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# The short external rotators in the anterior approach hip arthroplasty: do the tendons heal or not? A prospective MRI study

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## Abstract

**Introduction:** Release of some of the short external rotator tendons may be needed in the direct anterior approach (DAA) for Total Hip Arthroplasty (THA). It is unknown if these tendons heal. The purpose of this prospective study is to examine short external rotator tendon healing after release and the associated effect on muscle volume. In addition, we examined the relation with external rotation force and patient reported outcome measures (PROMs).

**Methods:** In 21 DAA THA patients, preoperative MRI was compared with postoperative MRI at 6 weeks and 12 months. PROMs and rotation force of both hips were assessed. Tendon integrity and muscle volume of the obturator internus and piriformis were assessed on MRI using dedicated software.

**Results:** In 5 patients all tendons remained intact, in 4 patients only the conjoined tendon was released and in 12 patients both the conjoined and piriformis were released. Obturator externus remained intact in all patients. In patients with tendon release, mean volume of obturator internus and piriformis muscle decreased 27% (SD 11) and 23% (SD 16) 6 weeks after surgery, respectively. Released tendons and muscle volume loss did not recover 12 months after surgery. We found no relation between tendon release and hip rotation force or PROMs.

**Conclusions:** We found absent tendon healing and muscle volume loss when the conjoined or piriformis tendons were released. Although we found no relation between tendon detachment and hip force or PROMs, we have adapted our operative technique to make it more preserving for the piriformis.



### Keywords

Anterior approach, total hip, soft tissue, femoral release, MRI, short external rotators

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## Introduction

The direct anterior approach (DAA) for hip arthroplasty was introduced by Judet and Judet[1] in 1947. Despite their early experience, worldwide adoption of this approach occurred only in the past decade. It is often defined as a 'muscle sparing approach' as Judet and Judet[1] already described in those early years. However, femoral release, a crucial step in the DAA, might affect some of the short external rotator muscles of the hip.

These rotators are 6 muscles with their insertion on the posterior surface of the greater trochanter (m. quadratus femoris), at the junction of the femoral neck and the

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posterior greater trochanter (m. obturator externus) or at the inside (medial surface) of the greater trochanter. Here, the m. obturator internus, gemellus superior and inferior insert as a conjoined tendon close to the junction of the superior femoral neck, while the m. piriformis insertion is more cranial, towards the tip, on the inside of the greater trochanter. The anatomy of this region is variable: the hip capsule can be fused with the external rotator tendons,[2] the tendons can be fused to each other and the tendon insertion sites vary.[3,4]

Most force around the hip is generated by muscles acting in the sagittal (flexors and extensors) and coronal planes (ab- and adductors). Although less powerful, the short external rotator muscles are dynamic stabilisers of the hip during various motions. All six muscles function as external rotators, but for example m. piriformis and obturator internus also generate some force as an abductor.[5]

During the posterior approach for total hip arthroplasty (THA), the hip is dislocated with flexion and internal rotation. Traditionally, this requires release of 5 of 6 short external rotators (although obturator externus goes unmentioned in many textbooks of surgical anatomy) with only quadratus femoris left partially intact.[6,7] Loss of external rotator muscle force after the posterior approach has been related to dislocation and muscular dysfunction.[5,8]

During the DAA for THA, adequate elevation of the femur for stem insertion relies on release of the soft tissues from the inside (medial surface) of the greater trochanter. Some authors describe this femoral release as detaching only hip capsule,[9,10] while others report release of some of the external rotators during the anterior approach, usually the conjoined tendon and sometimes piriformis.[11,12]

Whether the short external rotator tendons demonstrate some form of healing after their release is not known. Although some authors state release of the rotator tendon creates little morbidity,[11,12] assuming these tendons do not recoil and heal in their anatomic positions, we found no studies that confirm such views. If healing would prove absent or incomplete, neither is it known whether this would be of consequence for patient satisfaction, hip function and muscle force.

We therefore performed a prospective MRI study hypothesising that: (1) the short external rotator tendons do not heal after release, followed by muscle volume loss; (2) external rotation force is less with incomplete healing; and (3) incomplete healing has no effect on patient reported outcome measures (PROMs) after DAA THA.

## Methods

### Patients

Patients, with a minimum age of 18 years, with unilateral symptomatic hip osteoarthrosis eligible for THA were included in this prospective study. Exclusion criteria were hip osteoarthrosis or a total hip prosthesis on the contralateral side, previous hip operations (any side), knee osteoarthrosis or knee replacement on ipsilateral side and passive hip flexion $<90°$.

