Retro-trochanteric sciatica-like pain
In-depth analyses of clinical symptoms, treatment options, histological and ultra structural findings in tendon biopsies

M. Khaled Meknas
A dissertation for the degree of Philosophiae Doctor
May 2010
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In-depth analyses of clinical symptoms, treatment options, histological and ultrastructural findings in tendon biopsies

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First of all, I would like to thank my supervisor, Professor Oddmund Johansen, for his patience, enthusiasm and support throughout this entire period.

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Last but not least, the greatest thank you goes to my family, Dana, Omar and Manar, for support and love.
LIST OF PAPERS

Paper I
Khaled Meknas, Anders Christensen, Oddmund Johansen (2003). The internal obturator muscle may cause sciatic pain; Pain 104: 375–380

Paper II

Paper III

Paper IV

The papers will be referred to in the text according to their roman numbers.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AB/PAS</td>
<td>Alcian Blue/Periodic Acid Schiff</td>
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<tr>
<td>CT</td>
<td>Computerised Tomography</td>
</tr>
<tr>
<td>ECM</td>
<td>Extra-Cellular Matrix</td>
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<tr>
<td>ESWL</td>
<td>Extracorporeal Shock Wave Therapy</td>
</tr>
<tr>
<td>FAI</td>
<td>Femuro-Acetabular Impingement</td>
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<tr>
<td>FCF</td>
<td>Fracture of the Collum Femoris</td>
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<tr>
<td>GAGs</td>
<td>Glycos-Amino-Glycans</td>
</tr>
<tr>
<td>H&amp;E</td>
<td>Haematoxylin and Eosin</td>
</tr>
<tr>
<td>MMP</td>
<td>Matrix Metalloproteinase</td>
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<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<td>OA</td>
<td>Osteoarthritis</td>
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<tr>
<td>PRP</td>
<td>Platelet-Rich Plasma</td>
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<td>TEM</td>
<td>Transmission Electron Microscopy</td>
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<td>VAS</td>
<td>Visual Analogue Scale</td>
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INTRODUCTION

Pain localised in the hip region may be part of a symptom pattern pointing towards well-known diseases. Additional complaints, clinical findings and supplementary examinations such as standard radiographs and MRI might point towards treatable pathology in the back, hip and even the knee. In some cases, the pain may have serious consequences for a patient; however, it may be diffuse and with a pattern that is not readily understood and treatment attempts may not be successful. For many years, our institution has continuously encountered a patient group of this kind which complains of pain in the hip region of a diffuse yet serious character, without a clear diagnosis and often with a very long history of unsuccessful treatment attempts. These patients have often undergone radiographic examinations of the hip, to verify or exclude osteoarthritis (OA); they may have been examined for pathology in the back using MRI or CT; and some of them may have been operated on because of pathology indicating a spinal cause diagnosed by well-established diagnostic procedures. As reported in Paper I in the present thesis [1], a surgical study was performed, as we expected the so-called “piriformis syndrome” in a number of patients with unclear pathology after performing multiple radiographic assessments. During the surgical procedure, no pathology was found around the piriformis muscle and tendon. Exploration, however, revealed a clear pathology in all cases, consisting of a very tense internal obturator tendon, which had an impact on the sciatic nerve. The observation in Paper I justified a study with a conservative approach. The described technique for treating a supposed tense piriformis muscle conservatively is often based on the assumption that it changes from an outward to an internal rotating muscle when the hip is in flexion [2]. This may not apply to the internal obturator muscle. Future exploration of the influence of the internal obturator muscle and tendon on the motion pattern of the hip joint is indicated in order better to understand what in fact constitutes the “piriformis syndrome” and how our findings are related to that syndrome.

Disc herniation

Low back pain is very common and the number of cases with additional sciatic pain is low in comparison. Compression of a nerve root is one of the most common causes of sciatica; a herniated disc is compressing the root in 90% of cases [3]. Other possible causes of sciatica include lumbar spinal stenosis and, more rarely, tumours or cysts. Typical dermatomal distribution of pain which worsens on coughing, sneezing or straining, increased finger-floor
distance and sensory symptoms, such as numbness or paresthesia, are significant predictors of nerve root compression in patients with low back pain radiating distally into the leg [4]. Medical history and physical examination are the mainstays of sciatica diagnosis. The straight leg raising test or Lasegue’s test is a commonly used test in patients with suspected sciatica. In addition, changes in the Achilles and patellar tendon reflexes, reduced strength in the big toe, ankle and knee are typical signs in patients with nerve root compression. The distribution of pain radiating in the lower limb, a characteristic and definitive feature of the condition, can be evaluated using pain drawings [3]. Disc herniation is reported in 20-36% of individuals without symptoms of sciatica or low back pain and, furthermore, many patients with clinical symptoms of sciatica do not display lumbar disc herniation on imaging [3]. Conservative treatment strategies for disc herniation are primarily aimed at pain reduction, either by using analgesics or by the non-surgical reduction of pressure on the nerve root using traction, spinal manipulation or physiotherapy, for example. Conservative treatment regimens are currently the first-line option for patients with sciatica. The adequate management of pain and an active approach, with patients being reassured and advised to continue their daily activities as much as possible, is the preferred treatment strategy [5]. If the patient has not improved after 6-8 weeks of treatment, imaging should be considered to determine whether a herniated disc with nerve root compression is present. Surgery may be needed to relieve the pressure on the nerve root. There are several surgical methods to treat disc herniation; they include discectomy, microdiscectomy, microendoscopic discectomy, transforaminal endoscopic discectomy and chemonucleolysis. The cauda equine syndrome is an absolute indication for immediate surgery, but elective surgery is the treatment of choice for unilateral sciatica [3].

**Lumbar spinal stenosis**

Lumbar spinal stenosis is defined as a narrowing of the spinal canal. In some patients, this condition becomes symptomatic. The classic presentation is that of bilateral neurogenic claudication, defined as intermittent pain radiating at varying degrees to the buttocks, thigh and leg, which gets worse with prolonged standing, walking, or lumbar extension [6]. However, many individuals remain asymptomatic and radiographic findings do not necessarily correlate with clinical symptoms. Lumbar spinal stenosis occurs with normal vertebral alignment, while some patients also suffer from concomitant degenerative “spondylolisthesis”, which is defined as the forward slipping of one lumbar vertebra in relation to another with an intact neural arch. In most cases, “spondylolisthesis” affects the
L4-L5 level. It commonly occurs in patients over the age of 50 and affects females six times more frequently than males. Degenerative spondylolisthesis is generally asymptomatic, but it can be associated with symptomatic lumbar spinal stenosis and radiculopathy [6]. Treatment options are either non-surgical methods or surgical intervention depending on the severity of the stenosis and the number of levels involved. Surgical fusion and laminectomy are the methods most commonly used to treat spinal stenosis [6]. The management of degenerative lumbar disease is demanding. Conservative treatment consisting of oral pain medication, epidural corticosteroid injections, traction and spinal manipulation has been described with varying results. Surgery may be necessary when the patient has symptoms due to either instability or neurological compression [5].

