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HIP ARTHROPLASTY

The direct lateral approach: impact on gait patterns, foot progression angle and pain in comparison with a minimally invasive anterolateral approach

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Abstract
Introduction Minimally invasive total hip arthroplasty has been successfully introduced in the past decade. Nevertheless, standard approaches such as the direct lateral approach are still commonly used in orthopaedic surgery due to easy handling, good intra-operative overview and low complication rates. However, a frequent occurrence of fatty atrophy within the anterior third of the gluteus medius muscle has been demonstrated when using the modified direct-lateral approach (mDL), which may be associated with a reduction in function, limitation of internal leg rotation, gait disorders and pain. The question addressed in this study is whether mDL-approach leads to unfavourable changes in foot progression angle (FPA), gait and to more postoperative pain compared with a minimally invasive anterolateral approach (ALMI).
Methods Thirty patients with primary osteoarthritis of the hip were recruited for this study. All subjects received an uncemented THA (Alloclassic®-Zweymüller stem, Allofit® Cup, FA Zimmer®), 15 through an ALMI-approach and 15 via the mDL-approach. Gait analyses were performed both preoperatively and 3 months after surgery to measure FPA, step length, stance duration, cadence and walking speed. Additionally, the Harris-Hip Score, pain according to the visual analogue scale and the Trendelenburg sign were evaluated.
Results No influence of the surgical approach could be observed on the gait patterns or FPA. Furthermore, neither increased external rotation of the limb nor restriction of internal rotation during walking could be established. Pain and Harris-Hip Score did not differ significantly between the two groups.
Conclusion In comparison with an ALMI approach, the mDL approach did not lead to a change in FPA postoperatively. No detrimental effect could be found on the gait pattern or pain after surgery. Based on these measurements, the minimally invasive anterolateral approach did not appear to provide functional benefits in outcome over the mDL approach. Consequently, both surgical approaches seem to be equally applicable approaches with good to very good functional results.

Keywords Total hip arthroplasty · Direct lateral approach · Minimally invasive anterolateral approach · Gait analysis · Foot progression angle

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Introduction

Minimally invasive total hip arthroplasty (THA) has become well established in recent years due to the supposed muscle-sparing effect. However, standard approaches, such as the direct lateral (transgluteal) approach, are still broadly applied. This is due to the fact that they are easy to learn, provide an excellent intraoperative overview [25], can be

extended if needed and carry little risk for fractures [13, 31] or dislocations [7, 8, 21]. The disadvantages of such standard approaches, at least for the traditional lateral approach of Bauer and Hardinge, include the risk of temporary or permanent neuromuscular damage to the hip abductors [29, 34] with subsequent insufficiency to hip abduction and stabilisation of the pelvis [8, 29].

In a previous study, an increased muscle trauma of the gluteal musculature was found when using a modified lateral approach (mDL) compared with an anterolateral minimally invasive approach (ALMI) [23]. However, in their patients operated via a lateral approach, a fatty atrophy of the anterior third of the gluteus medius muscle was observed [23]. Apparently, this was a result of the partial incision and detachment of muscle and tendon fibres. However, any consequences for the functional ability of the patients remain unclear. Beside its function to abduct the limb, the gluteus medius muscle also acts as a rotator with the anterior fibres causing an internal rotation of the limb, while the posterior fibres are able to produce external rotation due to their fibre orientation. Partial damage of the anterior fibres might therefore cause a muscular imbalance between internal and external rotational strength, thus leading to an impaired ability to rotate the limb internally. As a result, those patients could present an outward rotation of the limb, as seen in the foot progression angle (FPA) during walking. Since muscular imbalance is associated with unphysiological joint loading, risk of early aseptic loosening [5, 12, 15], risk of falling as well as inefficient gait patterns [24] and pain [18, 30, 32], a potentially unfavourable effect of the transgluteal approach on patient function can be postulated.

Therefore, the aim of this study was to investigate whether patients who received a THA through an mDL approach (I) exhibit an increased external rotational alignment of the affected limb during walking, (II) show significant differences in their gait patterns compared between time points and (III) report more pain compared with patients operated through ALMI approach.