Patients were recruited between October 2016 and April 2017. They were asked to fill in online PROM questionnaires preoperatively, at 6 weeks and 12 months after surgery. Around these time points patients visited a physiotherapist for hip rotation force measurements and had MRI of their hip joints. Informed consent was obtained from all patients.

This study was approved by the local medical ethical committee.

### Surgical technique

The technique for femoral elevation as described by Corten[11] was used. Briefly, after capsulotomy and antero-superior capsulectomy the femoral neck is cut. Femoral release starts with release of the pubofemoral ligament at the calcar femorale with the leg in figure of 4 position. Next, the inside (medial side) of the greater trochanter is visualised with slight external rotation. A double bent Hohmann or Langenbeck retractor is placed over the tip of the greater trochanter to protect the gluteus minimus and medius. The remaining anterolateral hip capsule was released from the inside of the greater trochanter, which is pulled forward using a bone hook inserted at the calcar. In this manoeuvre, a single layer of capsule and tendon was released from the inside of the greater trochanter, with the electrocautery moving perpendicular to bone, from the superior femoral neck to the tip of the greater trochanter (inside-out). This release starts at the anterior aspect of the greater trochanter, but preserves the gluteus minimus insertion, and proceeds to the posterior aspect of the greater trochanter. Traction with a bone hook at the calcar brings the femur forward, and the release stops when this elevation is judged sufficient for stem insertion. The obturator externus was never released. The antero-inferior hip capsule was preserved in all cases.

### Magnetic resonance imaging (MRI)

All MRI scans were performed on a 1.5-Tesla scanner (Magnetom Aera, Siemens, Germany) using the local clinical hip protocol. Postoperative scans were performed with metal artifact reduction sequence (MARS) using WARP technique. Transverse, coronal and sagittal proton density (PD) turbo spin echo (TSE) and coronal T1 turbo inversion recovery magnitude (TIRM) scans were made. MRI parameters are summarised in Table 1.

2 examiners (WE, EvdV) independently assessed the soft tissues surrounding the hip. In case of inter-observer discrepancy, images were discussed with a third examiner (a musculoskeletal radiologist with $>15$ years' experience) to reach consensus.

Specifically, first the conjoined and piriformis tendons were assessed preoperative and at 6 weeks and 12 months

**Table 1.** Settings for MARS WARP THA 1.5-Tesla MRI imaging (Magnetom Aera, Siemens, Germany).

| | Coronal T1-TIRM | Transverse PD-TSE | Transverse T1-FL2D | Coronal PD-TSE | Sagittal PD-TSE |
|---|---|---|---|---|---|
| Imaged | Whole pelvis | Whole pelvis | Affected hip | Affected hip | Affected hip |
| Voxel size | 1.8 × 1.8 × 3.5 | 1.0 × 1.0 × 5.0 | 0.7 × 0.7 × 5.0 | 0.7 × 0.7 × 4.0 | 0.6 × 0.6 × 4.0 |
| TR (ms) | 4500 | 4000 | 654 | 4000 | 4220 |
| TE (ms) | 38 | 21 | 7.1 | 24 | 34 |
| TI (ms) | 150 | – | – | – | – |
| Flip angle (deg) | 150 | 120 | 60 | 120 | 150 |
| Bandwith (Hz/Px) | 454 | 1302 | 250 | 868 | 149 |
| Echo spacing (ms) | 6.36 | 6.94 | - | 7.98 | 11.2 |
| Phase enc. dir. | F > H | A > P | A > P | R > L | A > P |
| Averages | 2 | 1 | 1 | 1 | 1 |
| FOV read (mm) | 450 | 380 | 160 | 260 | 270 |
| FOV phase (%) | 100 | 100 | 100 | 100 | 100 |
| Base resolution | 256 | 384 | 224 | 384 | 448 |
| Phase resolution (%) | 100 | 82 | 75 | 78 | 80 |
| Slice thickness (mm) | 3.5 | 5.0 | 5.0 | 4.0 | 4.0 |

TR, repetition time; TE, echo time; TI, inversion time; FOV, field of view.