**Tendinitis/tendinosis/tendinopathy**

Tendons function to transmit muscular force across joints, resulting in body movement and joint stabilisation. Tendons are primarily composed of collagen, proteoglycans, water and cells. The predominant constituent is collagen, which makes the tendon ideally suited to withstand and transfer tensile loads. Ninety-five per cent of the collagen content is type I, while the remaining 5% is type III and IV. The predominant cell type is the tenocyte, which synthesises and supports the tendon matrix. Vascularity within the tendon is relatively sparse and corresponds to the low metabolic turnover rate of these tissues [7].

Tendinitis is an inflammation in a partially torn tendon. The tendon damage occurs through acute and chronic injury. An acute injury disrupts vascular tissues within the tendon and results in a well-studied healing process involving three phases: inflammation, repair and remodelling. The first phase, inflammation, occurs as a haematoma forms from erythrocytes and activated platelets. This is followed by the infiltration of inflammatory cells, including neutrophils, monocytes and macrophages that migrate to the injury site to remove debris. Shortly afterwards, chemotactic signals induce fibroblasts to start synthesising collagen. The second phase, repair, is highly vascular and cellular and involves the deposition of collagen and tendon matrix components. During the final phase, remodelling, the vascularity and cellularity of the injury site decrease and the collagen becomes more structured and organised. The injured site never achieves the original histological or mechanical features of a healthy uninjured tendon. Tendinitis develops within a short time frame, as a result of a single traumatic episode. After the initial traumatic episode, the term “tendinitis” wrongly continues to be used clinically to describe any painful condition of the tendon. Instead, accurate histological and pathophysiological terminology should be used [7].
The term “tendinosis” is used in histological descriptions to indicate degenerative changes without inflammatory cells but with changes such as collagen fibril disorientation, rounding of tenocyte nuclei, increased ground substance, hypervascularity and increases in proteoglycan content in the histological specimen [8-10]. Tendinosis refers to the intratendinous degeneration that is thought to be a result of chronic overuse and it requires a more prolonged time frame than tendinitis to develop.

“Tendinopathy” is a term that is commonly used in chronic tendon disorders and is a broad, overarching term referring to any abnormal condition of the tendon when the patient seeks help as a result of pain.

The terminology when discussing tendon pathology is fairly confusing. It is, however, generally accepted that an inflammation plays a role only in the initiation, but not in the propagation and progression, of common tendon disorders [8].

In particular, tendons are more elastic at low strain rates and stiffer at higher rates of tensile loading. Accordingly, the rate of tissue loading can influence the injury pattern of a tendon. Total tendon strains (percentage deformity) of 1% to 2% result in the straightening of the crimp pattern of unloaded tendon collagen. Strains of 2% to 6% are well tolerated by most healthy tendons. With a strain higher than 6%, incomplete tears start to occur within the tendon. Complete structural failure typically occurs in the range of 8% to 10% [7].

Tendon microtrauma can also result from non-uniform stress occurring within a tendon, producing abnormal loading concentrations and localised fibre degeneration. There is empirical evidence that a repeated load associated with athletic activity leads to tendinopathy. The common injury sites include the Achilles, patellar, rotator cuff and thigh adductor tendons [8]. An impingement theory of tendinopathy has also been suggested, in addition to the vascular theory that suggests that tendons generally have a poor blood supply [8].

Recently, some interest has focused on the role of the nervous system in the tendinopathy process. Neuraly mediated mast cell degranulation could release mediators such as substance P and calcitonin gene-related peptide. Substance P, a pro-inflammatory mediator, is definitely increased in rotator cuff tendinopathy [8]. Larger amounts of the neurotransmitter glutamate have been identified in the ultradialysate in Achilles tendinopathy compared with normal tendons [11]. However, the neural theory does not explain why morphologically pathological tendons are not always painful [8].

When tendinopathic specimens were histologically analysed in one study, no inflammatory cells were found. However, it is presumed that a chemical inflammatory response as
cytokines and prostaglandins and an angina-like effect in the tissue, can be pain producers in different ways in tendinopathically changed tendon [12].

**Tendon degeneration and retro-trochantric pain**

The examination of the histological and ultrastructural characteristics of the peri-articular tendons in the hip region could be one way of better understanding the patho-physiological process in this area.

Degenerative tendon disorders and overuse injuries in sports and repetitive occupational activities are major problems in the general population, as well as being difficult to treat [8;13]. A better understanding of the cellular interaction during tendon injury and degeneration may help to increase the opportunity to treat the condition.

Magra et al. [14] stated that the interaction between the various intrinsic and extrinsic factors and the genetic “make-up” of an individual may increase the likelihood of one individual developing tendinopathy compared with another. They speculated that gene therapy might prove to be an effective method to aid tendon healing. The morphological changes in tendinopathy have been analysed in several studies [15-19] including the shoulder [19-22], elbow [10], patellar and Achilles tendons [23-28]. However, there is limited information in the literature in terms of the ultrastructural and histological changes in the tendons in the hip and gluteal region. Lempainen et al. [29] confirmed tendinosis using histological analysis in 103 cases of proximal hamstring tendinopathy in athletes. Grimaldi et al. [30] used magnetic resonance imaging (MRI) and showed a significantly smaller piriformis muscle in patients with hip OA compared with patients with non-osteoarthritic hips, while Broadhurst et al. [31] found an abnormal piriformis morphology in a significant number of patients with chronic buttock pain using ultrasonography. Lequesne et al. [32] studied the correlation between MRI findings and clinical and surgical findings in “refractory greater trochanteric pain syndrome”. They found tears in the gluteus medius and minimus tendons and they introduced the term “hip rotator cuff syndrome” [33]. Pathology in the short rotators of the hip is regarded as a possible source of retro-trochanterically located sciatica-like pain [34] and it was suggested that the overuse of the piriformis muscle contributed to the “piriformis syndrome” [35]. Recently, the approach to symptoms from the hip joint has become more active. The opportunity to perform hip arthroscopies and address pathology such as labral lesions and FAI syndrome has increased the potential for treating symptoms from the hip joint before it is subjected to joint replacement surgery [36-38].
Some authors suggest that pain in the osteoarthritic joint may be caused by the spasm and pressure in the surrounding muscles and tendons towards the joint capsule, which is richly innervated [39;40]. Theoretically, the pathology in the short rotator muscle tendons could contribute to the symptoms experienced by patients with osteoarthritic hips or degenerative lumbar disease. Treatment of the tendinosis in patients with mild and moderate OA might therefore be an option in order to reduce the symptoms. The overall incidence of retro-trochanteric pain is unknown, as it is often an exclusion diagnosis.

**Osteoarthritis**

Osteoarthritis (OA) is the most common form of arthritis and a leading cause of chronic disability. OA characterised by joint pain, tenderness, limitation of movement and a varying degree of inflammation is most common in the hip, knee and hand joints. Synovitis is an intrinsic component of OA, which becomes more extensive as the disease progresses. It may not be apparent clinically, but it can be detected by arthroscopy, MRI and ultrasound. Synovitis may contribute to the progression of cartilage degradation [41]. The conservative treatment for hip and knee OA includes physiotherapy with an exercise and muscle strengthening programme, cryotherapy, or orthotic management such as footwear or bracing. Furthermore, pharmacotherapy with NSAIDs and analgesics is extensively used in clinical settings, as are intra-articular injections with corticosteroids. However, the treatment of choice for advanced hip and knee OA in elderly patients is still arthroplasty [42].