Methods

Thirty patients (14 males, 16 females; age 65 ± 7 years) with primary coxarthrosis were prospectively enrolled. The study was approved by the local institutional review board (EA1/025/07). Exclusion criteria were high degrees of dysplasia (>Crowe I), fractures, bone malalignments, previous surgery, the requirement for an osteotomy or the existence of osteoarthritis or endoprothesis on the contralateral side. All patient demographics were similar between groups (Table 1). Preoperatively, patients were randomly assorted into either the ALMI or the mDL group. The randomisation was carried out by throwing dice where uneven numbers implied the mDL group and even numbers the ALMI group. The assorted surgical approach was disclosed to the surgeon directly before surgery. Postoperative mobilisation started on the first day after surgery. Pain medication and physiotherapeutic treatment were equally applied to all patients. Forearm crutches had to be used during walking, with full weight bearing only after the 6th postoperative week.

Table 1 Patient demographics

	mDL	ALMI	*p* wert
Number	15	15	
Age (years)	66.2 ± 8	64.3 ± 7	0.41
Gender (male/female)	5/10	6/9	0.7
BMI (kg/m²)	27.0 ± 3.1	26.9 ± 3.3	0.88

Surgical procedure: approach and implant

The arthroplasties were conducted by two experienced surgeons (C.P., S.T.) who had both implanted more than 2,000 THAs using each surgical approach. The intramuscular mDL-approach is a modified technique of the initial Bauer and Hardinge approach. The modification comprises shorter incisions than more traditional procedures: the approach is conducted using approximately a 10-cm skin incision, the gluteus medius muscle is incised by a maximum of 3 cm and the incision is extended only to the aponeurosis of the vastus lateralis muscle at the greater trochanter [25]. The ventral aspect of the gluteus medius is then detached from the greater trochanter together with the underlying gluteus minimus. After implantation, the reinsertion is effected by two or three periostal sutures (2.0, Ethibond, Ethicon, Somerville, US). The benefit of the transgluteal approach is the pre-eminent overview of the joint with associated view of all important landmarks, as well as the possibility to unproblematically extend the approach if needed. One known risk factor, however, is the possible intra-operative damage of muscle fibres or nerve with subsequent transient or persistent gluteal insufficiency.

The ALMI approach is a modified version of the approach described by Watson-Jones [3]. The preparation of the hip joint is performed intermuscularly between the gluteus medius and the tensor fasciae latae (TFL) without incising or detaching muscle or tendon fibres [3]. While the muscle-sparing aspect of the approach is advantageous, the limited overview, the higher risk of trochanteric fractures [16] and the difficult preparation of the proximal femur are all known detrimental factors.

Uncemented Press-fit cups (Allofit®, Zimmer®, Warsaw, Indiana, US) and uncemented straight stems type Zweymüller (Alloclassic®, Zimmer®, Warsaw, Indiana, US) were implanted.

Study protocol

The protocol included gait analysis, clinical assessment (including ranges of motion and the Trendelenburg test) and evaluation using the Harris-Hip Score both preoperatively and at 3 months postoperatively. The Trendelenburg test was rated as either negative (patient capable to perform one-legged stance), slightly positive (one legged stance possible, but unstable) or positive (patient not capable to perform one-legged stance). Additionally, the perceived pain was recorded using the visual analog scale (VAS, scale 0–10) at the 3-month follow-up time point. All clinical assessments were conducted by an independent observer (M.M.) who was blinded to the patient cohorts and not involved in the operations. One day pre-op and 7 days postoperatively, X-rays were collected (anterior/posterior, Lauenstein) for planning the endoprosthesis and for assessing the postoperative alignment of the components, respectively.

Gait analysis and measurement of the FPA

Gait analyses were conducted one day pre- and 3 months postoperatively using three-dimensional motion analysis (VICON Metrics, Oxford, UK), which consisted of 12 infrared cameras and retroreflective markers attached to the skin using double-sided tape. The markers were positioned on bony landmarks of the foot (first and fifth metatarsal head, calcaneal tubercle and the medial malleolus). All patients performed practice trials to become familiar with the laboratory environment. Afterwards they were asked to walk five times along a 10-m walkway at self-selected speed, while the FPA, step length, stance duration, cadence and walking speed were all measured. The FPA was defined as the angle between the foot axis and the direction of walking (Fig. 1), where the long axis of the foot was formed by the vector of the heel marker and the midpoint of the two markers on the metatarsal heads (Fig. 2). The direction of walking was defined as the course of the heel marker over each 10-m walk. Since the foot moves from initial inversion at heel strike to eversion at toe off [26], mid-stance was chosen as the time point at which the rotation/version of the foot was determined. Mid-stance was defined as the time point when both markers on the two medial malleoli were closest to each other in transverse plane. For each patient and measurement (time point), 20 values of the FPA were collected and averaged.