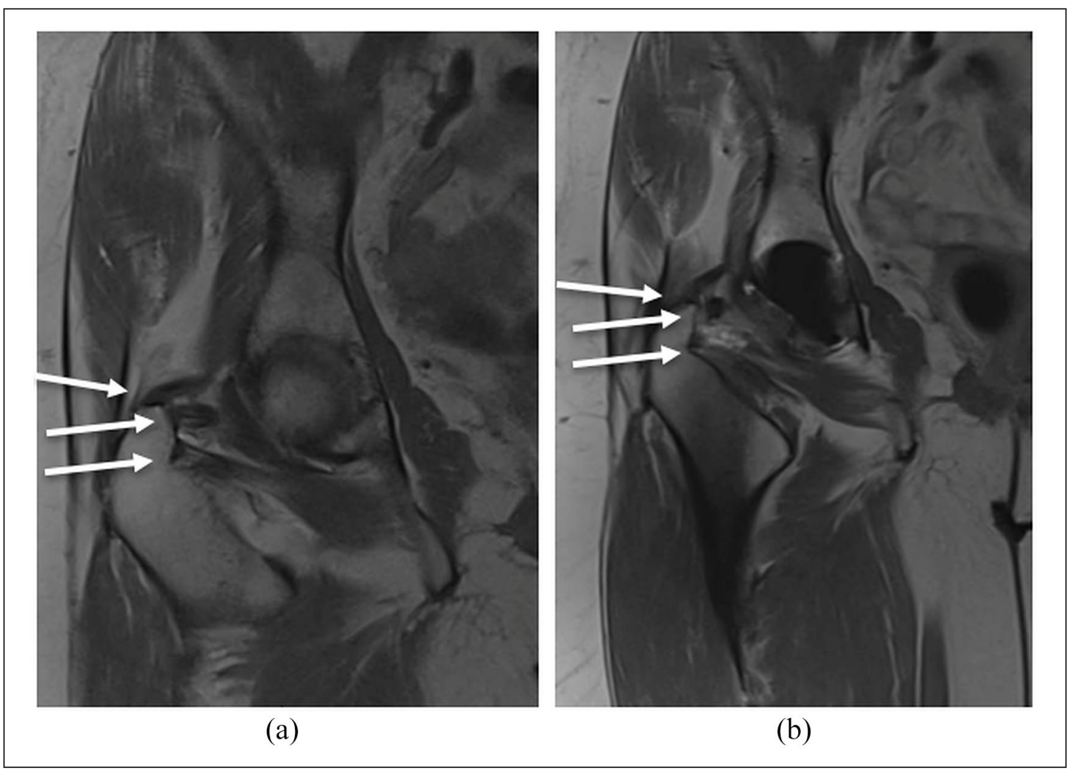

**Figure 1.** Piriformis (upper arrow), conjoined (middle arrow) and obturator externus tendon (lower arrow) intact preoperatively (a) and intact 6 weeks after surgery (b).

after surgery (Figure 1(a) and (b) and Figure 2(a) and (b)). The tendons were quantified as "released" if there was no contact between tendon and bone at the insertion site.

Second, muscle atrophy of piriformis and obturator internus was assessed by measuring muscle volume of the affected (osteoarthrosis) side as a percentage of the unaffected contralateral side. For these measurements we used 3D Slicer (version 4.10.0),[13] an open source software platform validated for semi-automated 3D muscle volume measurements based on pixel count with good inter-observer reproducibility.[14] In the axial MRI pelvis view the muscle bellies of obturator internus and piriformis of both hips were semi-automatically selected (Figure 3(a) and (b)) for 3D reconstruction, with total volume of the muscle given in $cm^3$.

