *t*-tests between groups and between sessions (S) for MIS and CONS were shown. Significant results $p < 0.05$ were highlighted in bold letters.

| Parameters | ANOVA | | | *t*-test between CON and MIS | | | *t*-test CON between sessions | | *t*-test MIS between sessions | |
|---|---|---|---|---|---|---|---|---|---|---|
| Spatio temporal | group | time | interaction | S1 | S2 | S3 | S1, S2 | S2, S3 | S1, S2 | S2, S3 |
| velocity | 0.637 | <0.001 | 0.213 | | | | 0.005 | 0.035 | <0.001 | 0.120 |
| step length | 0.858 | <0.001 | 0.391 | | | | 0.038 | 0.016 | <0.001 | 0.731 |
| cadence | 0.777 | <0.001 | 0.088 | | | | 0.004 | 0.082 | 0.004 | 0.592 |
| Kinematics | | | | | | | | | | |
| peak thorax lean stance | 0.317 | 0.279 | 0.621 | | | | | | | |
| peak pelvis hike stance | 0.207 | 0.213 | 0.048 | | | | | | | |
| peak hip extension | 0.211 | <0.001 | 0.486 | | | | 0.025 | 0.644 | 0.009 | 0.348 |
| Kinetics | | | | | | | | | | |
| mean GRF side difference | 0.005 | 0.004 | 0.157 | 0.026 | 0.614 | 0.092 | 0.005 | 0.116 | 0.048 | 0.123 |
| mean hip abduction moment stance | 0.023 | <0.001 | <0.001 | <0.001 | 0.314 | 0.512 | 0.003 | 0.031 | 0.345 | 0.001 |
| hip generation energy stance | 0.379 | <0.001 | 0.058 | | | | 0.033 | 0.034 | 0.049 | 0.014 |
| EMG activity duration | | | | | | | | | | |
| gluteus medius | 0.217 | 0.619 | 0.018 | | | | | | | |
| gluteus maximus | 0.684 | 0.345 | 0.264 | | | | | | | |
| tensor fasciae latae | 0.048 | 0.004 | 0.009 | 0.279 | 0.015 | 0.000 | 0.001 | 0.793 | 0.736 | 0.692 |

they did not feel comfortable without assistance. Patients were instructed not to put weight on the crutches. However, video analysis revealed that 6 of 16 patients in the CON group used three-point crutch gait (first move both crutches and the weaker lower limb forward, then bear the weight down through the crutches). These 6 patients in the CON group were excluded from the first session. Analysis of ground reaction forces in these 6 patients supports the observation, because 48% (SD = 12%) unloading of the involved side was observed, whereas it was 6% (SD = 5%) in the other patients in the CON group that uses the crutches only for safety reasons.

The spatiotemporal gait parameters were shown in Fig. 1, Table 2 and statistics in Table 3. Walking speed, cadence and step length showed a significant time effect (all $p < 0.001$). Post-hoc tests indicated that the time effect was mainly between 3 days and 3 months for both groups. In addition walking speed and step length further increased significantly between 3 and 12 months for the CON group.

The kinematic gait parameters were shown in the left column of Fig. 2 and Table 2. There was a significant time effect for peak hip extension between 3 days and 3 months for both groups.

The kinetic gait parameters were shown in the right column of Fig. 2 and Table 2. The side difference in the mean ground reaction force was on average −6% for the CON group and −2% for the MIS group in the first session. This indicated relative unloading of −6% and −2% of the side where the THA was done. There was a significant group effect of the unloading with a significant interaction effect. Post-hoc test indicated that the difference between groups was only significant at three days. In addition, the unloading showed a time effect that was significant between 3 days and 3 months. The hip abduction moment showed a group and time effect with a significant interaction. Post-hoc tests demonstrated a significantly smaller moment for the CON group 3 days post operatively. The increase in time was significant for the CON group between all sessions for the MIS group between 3 and 12 months. Hip generation energy increased significantly over all times for both groups in all sessions.