**Piriformis syndrome**

The piriformis muscle originates from the anterior surface of the sacrum and inserts into the upper part of the greater trochanter, passing out of the pelvis through the greater sciatic notch. Contracture of the piriformis muscle has been thought to cause the “piriformis syndrome”, with a well-known clinical picture with sciatica-like symptoms [35]. Back in 1928, Yoeman [43] reported that sciatica might be caused by a periarthritis involving the anterior sacroiliac ligament, the piriformis muscle and the adjacent branches of the sciatic nerve. In 1947 [44], Robinson introduced the term “piriformis syndrome”. The incidence of “piriformis syndrome” among patients with low back pain has been reported to be 5-36% [45;46]. One MRI imaging paper has shown a lack of nerve root compression in the lumbar
spine in spite of symptoms of sciatica in 16.4% of the patients in a cohort paper and 4.9% of them were found to have the “piriformis syndrome” [47].

It has been argued that the piriformis muscle may irritate the sciatic nerve due to an anatomical abnormality such as a hypertrophic muscle. The entrapment and irritation of the sciatic nerve in the hip region has been largely thought to be influenced by the piriformis muscle. Anatomical variations such as a bipartite piriformis muscle [48;49] and the piriformis muscle lying anterior to the nerve [50] have been described as irritating the sciatic nerve.

The etiology of “piriformis syndrome” is not clearly known, although it has been argued that the pain syndrome may be caused by trauma to the pelvis or buttock [35;51], in addition to anatomical abnormalities of the piriformis muscle, as mentioned above [48;49], or as a recurrent problem after spinal surgery [52]. Adhesions between the piriformis muscle and the sciatic nerve have been reported by Benson et al. [51]. Cox et al. [34] argued that the gemelli-obturator internus muscles and the associated bursa should be regarded as possible sources of retro-trochanterically located sciatica-like pain. Overuse of the piriformis muscle was suggested to contribute to the “piriformis syndrome” by Mayrand et al. [35]. The “piriformis syndrome” has also been reported as a complication following hip replacement surgery [53;54].

There are no laboratory or radiographic methods for diagnosing the syndrome [55-60], and there are a few reports in the literature regarding electrophysiological analysis [61;62].

A number of methods exist for the treatment of the “piriformis syndrome” in the hip region. They include physiotherapy [2;34;35], extracorporeal shock wave therapy (ESWT) [63;64], injections with platelet-rich plasma (PRP) as used in other tendinopathies [65;66], injections of anaesthetic agents with or without steroids [52;67-69] and the surgical release of the tendon [1;51;70]. A surgical tenotomy to relieve the nerve from the pressure of the tense muscle has resulted in immediate pain relief [48;50;52]. Dezawa et al. [71] even described an arthroscopic technique for the release of the piriformis tendon.

**Obturatorius internus syndrome**

The obturator internus muscle is located inferior to the piriformis and arises within the pelvis. It originates at the medial surface of the pubis, covers the obturator foramen and passes through the lesser sciatic notch to insert onto the greater trochanter laterally.

There are 6 external rotator muscles of the hip: the piriformis, superior gemellus, obturator internus, inferior gemellus, obturator externus and quadratus femoris. They are in close
anatomical proximity to one another and they work as a functional unit as a triceps muscle [57].

The tendon of the piriformis muscle was found to have fused with the internal obturator tendon in 48 of 112 cases in an anatomical study [72], which can indicate a strong interaction between the piriformis and internal obturator muscles and the sciatic nerve, and it also runs parallel to the piriformis muscle in its attachment to the trochanter major. Pathology in the internal obturator muscle may be obscured by the complex anatomy in the region. Because of its proximity and similarity in both structure and function, most treatment for the “piriformis syndrome” also affects the internal obturator [46].
AIMS OF THE STUDY

The initial aim of this work was to clarify the role of the so-called “piriformis syndrome” in patients with retro-trochanteric pain. Observations in Paper I provided a broader perspective, with the internal obturator muscle and tendon possibly playing a role in the syndrome. Additionally, modifications of treatment of the “retro-trochanteric pain syndrome” evolved as equally important aims.

The specific aims of the four individual studies included in this thesis were as follows:

- To evaluate the short-term results after surgical treatment in patients with the so-called “piriformis syndrome”

- To evaluate the medium-term results of conservative treatment of patients with retro-trochanteric pain syndrome using a specific stretching programme

- To evaluate the long-term results for the patients included in Paper I

- To evaluate the ultrastructural and histological characteristics of the internal obturator tendon in patients with hip OA and in patients with a fracture of the collum femoris (FCF)
DESIGN AND DEMOGRAPHICS OF THE STUDIES

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<tr>
<td>Paper I</td>
<td>6 surgically treated patients and 6 controls</td>
<td>All 9/12 patients were also included in Paper III</td>
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<tr>
<td>Paper II</td>
<td>13 patients</td>
<td>All 9 patients were also included in Paper I</td>
</tr>
<tr>
<td>Paper III</td>
<td>4 surgically treated patients and 5 controls</td>
<td>All 9 patients were also included in Paper I</td>
</tr>
<tr>
<td>Paper IV</td>
<td>10 patients with OA and 10 patients with FCF</td>
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**Paper I**
Twelve patients (three males and nine females), mean age 47 (25-66) years, with retro-trochanteric pain in the buttock, radiating distally to the knee and intolerance to sitting more than 40 min, were included in a prospective, randomised study with either surgical or no treatment. Sealed envelopes were used during the randomisation procedure. The median duration of symptoms was 7.5 (2-20) years and all the patients had undergone various conservative treatments before inclusion in the study. The patients were followed for six months and they were repeatedly questioned about pain and examined during the follow-up period.

**Paper II**
Thirteen patients (one male and twelve females), mean age 49 (36-61) years, who had localised retro-trochanteric pain in the hip region, which spread diffusely down the lower extremity, were included in this conservative treatment study. The median duration of the symptoms was 8 (1-20) years. The patients had made previous attempts at conservative treatment such as physiotherapy, non-steroidal anti-inflammatory drugs and injections of local anaesthetic agents in combination with corticosteroids. None of the patients had previously undergone an extended period of physiotherapy aimed at stretching and relaxing the internal obturator muscle. All the patients had to wait for a minimum of six months between inclusion in the study and the start of the treatment. During that time period, no patient improved spontaneously and their symptoms remained unchanged.

**Paper III**
This is a long-term report on the twelve patients included in Paper I. Nine of twelve of the initial patients from Paper I could be followed up in Paper III.
**Paper IV**

The material in Paper IV consisted of tendon samples from the short external rotators of the hip, e.g. the internal obturator muscle, obtained during open surgery at the time of total hip replacement in 10 consecutive patients with OA of the hip; median age 60 (48-75) years. Samples from 10 consecutive patients with FCF (Garden III or more), median age 82.5 years (60-85), who also underwent a total hip replacement, served as controls. A minimum of two samples were obtained from each patient.
METHODS

Clinical examination

The pain was classified using a visual analogue scale (VAS) graded from 0-10, where 0 indicated no pain and 10 indicated the worst possible pain. The patients were tested for pain and weakness on resisted abduction and external rotation of the thigh in a sitting position; the Pace sign, which was categorically classified by the patient as positive (pain) or negative (no pain) (Figure 1). Correspondingly, the Freiberg sign for pain and weakness on forced passive internal rotation of the extended thigh was used and it was also categorically classified by the patient as positive (pain) or negative (no pain) (Figure 2).