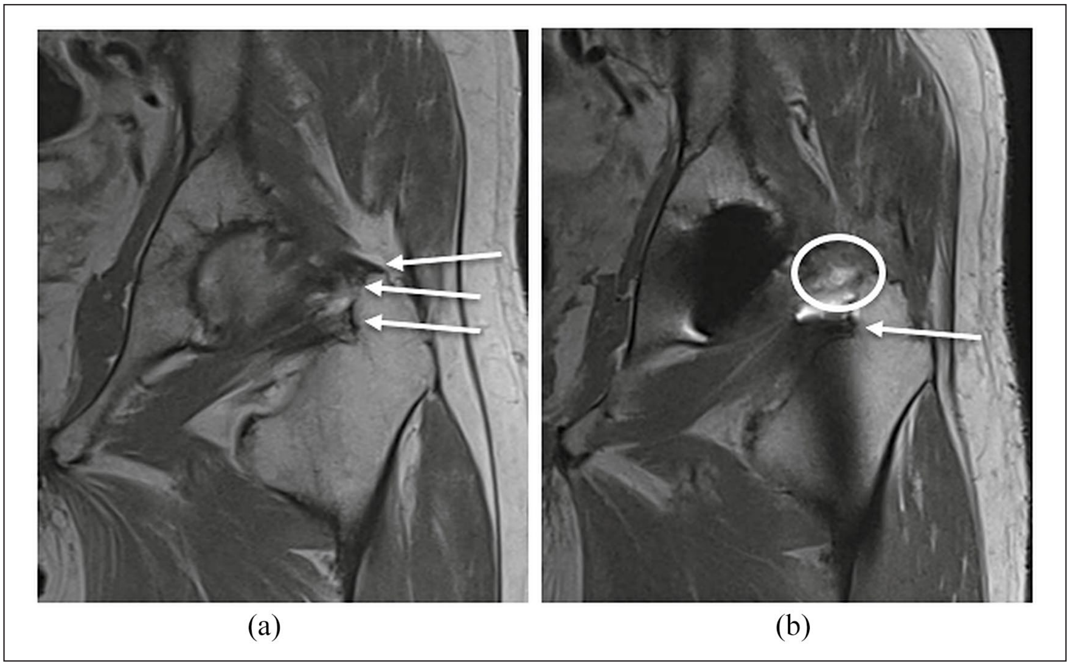


**Figure 2.** Piriformis, conjoined and obturator externus tendon intact preoperatively (a) 6 weeks after surgery conjoined and piriformis tendons are released (circle), obturator externus remained intact (lower arrow) (b).

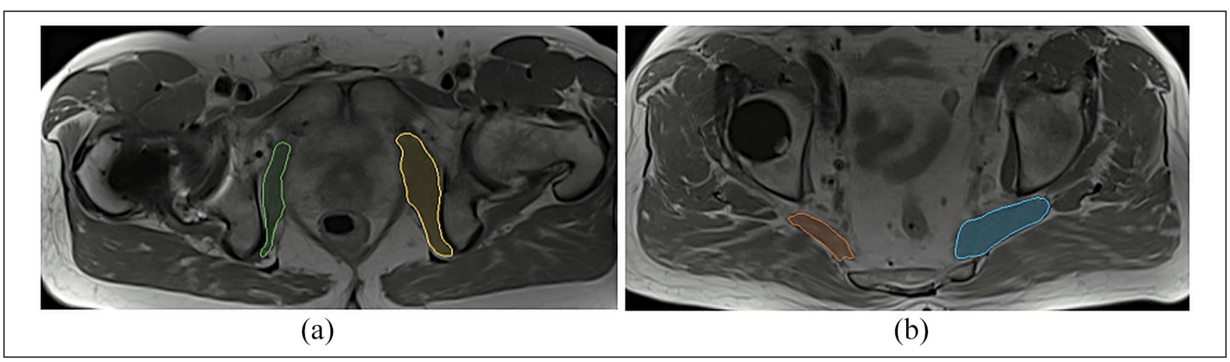


**Figure 3.** Obturator internus (a) and piriformis (b) coloured with 3D slicer one year after surgery. Both patients had THA on the right side, both muscles on the operated side had less volume compared to the left side.

Third, the tendons and muscles of obturator externus, gluteus minimus, and tensor fascia latae, were assessed for damage.

## *External and internal rotation force measurements*

External and internal rotation force were measured by the same physical therapist before surgery and 6 weeks and 12 months after surgery, except for 6 patients in which a second physical therapist performed the measurements at 6 weeks and/or 12 months. Rotation force was measured using a handheld dynamometer (HHD, MicroFET 2, Hoggan Health Industries). Patients were in supine position, with the hip and knee flexed in 90°. The HHD was applied above the malleolus, while the other hand stabilised the knee to prevent adduction and abduction movement. Maximum isometric external and internal rotation force was measured in kilograms. Each measurement was done 3 times and the mean outcome was used for analysis.

To assess reliability, 4 physical therapists performed repeated measurements on several test subjects. The interobserver agreement was high with an intraclass correlation coefficient (ICC) >0.9.

## *PROMs*

Questionnaires consisted of a pain score using Numeric Rating Scale (NRS),[15] a Hip disability and Osteoarthritis Outcome Score – Physical function Short form (HOOS-PS)[16] and EQ-5D quality of life score[17] and were obtained from all study participants through email.

**Table 2.** Patient characteristics.

| Patients *n* | 21 |
|---|---|
| Gender *n* | 10 Male<br>11 Female |
| Mean age *years (SD, range)* | 64 (9, 46–78) |
| Affected side | 16 R, 5 L |
| Mean BMI *kg/m2 (SD, range)* | 26.5 (3, 20–34) |

### *Statistics*

*Descriptive statistics: baseline characteristics*

> Hypothesis 1: Description of tendon healing at 6 weeks and 12 months compared to baseline. Muscle volume (as percentage of contralateral unaffected side) at 6 weeks and 12 months compared to preoperative with a linear mixed model.

> Hypothesis 2: Association of degree of muscle volume loss with external and internal rotation strength, using ICC. Also, rotation strength was compared with the unaffected contralateral side with a linear mixed model.

> Hypothesis 3: Association of external rotator muscle volume loss with PROMs at 6 weeks and 12 months with a linear mixed model.

Standard deviation is given as SD and 95% confidence interval as 95% CI.