Statistics

For the statistical analysis, SPSS® (Version 15, SPSS Inc., Chicago, USA) was used. In order to compare means between time points, Student *t* tests for paired samples were chosen. Student *t* tests for unpaired samples were used to test the significance between the two cohorts.

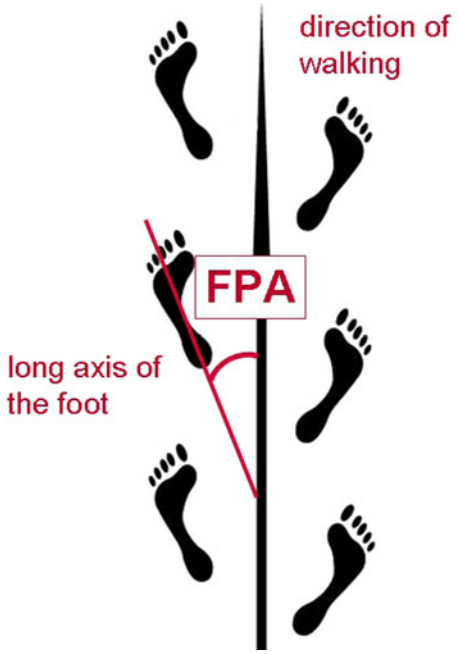

Fig. 1 Foot progression angle: defined as the angle between the foot axis and the direction of walking

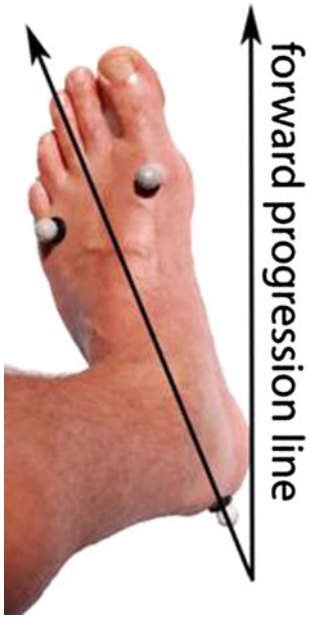

Fig. 2 Long axis of the foot: formed by the vector of the heel marker and the midpoint of the two markers on the metatarsal heads (I and V)

An a priori power analysis tested the required number of subjects per cohort. Assuming an effect size of >1, alpha 0.05 and a power of 0.8, a sample size of 14 patients per cohort was computed. The assumption of the effect size was based on the results of previous studies [22, 23] and was defined by a statistician. There, a higher grade of fatty atrophy of the anterior third of the gluteus medius muscle could

Table 2 Gait parameters

	Pre-operative		3-months-follow-up			
	ALMI	mDL	ALMI	Δ	mDL	Δ
Speed (m/s)	0.84 ± 0.23	0.96 ± 0.16	0.95 ± 0.09	0.1	0.99 ± 0.19	0.0
Cadence (steps/s)	1.67 ± 0.29	1.76 ± 0.17	1.69 ± 0.19	0.0	1.74 ± 0.20	0.0
Step length (m)	0.3 ± 0.04	0.33 ± 0.03	0.33 ± 0.02	0.0	0.33 ± 0.03	0.0
Stance duration (s)	0.88 ± 0.29	0.72 ± 0.10	0.79 ± 0.16	−0.1	0.76 ± 0.15	0.0

Δ denotes the difference to the pre-operative value (change)

p values between surgical approaches were all >0.05

Table 3 Foot progression angle

	ALMI	mDL	*p**
Number	15	15	
FPA before implantation	12.5 ± 5	12.5 ± 7	0.98
FPA after 3 months	13 ± 5	10 ± 6	0.22
Change in FPA (Δ)	0.5 ± 5	−2.5 ± 6	0.25

* Student *t* test

Table 4 VAS and Harris-Hip Score (mean ± SD)

	mDL	ALMI	*p**
VAS (0–10)			
3 months	2.3 ± 2	1.6 ± 1.2	0.25
Harris-Hip Score (mean ± SD)			
Preoperatively	47.2 ± 15	53.4 ± 17	0.7
3 months	81.9 ± 17	80.2 ± 19	0.68

* Student's *t* test

Table 5 Incidence (%) of a positive Trendelenburg's sign for the ALMI and mDL group