All these tests are poorly validated despite they are frequently used in the clinical setting. Buttock and leg pain during passive straight leg raising performed by the examiner (Lasegue’s sign) was classified as positive if the patient reported that radiating pain occurred before 60° of hip flexion.

Limping and tenderness at palpation were performed and categorically classified by the examiner and the patient respectively as either positive or negative. The patients’ sitting and walking ability was classified by the patients according to five-grade scales.

The use of analgesic and anti-inflammatory drugs for each patient was classified using a five-grade scale. Zero points represented no drugs, one point represented paracetamol irregularly, two points paracetamol/codeine or NSAID regularly, three points paracetamol/codeine and NSAID regularly and four points paracetamol/codeine and additionally buprenorphin, tramadol or morphine. These evaluations were made at the start of the study, at 6 months and at 8 years in both the surgical and the control group.
Radiographic assessments

The patients in Papers I, II and III underwent standard antero-posterior radiographs of the pelvis and hips, a lateral view of the hips (bilaterally) and either CT using a Siemens Somatom Sensation (Siemens AG, Erlangen Germany) or MRI using a Philips Intera 1.5 Tesla (Royal Philips Electronics, Amsterdam, Netherlands) of the lumbar spine. The examinations were performed to rule out the possibility that the symptoms experienced by the patients in Papers I, II, and III originated from the spine or the hip joint.

All the radiographic assessments were performed by an experienced radiologist following standard evaluation protocols for the examinations. However there were no specific intra- or inter-observer classifications were performed.

Non-surgical rehabilitation programme

In Paper II, all the patients were hospitalised at the Rehabilitation Centre of North Norway for a four-week supervised rehabilitation programme. They participated in two daily treatment
sessions of approximately 30 minutes each. The exercise programme in the present paper aimed at reducing the tension in the internal obturator muscle. The exercise programme was designed to be simple to teach, remember and perform both at the clinic and subsequently at home without supervision. It aimed to stretch the muscles around the hip by separate active and passive abduction, flexion and extension exercises (Figure 3 A-D). During abduction and flexion of the hip, the knee was kept extended (Figure 3A and C). During extension of the hip, the patient grasped his/her ankle and helped force the knee into flexion, while keeping the body in an upright position (Figure 3B). Two additional exercises were also included for the treatment of the small external rotators. One was a combined forced passive internal rotation with additional pressure towards hip flexion and adduction (Figure 3D). The other was direct massage of the insertion of the small external rotators by a therapist. All these exercises were performed for 15-30 seconds at a time and repeated 5-15 times, depending on the ability of the patient to tolerate the stretching. If the pain was intolerable, that specific exercise was discontinued and the patient moved on to the next exercise. During the next session, a new attempt to tolerate that specific exercise was made. The patients were not denied access to other training activities, as they were accommodated at the rehabilitation centre, but they were only formally instructed and motivated for the specific programme.
Figure 3. The stretching exercises in flexion (a), extension (b), abduction (c) and a combined flexion, adduction and internal rotation position (d), copyright Ninni Sernert.

**Surgical technique and postoperative management**

In Papers I and III, an exploratory operation was performed using a postero-lateral approach in the hip region. The fascia lata was split and the external rotators and the sciatic nerve were identified. Examinations of the anatomy, as well as the relationships between structures during passive flexion and internal rotation, plus the Lasegue test, were made during the operation. The internal obturator muscle was found to be tense, hyperaemic and in close contact with the sciatic nerve (Figure 4A and B). The nerve was flattened and slightly hyperaemic. During the Lasegue manoeuvre performed on the operating table, the internal
obturator and not the piriformis muscle impinged on the sciatic nerve at an early stage during the hip flexion movement. To relieve the tension towards the sciatic nerve from the internal obturator muscle, a sectioning of the tendon was performed at its insertion to the greater trochanter. An immediate release of the tension towards the sciatic nerve during the Lasegue manoeuvre was observed after sectioning the tendon (Figures 5A and B). Prophylaxis against infection was administered intravenously using 2 grams of Cefalotin (ACS Dobfar Generics, Luxembourg) just before the operation. Weight-bearing supported by crutches was allowed immediately after surgery. A gradual increase in activity as tolerated by the patients was allowed. The patients underwent no formal sessions of physiotherapy.
Figure 4. The sciatic nerve and the internal obturator tendon as found during an operation for retro-trochanteric pain syndrome. The internal obturator tendon is tense and hypertrophic, lying in close contact with the sciatic nerve, which turns sharply over the tendon. Figure 4 A is used and modified with permission from the IASP® (International Association for the Study of Pain®), originally published in Meknas et al [1]. Figure 4 B, copyright Catarina Kartus.
Figure 5. After sectioning the internal obturator tendon, the sciatic nerve is released from the tendon. Figure 5A is used and modified with permission from the IASP® (International Association for the Study of Pain®), originally published in Meknas et al. [1]. Figure 5B, copyright Catarina Kartus.
**Biopsy procedure**

In Paper IV, the biopsies were obtained in an open fashion during total hip replacement using a postero-lateral approach in the hip region. The fascia lata was split and the external rotators and the sciatic nerve were identified. Before entering the intra-articular area, macroscopic biopsies from the short rotator (internal obturator tendon) were taken using a standard surgical knife.

**Histological analysis**

The samples destined for light microscopy were fixed in 4% formalin, embedded in paraffin blocks and sectioned at 4-5μm. The sections were stained with haematoxylin-eosin (HE), to evaluate the fibre structure, cellularity and vascularity, and with Alcian Blue/Periodic Acid Schiff (AB/PAS), to detect sour/neutral mucins for glycosaminoglycans (GAGs). Furthermore, the Perl, van Gieson and van Kossa stains were performed to identify hemosiderin, collagen and calcium deposits respectively. The fibre structure, cellularity, vascularity and the presence of GAGs were classified according to a semi-quantitative scoring system (Table 2) [73]. The staining for hemosiderin and calcium deposits was dichotomously classified as positive/negative. All biopsies were evaluated by two independent, experienced pathologists.
Table 2. Evaluation of biopsy samples with a semi-quantitative 4-point scoring system

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<th>Grade 2</th>
<th>Grade 3</th>
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<tr>
<td>Fibre structure</td>
<td>Straight, parallel, packed fibres, with slight waviness</td>
<td>Slight separation of fibres, increased waviness</td>
<td>Separation of fibres, deterioration of fibres</td>
<td>Complete loss of fibre structure and hyalinisation</td>
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<tr>
<td>Cellularity</td>
<td>&lt; 100 cells/high power field (HPF)</td>
<td>100-199 cells/HPF</td>
<td>200-299 cells/HPF</td>
<td>&gt; 200 cells/HPF</td>
</tr>
<tr>
<td>Vascularity</td>
<td>Vessels running parallel to the collagen fibre bundles in the septa</td>
<td>Slight increase in vessels, including transverse vessels in the tendon tissue</td>
<td>Moderate increase in vessels within the tendon tissue</td>
<td>Markedly increased vascularity with clusters of vessels</td>
</tr>
<tr>
<td>Glycosaminoglycans</td>
<td>No alcianophilia</td>
<td>Slight alcianophilia between the collagen fibres</td>
<td>Moderate increase in alcianophilia</td>
<td>Markedly increased alcianophilia forming blue lakes</td>
</tr>
</tbody>
</table>

Ultrastructural analysis

For the transmission electron microscopy (TEM) analysis, the specimens were fixed in 8% formaldehyde in Hepes buffer. The biopsies were cut into small cubes and half the material was immersion-fixed in McDowell’s fixative for electron microscopic studies [74]. Ultrathin sections were mounted on formvar-coated 100 mesh copper grids and stained with 5% uranyl acetate and Reynold’s lead citrate [75]. Micrographs were obtained using a Jeol JEM 1010 (Tokyo, Japan) with a Morada camera system (Olympus Soft Imaging Systems, Münster, Germany).