## Results

23 patients were included, 2 patients withdrew from participation before MRI was made. Therefore, the study group consisted of 21 patients (Table 2). No wound problems, dislocations or infections occurred.

### *Tendon integrity (MRI)*

MRI at 6 weeks postoperative showed all short external rotator tendons remained intact in 5 patients (24%). In 4 patients (19%) only the conjoined tendon was released, and in 12 patients (57%) both the conjoined tendon and the piriformis were released.

1 year postoperatively, none of the released tendons were healed or re-attached at their insertion site on the greater trochanter. The tendon of the obturator externus remained intact in all patients. No damage was found in the gluteus minimus or tensor fascia latae.

### *Muscle volume of piriformis and obturator internus (MRI)*

Preoperatively, obturator internus and piriformis muscle volume were already decreased with 15–30% compared to the unaffected contralateral side in 48% and 33% of the patients, respectively.

Postoperatively, a further decrease in mean obturator internus muscle volume occurred, with 22% (95% CI, 14–29) and 34% (95% CI, 27–42) at 6 weeks and 12 months, respectively. Similarly, piriformis muscle volume decreased with 13% (95% CI, 6–21) and 23% (95% CI, 16–31) at 6 weeks and 12 months, respectively (Table 3).

Tendon release resulted in muscle volume loss in all patients (Figure 4(a) and (b)), except for 1 patient who had no change in volume of the piriformis at 6 weeks and 12 months after surgery (patient 10) (Figure 4(b)). *Vice versa*, we found 1 patient with progressive piriformis muscle volume loss, while the tendon was intact (patient 13) (Figure 4(b)). In all other patients with intact tendons muscle volume remained stable at 6 weeks and 12 months after surgery (Figure 4(a) and (b)). Mean muscle volume loss at 6 weeks was 27% (SD 11) in the group with the conjoined tendon released compared to 4% (SD 9) with an intact tendon. Mean piriformis muscle volume decreased with 23% (SD 16) in patients with a tendon release and 1% (SD 9) in those with an intact tendon.

### *Hip rotation force*

Preoperative, loss of both external and internal rotation force was more than 20% of the contralateral unaffected hip in 7/21 patients. Another 4 patients had only external rotation force loss, and 4 patients only internal rotation force loss. In the remaining 6 patients measured rotation force loss was small (<20%).

At 6 weeks and 12 months postoperative we found that the individual change in external and internal rotation force was highly variable for the affected hip but also for the contralateral hip. Overall, preoperative mean external rotation force was 77% in the affected hip relative to the unaffected hip, at 1 year this was 93%. But these differences were not statistically significant, nor were their changes (Table 4). We found no statistically significant relation between external or internal rotation force and muscle volume loss of piriformis and/or obturator internus on MRI.

### *PROMs*

Mean NRS pain score decreased with 43 points (95% CI 33–52) at 6 weeks after surgery compared to preoperative. At 12 months further decrease was not significant. Mean HOOS-PS improved with 29 points (95% CI, 22–36) at 6 weeks after surgery and improved with a further 9 points (95% CI, 2–16) at 12 months. EQ-5D improved with 17 points (95% CI, 10–24) 6 weeks after surgery and did not further change significantly after 12 months (Figure 5).

We found no statistically significant relation between short external rotator muscle volume loss and individual PROM changes over time.

**Table 3.** Mean volume (cm$^3$) of the short external rotator muscles ($n$=21). Variable volume of the affected side is also displayed as (mean) percentage of the constant volume of the unaffected side.

| | Mean volume obturator internus | | | Mean volume piriformis | | |
|---|---|---|---|---|---|---|
| | Affected side (*SD*) | Contralateral side (*SD*) | % (*SD*) | Affected side (*SD*) | Contralateral side (*SD*) | % (*SD*) |
| Preoperative | 34 cm³ (7) | 39 cm³ (6) | 86% (11) | 29 cm³ (7) | 32 cm³ (9) | 93% (13) |
| 6 weeks | 26 cm³ (8) | 40 cm³ (7) | 64% (15) | 24 cm³ (8) | 33 cm³ (10) | 80% (22) |
| 12 months | 21 cm³ (9) | 40 cm³ (7) | 51% (20) | 21 cm³ (9) | 32 cm³ (9) | 70% (25) |

*SD*, standard deviation.
Baseline (preoperative) muscle volume of affected side was lower compared to the unaffected side.