The activation times of all muscles were shown in Fig. 3 and Table 2. Only muscle tensor fascia latae demonstrated a significant group and time effect with a significant interaction. Post-hoc test revealed significantly longer duration in the CON group at 3 and 12 months and a significant increase only for the CON group between 3 days and 3 months. The other muscles as well as the MIS group did not show any significant differences.

## 4. Discussion

We hypothesized that patients who underwent THA by means of the MIS Yale 2-incision approach would show a faster recovery towards normal gait compared to patients after the conventional lateral approach. This could be confirmed based on the results of this study since 3 days post-surgery a significantly greater loading

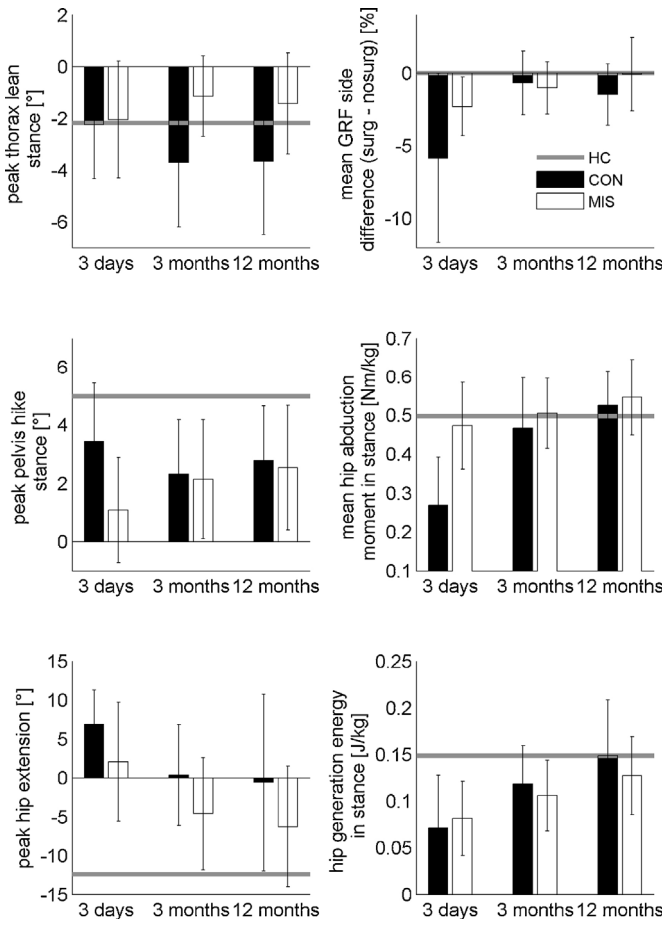


**Fig. 2.** Kinematic and kinetic parameters of the thorax, pelvis and the hip joint. Mean values of healthy controls are show in grey.

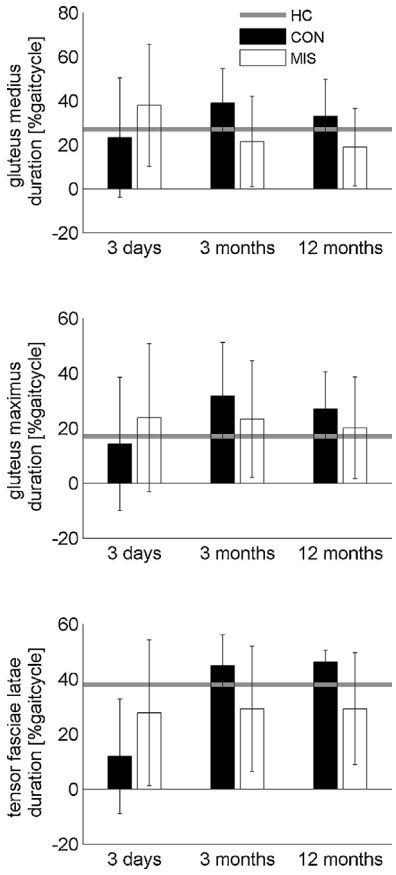


**Fig. 3.** EMG duration of activity during stance phase, Mean values of healthy controls are show in grey.

of the treated limb and increased hip abduction moment was observed in the MIS compared to the CON group. In addition, the main increase in walking speed and step length was in the MIS groups from 3 days to 3 months, whereas the CON group showed an additional significant gain between 3 and 12 month that was considerably smaller and not significant in the MIS group. Further, m. tensor fasciae latae showed an increase between 3 days and 3 months post-op that was not seen in the MIS group.