For sampling, two blocks from each patient were sectioned and mounted on carbon-coated formvar films on copper grids.

Micrographs for measuring the fibril diameters were obtained at random, from one to three groups of cross-sections from each block. At a magnification of x 50,000, a minimum of 100 fibril diameters were measured using the Soft Imaging System (Olympus, Münster, Germany). The relative fibril diameter distribution was calculated in percent. The morphology of the extracellular matrix (ECM) was evaluated and dichotomously classified as homogeneous or irregular at a magnification of x 3000. One experienced technician evaluated all the micrographs.
Statistical Methods

Paper I
Wilcoxon’s paired samples rank sum test was used to test the outcome of the treatment of pain. A $p$-value of $p < 0.05$ was considered statistically significant. Median values are reported, apart from age, where the mean value is used.

Paper II
All values are reported as median values unless otherwise indicated. Wilcoxon’s paired samples rank sum test was used for the longitudinal comparisons. A $p$-value of $p < 0.05$ was considered statistically significant.

Paper III
The power analysis was performed before the start of the long-term follow-up using the data collected from the short-term Paper I. The decrease in pain in the treatment group as measured with the VAS was the primary variable. It was hypothesised that there would be a mean long-term decrease in the pain score of 3 on the VAS, with a standard deviation of 1.5, compared with the preoperative values. With the alpha value set at 0.05 and the power at 80%, the required sample size would be four patients in the treatment group. Based on these calculations, it was decided that the six patients enrolled in each study group in Paper I were sufficient to justify the long-term paper. Mean standard deviation (SD) values are reported for the VAS and median (range) values for the other variables. The repeated measures ANOVA test and Fisher’s post-hoc test were used to analyse the change over time in terms of the VAS for pain within the study groups. For all other ordered variables, within-group comparisons were made using the Wilcoxon’s paired samples rank sum test. Dichotomous variables were analysed using Fisher’s exact test.

Paper IV
Median (range) values are presented. The Mann-Whitney U test was used for comparisons between the OA and FCF groups. The within-group comparisons were made using the Wilcoxon’s paired samples rank sum test and the dichotomous comparisons were made using Fisher’s exact test. A $p$-value of $< 0.05$ was regarded as statistically significant. The comparison of the fibril diameter distribution was performed at group level and involved 1,145 fibrils in the OA group and 1,215 fibrils in the FCF group.
Ethics
All the studies were approved by the regional ethics committee of northern Norway.
SUMMARY OF PAPERS

Paper I

Twelve patients, three male and nine female, mean age 47 (25-66) years, with pain in the buttoc, radiating pain distal to the knee, were included in a prospective, randomised study for either surgical or conservative treatment. The median duration of symptoms was 7.5 (2-20) years. Six patients were operated on in the hip region in an attempt to relieve pressure on the sciatic nerve. The piriformis muscle and tendon, as well as their relationship to the sciatic nerve, were found to be normal. However, the internal obturator tendon was found to be very tense, slightly hyperaemic and compressing the sciatic nerve; the nerve was slightly flattened where the obturator muscle was lying against it (Figure 4 A and B). To relieve the tension on the sciatic nerve from the obturator muscle, a sectioning of the tendon to the internal obturator muscle was performed at its insertion on the greater trochanter in all surgical cases. An immediate release of the tension in the sciatic nerve during Lasegue’s test was observed after sectioning the tendon (Figure. 5 A and B).

The median pain score was reduced from the preoperative value of 8.5 (7-10) to 3.5 (0-9) at 6 weeks (p < 0.05), 3.5 (0-10) (p < 0.05) at 3 months and 5.5 (0-10) at 6 months (n.s.) postoperatively (Table 3). No significant reduction in pain was found in a control group. There was a tendency towards a lower consumption of drugs in the surgical group at 6 months. This tendency towards lower drug consumption was not found in the control group.

Conclusion

A syndrome clinically similar to the “piriformis syndrome” has been described. It was observed during the operation that the internal obturator tendon was lying against the sciatic nerve and impinged it. Sectioning the internal obturator tendon reduced the pain significantly at six weeks and three months. The reduction seen at six months was no longer significant.
Table 3. Pain as expressed on a VAS for patients in the surgical and control groups

<table>
<thead>
<tr>
<th>Patient no</th>
<th>Pain Score</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At inclusion</td>
<td>At 6 weeks</td>
<td>At 3 months</td>
<td>At 6 months</td>
</tr>
<tr>
<td>Surgical group</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
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<tr>
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<td>9</td>
<td>5</td>
<td>5</td>
<td>8</td>
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<tr>
<td>3</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>8</td>
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<td>6</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
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<td>8</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Paper II

Thirteen patients (one male and twelve females), mean age 49 (36-61) years, who suffered from pain in the hip region, which spread diffusely down the lower extremity, were included in this conservative treatment study.

The median duration of the symptoms was 8 (1–20) years. The patients were treated using a specific supervised stretching programme with special emphasis on the internal obturator muscle. The duration of the stretching programme was four weeks. At inclusion, the median pain on the VAS was 6.0 (3-7). The VAS for pain decreased to 4.0 (0-7) (p = 0.01) at 12 weeks. Five years after treatment, the VAS for pain was still significantly lower than at inclusion, 4.0 (0-7) (p = 0.018). A significant reduction in the number of patients limping was also observed, both at 3 months and at 5 years after the treatment (Table 4).

Six of thirteen patients had a positive Lasegue test at inclusion, while at 12 weeks the test was negative in all thirteen patients and three patients had a positive Lasegue test at five years (p = 0.014, p = 0.016 respectively). Significantly fewer patients had a positive Freiberg sign at three months and five years (p = 0.025, p = 0.018 respectively) than at inclusion.

There was no significant reduction in pain on palpation of the external rotator muscles neither in positive Pace sign at 5 years compared with before the treatment (Table 4).