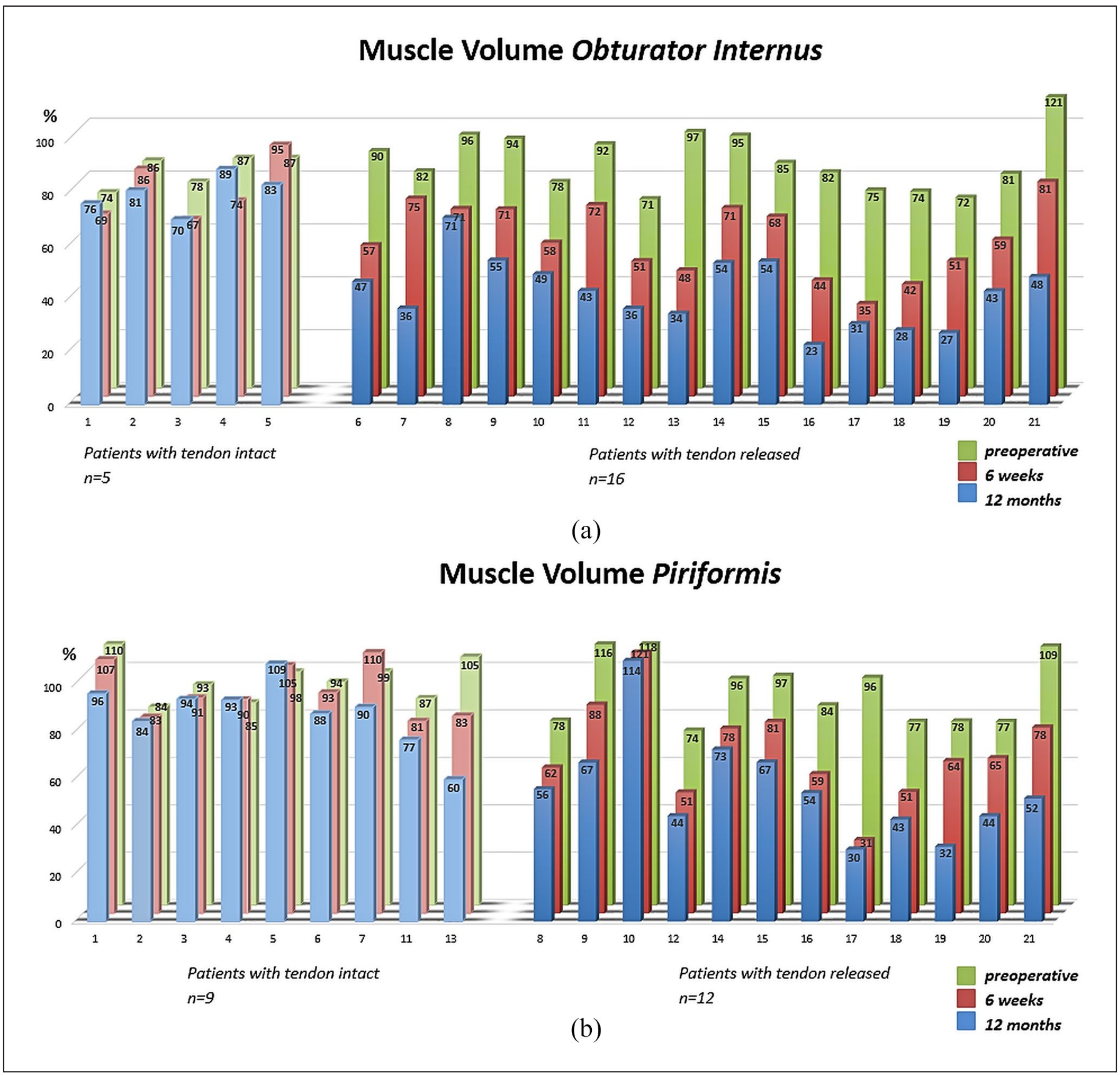


**Figure 4.** Percentage muscle volume of the obturator internus (a) and piriformis (b) compared to the unaffected contralateral muscle. Before operation, at 6 weeks and 12 months. Each number represents one patient (total $n$=21). If the tendon remained intact, muscle volume did not change significantly over time (light-coloured bars). In patients where the tendon was released, muscle volume decreased after 6 weeks and did not recover after 12 months.

**Table 4.** Mean external rotation (ER) and internal rotation (IR) force of the affected and unaffected contralateral hip, before surgery and 6 weeks and 12 months postoperative.

| Mean Kg (range) | Preoperative | 6 weeks | 12 months |
|---|---|---|---|
| ER force affected hip | 12.7 (8.8–21.8) | 12.4 (6.8–18.7) | 14 (7–20.7) |
| ER force unaffected hip | 16.4 (10–26) | 17.5 (9.7–25.2) | 15.3 (10.1–25) |
| IR force affected hip | 11.8 (5.3–17.4) | 13.2 (6.6–20.2) | 13.4 (6.7–20.4) |
| IR force unaffected hip | 14.3 (6.9–23.2) | 15.7 (9.5–21.8) | 14 (8.9–20.3) |