3 months	mDL (%)	ALMI (%)	*p*
Negative	69	81	0.32
Slightly positive	31	19	
Postitive	–	–	

Table 6 ROM-analysis

	Pre			3 months		
	ALMI	mDL	*p**	ALMI	mDL	*p**
Flexion (°)	98 ± 18	94 ± 12	0.4	102 ± 13	98 ± 9	0.26
Abduction (°)	22 ± 9	20 ± 13	0.56	31 ± 7	27 ± 8	0.1
Adduction (°)	14 ± 10	12 ± 10	0.5	21 ± 7	20 ± 6	0.62
External Rot. (°)	19 ± 13	18 ± 12	0.8	29 ± 8	26 ± 11	0.32
Internal Rot. (°)	4 ± 5	5 ± 10	0.7	11 ± 7	14 ± 7	0.17

* Student's *t* test—differences between ALMi and mDL cohorts

be found in almost 50% of the patients with a lateral approach. This fatty atrophy was not evident in patients who had received a THA using an anterolateral MIS approach. Thus, effects on gluteal muscular function particularly in internal rotation should clearly differ between the patient groups.

Results

All recruited patients underwent the complete follow-up. An examination of the postoperative alignment of the components by X-ray revealed no deviations from conventional values for implantation. Except in one case of prolonged wound healing in the ALMI group, no other complications occurred.

Gait parameters and FPA

In terms of the gait parameters of walking speed, cadence, step length and stance duration, no significant differences were found between the data available for the two cohorts (Table 2) either at the pre- or the postoperative follow-up. The FPA averaged 12.5° before surgery for both the ALMI (SD 5°) and mDL (SD 7°) group. At the 3-month postoperative time point, the ALMI group had a FPA of 13° (SD 5°) and the mDL group of 10° (SD 6°) (Table 3). This resulted in an average FPA change of +0.5° (SD 5°) for the ALMI ($p = 0.76$) and −2.5° for the mDL ($p = 0.2$) approach. The difference between surgical approaches was not statistically significant ($p = 0.22$) (Table 3).

Harris Hip Score, VAS and Trendelenburg tests

Differences in regard to the Harris Hip Score and VAS were not evident. Both patient cohorts recorded approximately the same scores (Table 4). Furthermore, no significant differences regarding the incidence of a positive Trendelenburg sign between ALMI and mDL were observed (Table 5).

Range of motion

In general, a marked increase in the range of hip motion after implantation was observed for all patients, but no differences were observed between groups (Table 6).

Discussion

Changes in the biomechanical situation and muscular balance of the hip joint are known to play a key role for gait patterns, proprioception, pain and the frequency of falls [2, 4, 18, 30, 32]. Implantation using a modified direct lateral approach is known to lead to muscle trauma with concomitant fatty atrophy of the anterior fibres of the gluteus medius muscle [22, 27]. Since the gluteus medius is not only the agonist for hip abduction but also a synergist for internal and external rotation of the hip, it seems plausible that damage to the internally rotating fibres could lead to an augmented external rotation of the entire limb, including the foot. This assumption is supported by the fact that when patients with a complete gluteal insufficiency lie in supine position, the affected limb falls sideward into external rotation, probably due to the lack of rotational support to retain the limb in its usual position. A change in dynamic rotational alignment can clinically be quantified using the FPA. A permanent unphysiologic change to the FPA is likely to cause overloading of both the hip joint [5] and the prosthesis [11], which, in turn, may influence the lifetime of the arthroplasty [12, 15]. Therefore, the primary objective of this study was to investigate whether a lateral standard approach compared with a minimal-invasive anterolateral approach has an unfavourable effect on the FPA, the gait patterns and pain experienced in patients with primary THA.

The results of this study show that the mDL approach has no adverse effect on the FPA, and an augmented external rotation of the extremity due to a lack of strength to rotate internally could therefore not be proven. Accordingly, the commonly occurring fatty atrophy of the anterior part of the gluteus medius muscle after using mDL approach apparently has little or no functional effect on the rotational alignment of the limb and foot during level walking.

The possible reasons for these findings could be that the damage only plays a minor role in the total function of the gluteus medius muscle and therefore the effects are more or less negligible. Also, the internal rotating function could be compensated by other muscles such as the gluteus minimus or TFL. The latter assumption is based upon previous findings in which the fatty atrophy of the ventral third of the gluteus medius was accompanied by an associated hypertrophy of the TFL muscle [22]. Commensurate with the anatomical fibre orientation, the TFL also acts—in addition to its function as a hip flexor and tensor of the iliotibial tract—as a hip abductor and internal rotator [10]. Hence the TFL seems to be capable of compensating for the limited function of the gluteus medius muscle, which would confirm the findings of the previous study.