**Conclusion**

It appears that a specific stretching programme results in both a short- and long-term decrease in symptoms in patients with suspected internal obturator muscle syndrome.
Table 4. The median VAS for pain and the clinical examination tests at inclusion, three months and five years after treatment; p-values indicate comparisons with inclusion values

<table>
<thead>
<tr>
<th></th>
<th>At inclusion</th>
<th>Three months</th>
<th>Five years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VAS for pain</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>6.0 (3-7)</td>
<td>4.0 (0-7)</td>
<td>4.0 (0-7)</td>
</tr>
<tr>
<td>p-values</td>
<td></td>
<td><strong>0.01</strong></td>
<td><strong>0.018</strong></td>
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<tr>
<td><strong>Lasegue’s test (positive)</strong></td>
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</tr>
<tr>
<td>p-values</td>
<td>6/13</td>
<td>0/13</td>
<td>3/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>0.014</strong></td>
<td>0.16 (n.s.)</td>
</tr>
<tr>
<td><strong>Tenderness on palpation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-values</td>
<td>13/13</td>
<td>9/13</td>
<td>11/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>0.046</strong></td>
<td>1.0 (n.s.)</td>
</tr>
<tr>
<td><strong>Freiberg’s sign positive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-values</td>
<td>7/13</td>
<td>0/13</td>
<td>0/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>0.025</strong></td>
<td><strong>0.018</strong></td>
</tr>
<tr>
<td><strong>Pace’s sign</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-values</td>
<td>9/13</td>
<td>6/13</td>
<td>5/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.16 (n.s.)</td>
<td>0.32 (n.s.)</td>
</tr>
<tr>
<td><strong>Walking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>3 (2-5)</td>
<td>2 (1-4)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td>p-values</td>
<td></td>
<td><strong>0.011</strong></td>
<td><strong>0.023</strong></td>
</tr>
<tr>
<td><strong>Limp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-values</td>
<td>10/13</td>
<td>3/13</td>
<td>3/11</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>0.014</strong></td>
<td><strong>0.014</strong></td>
</tr>
<tr>
<td><strong>Sitting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>3 (2-4)</td>
<td>2 (2-3)</td>
<td>2 (1-3)</td>
</tr>
<tr>
<td>p-values</td>
<td></td>
<td><strong>0.034</strong></td>
<td><strong>0.034</strong></td>
</tr>
</tbody>
</table>
Paper III

Twelve patients suspected to have piriformis syndrome were randomised to either operative treatment or a control group as previously reported in Paper I. At inclusion all patients underwent both clinical and radiographic examinations of the hips and either CT or MRI of the lumbar spine. At six months all patients underwent clinical examinations (Table 5). Six patients were operated on with sectioning of the tendon to the internal obturator near its insertion to the trochanter major. There was no significant pain decrease in either group at 6 months (Table 6). At 8 year 9/12 patients were reexamined, four patients in the surgical groups and five in control group. One patient had died in each group and one patient in the surgical group refused to attend the long-term follow-up examination. At 8 years, the decrease in pain was significant in the surgical group (p = 0.03) but not in the control group (Table 6). Three patients who needed opioids preoperatively managed without such drugs at 8 years after the operation. Two patients in the operated group were working half time at the 8-year follow up after having been out of work for 3 and 10 years preoperatively. At inclusion 4/12 patients had minor degenerative changes at the L3–L5 level as seen on CT or MRI. At 8 years, the corresponding change was found in 7/9 patients (p = 0.025). No per- or postoperative complications or re-operations were registered during the period of the study. The level of pain medication decreased significantly in the whole study cohort at six months (p = 0.03) and at eight years (p = 0.02) compared with the levels at inclusion. If the study groups were analyzed separately the decrease was only significant in the surgical group at six months (p = 0.04).

Conclusion

Surgical release of the internal obturator muscle decreases the pain significantly in patients with obturatorius internus syndrome up to eight years after the surgical procedure.
Table 5. The clinical examination tests at inclusion, after six months and eight years

<table>
<thead>
<tr>
<th>Test</th>
<th>At inclusion</th>
<th>At six months</th>
<th>At eight years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surgical group (n = 6)</td>
<td>Control group (n = 6)</td>
<td>Surgical group (n = 6)</td>
</tr>
<tr>
<td>Lasegue (positive)</td>
<td>5/6</td>
<td>5/6</td>
<td>1/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.08 (n.s.)</td>
</tr>
<tr>
<td>Tenderness on palpation</td>
<td>6/6</td>
<td>6/6</td>
<td>6/6</td>
</tr>
<tr>
<td>Freiberg’s sign positive</td>
<td>6/6</td>
<td>4/6</td>
<td>1/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Pace’s sign positive</td>
<td>4/6</td>
<td>4/6</td>
<td>1/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.08 (n.s.)</td>
</tr>
<tr>
<td>Walking problems Yes/No</td>
<td>6/6</td>
<td>6/6</td>
<td>3/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.08 (n.s.)</td>
</tr>
<tr>
<td>Limping Yes/No p-values versus inclusion</td>
<td>5/6</td>
<td>4/6</td>
<td>2/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.08 (n.s.)</td>
</tr>
<tr>
<td>Sitting problems Yes/No</td>
<td>6/6</td>
<td>5/6</td>
<td>4/6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.16 (n.s.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. The VAS at inclusion, six months and eight years

<table>
<thead>
<tr>
<th>VAS for pain Median (range)</th>
<th>Surgical group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>At inclusion</td>
<td>At six months</td>
<td>At eight years</td>
</tr>
<tr>
<td>8.5 (7-10)</td>
<td>6.5 (0-10)</td>
<td>4 (1-7)</td>
</tr>
<tr>
<td>VAS for pain Mean (SD)</td>
<td>Surgical group</td>
<td>Control group</td>
</tr>
<tr>
<td>At inclusion</td>
<td>At six months</td>
<td>At eight years</td>
</tr>
<tr>
<td>8.3 (1.2)</td>
<td>5.5 (3.9)</td>
<td>4.0 (2.6)</td>
</tr>
<tr>
<td></td>
<td>0.10 (n.s.)</td>
<td>0.03</td>
</tr>
<tr>
<td>p-values versus inclusion</td>
<td></td>
<td>6.8 (1.9)</td>
</tr>
<tr>
<td>6.5 (1.8)</td>
<td>0.81 (n.s.)</td>
<td>4.0 (3.2)</td>
</tr>
<tr>
<td>0.06 (n.s.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ten patients, median age 60 years (48-75), with OA of the hip, and ten patients, median age years 82.5 (60-90), who had suffered an FCF (Garden III or more), underwent an open biopsy procedure in conjunction with a total hip replacement.

The histological analysis demonstrated significantly more scar tissue ($p = 0.02$), calcium deposits ($p = 0.001$) and GAGs ($p = 0.023$) in the biopsies from the internal obturator in the OA group than in the FCF group (Tables 7 and 8, Figure 6 A, B, C, D). The van Kossa stain revealed that calcium salts had precipitated within the areas of scar tissue in 8 of 9 specimens in the OA group (Figure 6 C). The AB/PAS staining for GAGs was positive in 8/9 specimens in the OA group and in 3/8 specimens in the FCF group (Figure 6 D). There was no evidence of inflammation in either group (Table 8). Furthermore, within the OA group, there was significantly more vascularity ($p=0.04$) and the fibre structure in the scar tissue had deteriorated to a significantly greater degree than in the non-scar tissue ($p = 0.02$) (Tables 7 and 8, Figure 6 A, B). The corresponding finding was not made in the FCF group. All the biopsies from the patients in the OA group had limited areas of scar tissue. The corresponding finding was made in 4/8 patients in the FCF group (Table 8).

The scar tissue was composed of both thin and thick irregular collagen bundles, oriented in a more or less wavy, crosswise fashion. The scar tissue was densely fixed to the tendinous tissue, indicating a previous tendon rupture site (Fig 6 B). In and close to these previous rupture sites, the Perl reaction was negative, indicating that there was no bleeding and no remnants of hemosiderin present.

The ultrastructural evaluation revealed that the distribution of fibril diameter displayed significantly fewer small and medium-sized fibrils in the OA group than in the FCF group ($p = 0.001$) (Figure 7 A, B, C and D).