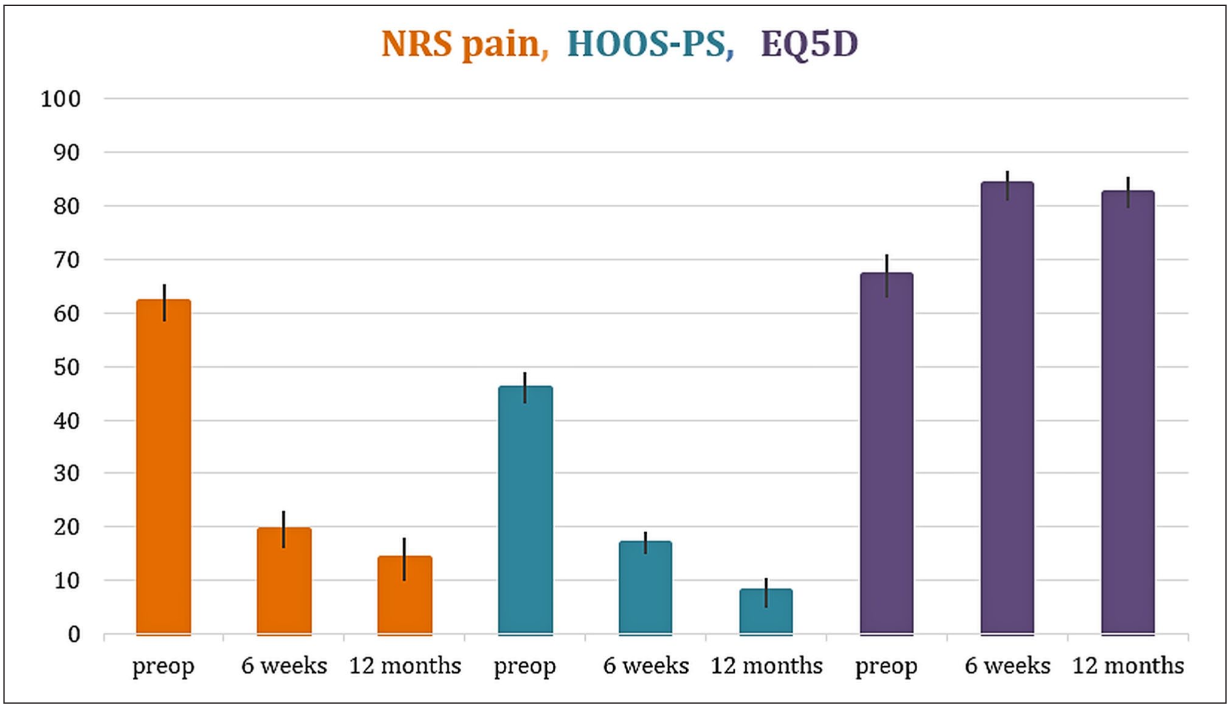


**Figure 5.** Mean NRS pain, HOOS-PS and EQ-5D with +/- standard error (black line). Lower NRS pain and lower HOOS PS equals better outcome; the opposite applies to EQ-5D.

## Discussion

We found incomplete healing and atrophy of the external rotator muscles following their tendon release in the direct anterior approach to the hip.

While aiming for release of the conjoined tendon at most (which is often inevitable due to its anatomical position close to the junction of the superior femoral neck), we found release of the piriformis tendon also in 57% of patients. Nevertheless, we found no correlation between PROMs and MRI findings for the short external rotators. Neither did we find a correlation between hip external rotation force and PROMs or MRI findings.

The unintended release of the piriformis may be due to the release of soft tissue as a single layer, of capsule and rotator tendons, that is developed from anterior to posterior on the inner surface of the greater trochanter.[11] We have adapted our surgical technique by first releasing the capsule, separating it outside-in (cranial to distal) from the tendon insertions. Releasing the capsule from 'outside' first involves detaching the connections of gluteus minimus with the cranial capsule. After capsule release, elevation of the femur is checked with a bone hook. Further release of the conjoined tendon is done only if needed, by dissection close to the femoral neck while elevating the femur. This opens up the plane between the conjoined tendon and piriformis.[3] Under traction, the conjoined tendon peels away from its insertion on the inner surface of the greater trochanter in a medial direction. The proximity of the piriformis insertion to the tip of the trochanter usually allows it to flip over the tip with elevation of the femur, obviating the need for its release. Release of the piriformis is avoided with this more graduated technique. Indeed, we found that additional release of the piriformis, after release of the conjoined contributes little to further elevation of the femur. This larger effect of releasing the conjoined tendon as compared to piriformis was also shown in a cadaver study with graduated release.[18]

We acknowledge several limitations to our study. First, the number of patients that we were able to include for

3 MRI scans is relatively small. This was primarily a challenge in funding the 75 MRI scans originally planned in a study of 25 patients. Nevertheless, we believe our findings, especially because they compare pre- and postoperative, are valuable for the surgical anatomy of the DAA.