Only few studies exist that investigate the FPA pre- and postoperatively in patients with THA. In a study by Martin and co-workers [20], the FPA was assessed after the two surgical approaches but only at a single time point (1 year after surgery). The postoperative values were similar to those found in this study.

As a further possible influencing factor on the FPA, besides muscular tension, the femoral anteversion has to be taken into consideration. In this study, the surgeons attempted to implant the stem with a standard anteversion angle of 10–15°, but this may have varied due to the subject specific intrafemoral anatomy and the anteversion of the femoral neck [9, 33]. Therefore, effects on the foot position due to the anteversion angle seem to be conceivable. To investigate this, knowledge of the native anteversion and the torsion of the stem would be required, and this is therefore the subject of future investigation.

The results of this study demonstrate that no significant differences occur between patient cohorts regarding the gait parameters and range of joint motion. All patients exhibited improvements in functional gait parameters after surgery but without a difference between groups. Apparently, there are no advantageous effects of the minimal-invasive approach on the motion patterns with regard to FPA after 3 months of implantation. Pospischill and co-workers [28] reached similar conclusions after having compared the ALMI and the lateral approach. Here, no influence of the surgical approach on several gait parameters was found after 3 months, but FPA was not quantified. Another study performed by Lugade and co-workers [19] compared an anterior to an anterolateral approach and found a more symmetrical gait for the anterior approach 6 weeks after surgery. After 16 weeks, these differences between the groups diminished, so that no difference between groups could be detected anymore. It seems that functional differences based on the surgical approach may only occur within the first few postoperative weeks during rehabilitation.

In addition, in this study, there were no approach-related effects with respect to the HHS, the occurrence of the Trendelenburg's sign or the intensity of pain. Similar results were found in previous studies comparing the mDL and ALMI approaches [22, 23]. It seems that certain pathomorphological changes of the abductor muscles do not necessarily have an impact on functional outcome scores. Other studies have described beneficial effects due to a minimally invasive surgical approach within the first six postoperative weeks [6, 17]. They reasoned this with a reduction of pain that allowed early postoperative mobilisation. In addition, evidence was provided that muscular processes of regeneration and functional compensation take place within the first postoperative (post trauma) weeks [14]. Thus, differences in function and pain may not be present anymore after 3 months.

Svensson and co-workers [35] as well as Baker and co-workers [1] demonstrated that a traditional surgical approach according to Bauer and Hardinge is often associated with hip abductor insufficiency in conjunction with limping and pain. For the modified approach investigated in this study, these deficits could not be observed. Patients with a mDL approach neither presented a more frequent positive Tendelenburg sign nor had a lower Harris-Hip-Score in comparison with the patients after an ALMI approach. The modification in terms of a shortened incision of maximum 3 cm into the gluteus medius muscle and the avoidance of an extension caudally into the vastus lateralis muscle are the determining factors to reduce muscle trauma and maintain the muscle function. Similar results about the gluteal function using this mDL approach have also been found by other authors [20, 25, 28, 31].

This study does have certain limitations. First, the sample size was small. However, other authors have assessed similar sample sizes in comparable gait analyses [19, 28] and drawn conclusions from them. Second, to provide evidence for the causal chain (the intraoperative muscle trauma leading to fatty atrophy, hip abductor insufficiency, lack of internal rotation and finally a change in the FPA), a selected cohort of patients with proven fatty atrophy of the anterior third of hip abductor would have been favourable. In order to provide evidence of similar atrophy patterns in our study cohorts, magnet resonance imaging (MRI) or electromyography (EMG) would have been necessary. Third, as already mentioned above, FPA might have been influenced by the surgical implantation of the femoral stem. Here, the anteversion was not additionally investigated and thus could not be excluded as a potential influencing factor on FPA.

Conclusions

In conclusion, a modified direct lateral approach does not lead to a higher degree of postoperative changes in FPA than a minimally invasive anterolateral approach. Likewise, no detrimental effects could be observed with respect to gait and pain. Conversely, no beneficial effects of a minimally invasive approach could be found on function. Both surgical approaches seem to be equally applicable approaches with good to very good functional results.

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