To our best knowledge only one research group investigated short term effects on gait parameters already 2 days after surgery [10,11] and they found no significant differences in gait performance between MIS and CON approaches at that point in time. Whereas in this study, group differences in 2/12 gait parameters were found 3 days after surgery. Two reasons might explain the significant results found in this study: First Bennet et al. [10,11] used a single-incision lateral approach for both the minimal invasive and the conservative approach that affected abductor muscles in both approaches, but to a smaller extend in the MIS approach. Contrary in this study the lateral muscles were not affected in the MIS procedure. The second important difference was that in the study of Bennett et al. all patients were using assistive devices (88/100 crutches and 12/100 frame walkers) that affects gait [33], whereas in this study only 6/16 patients in the CON group were using crutches for weight bearing 3 days postoperatively. These 6 patients were excluded from the data evaluation in the first gait analysis 3 days postoperatively. Since patients with MIS had unloading of only 2% (SD = 2%) they experienced a more efficient muscular training under dynamic conditions, that further supports the benefit in early recovery of the MIS approach.

The significant recovery towards normal gait velocity, step length and hip extension from 3 days to 3 months was similar in both groups. This is in agreement with the literature [10–17] that did not find significant differences in recovery of gait at any points in time investigated. Regarding the long-term recovery between 3 and 12 months, this study showed significant improvements of velocity and step length in the CON group that did not appear in the MIS group. Since there were no significant group differences between CON and MIS at 12 months for these gait parameters, the MIS group reached its best gait performance already at 3 month whereas the CON group required a longer period of time.

Pelvic hike (Trendelenburg limp) is a typical consequence of weak abductors that might have weakened through the CON surgery. However, no group differences have been observed. Trendelenburg limping may have been masked by thorax ipsilateral lean (Duchenne limping) to compensate for weak abductors. But, no group or time differences were seen in thorax lean that was similar to other studies that measured thorax lean 10 days and 12 weeks postoperatively [13] or 6 weeks, 3 months and 6 months postoperatively [16]

Regarding muscle activity it was shown in a previous study that in most of the patients where the m. tensor fasciae latae was dissected, this muscle was operating significantly longer [13]. This could be confirmed by the results of this study where at 3 and 12 month the operating time of m. tensor fasciae latae was on average longer in CON than in MIS approach. This behavior was probably to compensate with longer activity for weakness caused by muscle dissection. Contrary to the CON group there was no change in activity of m. tensor fasciae latae for the MIS group at any timepoint investigated. This indicated that m. tensor fasciae latae was more irritated by the use of a transgluteal approach that involves splitting the fascia latae than by the use of a minimally invasive approach.

### *4.1. Limitation of the study*

In this study gait was not analyzed prior to surgery that allowed for comparison of gait differences between groups. This was not done because osteoarthritis or inflammatory arthritis of the hip cause severe pain [8] and functional limitations through pain are so inconsistent that a conclusion about the severity cannot be reliable evaluated by gait analysis [34]. Instead anthropometric parameters and clinical and physiological scores were indicating that there were no significant differences between groups.

## 5. Conclusion

The results of this study showed differences in recovery of function between the CON Bauer transgluteal-approach and MIS Yale 2-incision approach that could be biomechanically related to less impairment of abductor muscles in the MIS approach. In particular the function of abductors 3 days after surgery was considerably different in the MIS group which suggests a more efficient earlier muscular use under dynamic conditions. Therefore the results of this study helps to explain the evidence for shorter hospital stay with the minimal invasive method reported in the literature.

## Conflict of interest

All authors do not have any financial and personal relationships with other people or organizations that inappropriately influence the work performed. The gait laboratory in the Centre of Social Paediatrics in Munich received financial support from De Puy Synthes (Johnson & Johnson Company) to run the gait analysis. Since both patients groups in this study received identical implants

from the supporting company, a conflict of interests of De Puy Synthes can be excluded.

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