Second, the method to measure external rotator muscle function may be questioned. We measured short external rotator force in hip flexion in accordance with recent general recommendations (isometric measurement on a stabilised patient familiarised to the situation[19]). We assume the patient position makes no difference as equal external rotation strength was found with the hip flexed in a seated position and extended in a supine position.[20] Nevertheless, external rotation of the femur may also be affected by the gluteus maximus and quadratus femoris, although the relative contribution of each muscle in seated position is unknown.[21,22] One could argue the quadratus femoris plays an important role as external rotation force is lower following the posterior approach.[8] The method used in our study likely has low sensitivity for force changes in obturator internus and/or piriformis, explaining the absent relation between muscle volume loss and force measurements. Compensation by other muscles, and/or the minor importance of the obturator internus and piriformis muscle for activities as assessed by PROMs, may also explain why we found no relation between tendon release and PROMs.

Third, we did not include healthy controls in our study. This may influence the generalisability of our results as the contralateral hip in persons with unilateral hip pain was found less powerful than in controls.[23]

We are not aware of other studies that combined prospective MRI, force measurements and PROMs in DAA. Yao et al.,[24] in a retrospective chart review, found conjoined tendon release was not predictive of length of stay, inpatient pain medication requirements, or outcome scores. Release of the tensor fascia latae muscle (reported in 9% of cases) was associated with longer hospital stay.[24] We did not release the tensor fascia latae in the patients of this study.

McLawhorn et al.[25] reported on 32 patients following DAA. No preoperative MRI was made, but on immediate postoperative MRI they found conjoined and piriformis tendon release in 65% and 25%, respectively. In contrast to our findings, at 12 months postoperative, they reported both tendons healed through scar with the capsule in all but one of the patients. However, at 1 year postoperative, they found muscle atrophy (graded using Goutallier classification) of the obturator internus and piriformis in 69% and 41% of patients, respectively, comparable to our findings.[25] A possible explanation for this discrepancy in the reported tendon healing is that we compared the postoperative aspect of the tendon with preoperative images, which might lead to a stricter interpretation of an intact tendon. We found no actual contact of a released tendon at or near the original trochanteric insertion site. Both studies found that nearly all muscles with tendon release have atrophy at 1 year postoperative, which indicates at least partial loss of function of the musculotendinous unit.

Pellici et al.[26] did MRI studies of the capsulotendinous repair of the posterolateral approach, but these were not related to force measurements or PROMs. They suggest the posterior repair functions as a biologic scaffold for restoration of the posterior soft tissue envelope.[26] This may explain the difference between the high failure rate in some radiographic follow-up studies and the considerable reduction in the incidence of dislocation with capsulotendinous repair.[27,28] Regarding this capsulotendinous repair, van Arkel et al.[29] suggested that capsule reefing may improve working of the posterior joint capsule after a posterior approach. Perhaps, capsular reefing is feasible when the capsule and tendons are not treated as one layer but separated from each other. However, Pellice et al. evaluated this type of posterior repairs and found a gap between tendons and greater trochanter of >25 mm in about 50%.[26] No preoperative MRI scans were made in this study[26] and, consequently, there are no clear data on muscle atrophy.

Yamaguchi et al.[8] compared muscle force after posterior capsulotendinous repair ($n=13$) to non-repair ($n=16$) and reported approximately 30% higher external rotation strength and also 40% higher abduction muscle strength in patients that had posterior repair. External rotation force was 12.5% less than the contralateral leg at a minimum of 1 year postoperative.[8] We found no statistically significant differences in external rotation force with the DAA when comparing between pre- and postoperative.

Several cadaver studies compared soft-tissue damage between DAA and other approaches.[30,31] They reported damage to other structures than the short external rotators in the DAA, such as the gluteus minimus and tensor fascia latae. Each study mentioned the importance of clinical outcome studies to ascertain the functional implications of their findings. We performed such a clinical outcome study but did not find the type of "collateral damage" these authors report in cadaver studies. Our postoperative MRI findings are comparable to those of Agten et al.[32]

In conclusion, we found that the conjoined and piriformis tendons do not heal when detached in the DAA, and that detachment is associated with muscle volume loss. However, we found no relation between tendon detachment and / or muscle volume loss with external rotation force or PROMs after DAA THA. Nevertheless, we have now adapted our technique for femoral release to make it more preserving for the piriformis tendon.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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