All the samples from the FCF group displayed a normal or close to normal homogeneous ultrastructural pattern, with collagen fibrils running in the same direction. The samples from the OA group displayed a more irregular pattern in 6/9 specimens, with pathological morphological characteristics – e.g. the collagen fibrils were oriented in different directions and there was an increased amount of non-collagenous ECM; in 3/9 samples, the ultrastructural pattern was more or less homogeneous ($p = 0.003$), as shown in (Figure 8 A, B).

Conclusion
Tissue samples from the internal obturator tendon in the OA group revealed more scar tissue, more GAGs and more precipitated calcium salts in the degenerative tissue, as seen in the light
microscope, as well as a change in fibril diameter distribution and more non-collagenous and irregular ECM, compared with the samples from the internal obturator in the FCF group, as seen in the TEM.

**Figure 6.** A. Normal tendon from a patient in the FCF group, H&E staining, original magnification x100. B. Scar tissue from a patient in the OA group indicating a ruptured tendon, H&E staining. C. Calcium deposits (black stain at arrows) in the scar of a previously ruptured tendon in a patient in the OA group. Van Kossa staining. D. Moderately increased amount of mucin, indicating GAGs between collagen structures in a patient in the OA group (blue stain at arrows). Alcian Blue/Periodic Acid Schiff staining, Original magnifications x 400.
Figure 7. A. Transmission electron micrograph showing fewer small and medium-sized fibrils in the OA group. B. Relative distribution of the fibril diameter size in the internal obturator tendon in the OA group. C. Transmission electron micrograph showing more small and medium-sized fibrils in the FCF group. D. Relative distribution of the fibril diameter size in the internal obturator tendon in the FCF group. Original magnifications x 50,000.

Figure 8. A. TEM micrograph from a patient in the FCF group, showing a homogeneous ECM, where collagen fibrils are running in the same direction. B.
Table 7. The histological, semi-quantitative, 4-point scoring system (0-3) for the non-scar tissue (NST) and the scar tissue (ST) in terms of fibre structure (Fibre), cellularity (Cell), vascularity (Vasc) and the presence of GAGs in the OA group and in the FCF group.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Fibre NST/ST</th>
<th>Cell NST/ST</th>
<th>Vasc NST/ST</th>
<th>GAGs NST/ST</th>
<th>Fibre FCF NST/ST</th>
<th>Cell FCF NST/ST</th>
<th>Vasc FCF NST/ST</th>
<th>GAGs FCF NST/ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0/0</td>
<td>0/2</td>
<td>1/-</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
</tr>
<tr>
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<td>1/1</td>
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<td>0/0</td>
<td>0/1</td>
</tr>
<tr>
<td>3</td>
<td>1/1</td>
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<td>0/0</td>
<td>0/1</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<td>0/-</td>
<td>0/-</td>
</tr>
</tbody>
</table>

X indicates that it was not possible to evaluate the sample, as there was too little tissue. Four patients in the FCF group did not have any scar tissue in their samples; this is indicated in the table with -.

Table 8. The characterization of calcium deposits, inflammation and scar tissue in both groups.

<table>
<thead>
<tr>
<th>Calcium deposits</th>
<th>OA</th>
<th>FCF</th>
<th>OA</th>
<th>FCF</th>
<th>Scar tissue, % of the sample</th>
<th>OA</th>
<th>FCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
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<tr>
<td>1</td>
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<td>90</td>
<td>0</td>
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<td>2</td>
<td>0</td>
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<td>50</td>
<td>10</td>
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<td>3</td>
<td>1</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>30</td>
<td>X</td>
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<tr>
<td>4</td>
<td>1</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>95</td>
<td>X</td>
<td></td>
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<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>Few</td>
<td>0</td>
<td>95</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>Few</td>
<td>0</td>
<td>20</td>
<td>50</td>
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<td>7</td>
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<td>Few</td>
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<td>50</td>
<td>70</td>
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<td>9</td>
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<td>10</td>
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<td>0</td>
<td>0</td>
<td>70</td>
<td>0</td>
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</tbody>
</table>

p = 0.001

X indicates that it was not possible to evaluate the sample, as there was too little tissue.
DISCUSSION

Background considerations before initiating the project

Buttock pain and tenderness extending from the sacrum to the greater trochanter, together with pain radiating to the lower extremity, have been described and the sciatic nerve has been suspected of being irritated [1;50;51;67;76]. In some cases, no clear clinical or radiographic pathology in the spine, hip or knee can be found when patients complain of buttock pain and tenderness extending from the sacrum to the greater trochanter. It has been claimed that soft tissue pathology in the hip may cause the diffuse, sometimes radiating pain [51;55;77] and then the sciatic nerve has been suspected of being irritated [51;70].

This kind of retro-trochanteric pain with radiation has been described as the “piriformis syndrome” [77;78], which may be associated with trauma to the pelvis or buttock [51], anatomical abnormalities like a bipartite piriformis muscle [48;49], the piriformis muscle lying anterior to the nerve [50], or a hypertrophic muscle irritating the sciatic nerve.

Niu et al. [79] suggested that several patients had persistent sciatica, despite lumbar decompression surgery for lumbar disc herniation or stenosis, and the “piriformis syndrome” was subsequently confirmed through a positive response to the injection of a local anaesthetic agent and a positive Freiberg test. The cohort in their study was thus successfully treated for the “piriformis syndrome” and they therefore suggested excluding the “piriformis syndrome” before diagnosing lumbar radiculopathy.

A number of methods with varying results exist for the treatment of the “piriformis syndrome”. However, no particular treatment has resulted in long-term improvement. Cox et al. [34] suggested that the distraction and manual stretching of the gemmeli-obturator internus and piriformis muscles was successful for treating retro-trochanteric pain. Keskula et al. [2] described the importance of stretching exercises for the “piriformis syndrome”, while Mayrand et al. [35] considered chiropractic care and muscle stretching beneficial. Benzon et al. [52] recommended an injection technique with special placement of the needle to avoid damage to the sciatic nerve, while Mullin et al. [67] reported significant pain relief after the injection of corticosteroids and local anaesthetics in 12 patients with a follow-up period of 9-24 months.

Complete pain relief immediately after the surgical release of the piriformis muscle in two patients with 10 and 11 months of follow-up was reported by Solheim et al. [70]. The
arthroscopic release of the piriformis tendon was performed in six patients with good results [71]. Yoshimoto et al. [47] examined 61 patients with persistent sciatica using MRI and found a lack of nerve root compression in 10 (16.4%) patients, despite exhibiting symptoms of sciatica. Three of these patients had “piriformis syndrome” and two underwent surgery involving piriformis excision, resulting in permanent pain relief.

At the start of the present work, we were unable to find any description in the literature of any syndrome similar to what we found in Paper I, where the internal obturator tendon had an impact on the sciatic nerve. Nor did we find any especially well-described conservative or surgical treatment options for such a condition. It has been established that, when clinical and radiographic examinations exclude other pathologies in the spine, hip and knee, pathology in the remaining structures around the hip must be considered; especially the muscle tendons in the peri-articular area, in line with other joints, e.g. rotator-cuff pathology in the shoulder.

The etiology of retro-trochanteric pain is multifactorial and the clinical diagnosis can be difficult to determine. It has been suggested that the pain in the osteoarthritic hip may be due to spasm and pressure in the surrounding muscles and tendons towards the joint capsule, which is richly innervated [40;80]. However, Tarasvicius et al. [80] found that the radiographic severity of OA of the hip was correlated to decreased elasticity in the joint capsule and decreased intracapsular pressure. Different treatment options for retro-trochanteric pain, including conservative and surgical treatments, are available, but no particular one is recognised as being superior.

**Surgical treatment of retro-trochanteric pain syndrome**

In Paper I, we suspected “piriformis syndrome” in twelve patients and randomised them to either a surgical or a non-surgical group. During the surgical procedure, an unexpected pathology in terms of a tense internal obturator muscle compressing the sciatic nerve was observed, whereas no anatomical abnormality or other pathology affecting the piriformis muscle and its tendon were found (Figure 4 A and B, Figure 5 A and B). We were not able to find any direct entrapment of the sciatic nerve caused by the piriformis muscle. The internal obturator muscle was, however, very tense, slightly hyperaemic and hypertrophic and it was found to be in close contact with the sciatic nerve. The nerve was slightly flattened where the obturator muscle was impinging towards it and the nerve was also slightly hyperaemic. As far as could be observed during the Lasegue manoeuvre performed on the operating table, the internal obturator and not the piriformis muscle impinged on the nerve at an early stage in the
hip flexion movement. These relationships between the internal obturator muscle and the sciatic nerve were defined as pathological. The findings made us consider the presence of the “internal obturator muscle syndrome” and not the “piriformis syndrome” as a cause of retro-trochanteric sciatica-like pain. We were unable to find any previous description in the literature of this pathology. Only anatomical abnormalities of the piriformis muscle supported the term “piriformis syndrome” [48;49]. Yoshimoto et al. Solheim et al. and Dezawa et al. [47;70;71] also reported immediate and significant pain relief after the surgical release of the piriformis muscle; however, their surgical treatment was based on the clinical diagnosis and there is no description of the small rotator characteristics during the operation. These studies were not randomised and no information was available about drug use before and after the treatment. Furthermore, the activity level and working ability were not reported either. In Paper I, two patients were able to return to work after the operation, after having been out of work because of pain for three and ten years respectively. These patients were still working part time at the eight-year follow-up, as reported in Paper III.

To our knowledge, no other randomised studies of the surgical treatment of retro-trochanteric pain syndrome can be found in the literature, apart from Papers I and III. A significant pain reduction was found after the surgical release of the internal obturator tendon, six and twelve weeks postoperatively. The pain was still significantly reduced eight years after the surgical procedure. There was a tendency towards a reduction in the amount of analgesic drugs consumed in the surgical group but not in the control group.

Six months postoperatively, the decrease in pain was not significant. The reason for this is unknown. The sectioning of the internal obturator muscle and the exploration of the sciatic nerve might have created bleeding and secondary scar formation. Furthermore, at eight years, all the patients initially included in the study could not be found and this naturally created some transfer bias in the conclusion at eight years.

Our findings emphasize that the “internal obturator muscle syndrome” must also be taken into consideration in the clinical setting when the “piriformis syndrome” is suspected.

**Conservative approaches towards retro-trochanteric pain syndrome**

Many studies have focused on ways of inducing the relaxation of the piriformis muscle. Even though it is an external rotator, the piriformis muscle has been found to rotate the femur internally when the hip is in flexion [2]. In Paper II, we did not choose to perform the stretching exercises by external rotation. Assuming that a tense internal obturator muscle
caused the problems, a different procedure was chosen. To our knowledge, there has been no
description of a change in action for the internal obturator muscle from external to internal
rotation when the hip is in flexion [2]. The patients in Paper II reported most pain during
passive internal rotation and this was therefore regarded as an efficient stretching maneuver
for the obturator muscle.

Maximum stretching of the internal obturator muscle was thought to be obtained by passive
internal rotation with simultaneous flexion and adduction of the hip. General stretching of the
hip muscles was performed in Paper II, supported by the observation that most muscles
around the hip appear to be tense in patients with retro-trochanteric pain syndrome. Specific
attention was, however, paid to the small rotators, because if “cramping” their proximity to
the sciatic nerve could theoretically cause the most problems.

Direct massage by a physiotherapist of the tendons of the small external rotators at their
insertion at the trochanter was also part of the treatment programme. The rationale for this
procedure is not completely known and it is possible that mechanisms similar to acupuncture
could be involved. The six-month observational phase preceding the treatment period in Paper
II revealed no improvement in symptoms. Anatomically, the internal obturator muscle is deep
to both the piriformis muscle and the sciatic nerve and it runs parallel to the piriformis in its
attachment to the trochanter major. Because of its proximity, similar pathway and function,
most conservative treatments for patients with “piriformis syndrome” would affect the
internal obturator muscle as well [46]. Guvencer et al. [78] suggested that the internal
obturator, gemelli and quadratus femoris tendons share common insertions with the piriformis
tendon and can thereby compensate for the loss of its function. The fusion of the piriformis
tendon with the obturator internus tendon was previously confirmed [72]. The clinical
improvement was seen only after the treatment programme and not in the period with any
other treatment. The decrease in symptoms seen after the stretching programme was therefore
probably not only a placebo effect.

One critical point is to get the patients to continue the stretching exercises for an extended
period of time. At the rehabilitation centre, the exercises were performed according to the
programme managed by physiotherapists associated with the paper. Since the exercises were
limited in number, it was our intention that the exercises would be remembered and used by
the patients after the initial treatment period. Unfortunately, we have no data on the extent to
which the patients actually continued the exercise programme. However, a significant
reduction in pain was still found after five years compared with the pre-treatment values. As
in Paper II, we recommend that, in future studies, patients with other pathology in the spinal column and the hip joint should be excluded. Close collaboration between patients, doctors and physiotherapists is also recommended to manage and stick to the specific stretching programme. Retro-trochanteric pain caused by the piriformis or internal obturator syndrome is often underdiagnosed or overlooked in the clinical setting, because the symptoms may be similar to lumbar spine disorders, such as disc herniations or spinal stenosis [46;47].

**Reflections on conservative and surgical treatment**

From our studies, it seems obvious that a tense internal obturator muscle may contribute significantly to the retro-trochanteric sciatica-like pain syndrome. There is no complete understanding of the aetiology or of the role played by the piriformis muscle. The median duration of symptoms in Papers I and III was 7.5 (2–20) years, while it was 8 (1–20) years in Paper II. This suggests that the patients had suffered for a long time from their symptoms and the disease had already reached a chronic stage. One problem in the clinical setting could be that patients of this type often receive a mixture of treatment algorithms for both back and hip problems. It is therefore important to recognise the problem at an early stage and to start a treatment programme to prevent the disease from progressing to a chronic stage. Larger, controlled studies should be set up thoroughly to evaluate the treatment of this type of pathology.

The concept of “obturatorius internus syndrome” has attracted more attention during the last few years and our paper has been commented on in subsequent work. After our publications, findings similar to those reported in Papers I and III that the internal obturator muscle and tendon and not the piriformis cause sciatic neuropathy have been published. In a case report involving only one patient, Murata et al. [81] also found that the obturatorius internus compressed the sciatic nerve. In line with the findings in Papers I and III, Carola [82] and Gajraj [83] reported an injection technique to reach the internal obturator muscle for the treatment of sciatica-like pain. The chronic nature of retro-trochanteric pain is probably the reason why the patients in Paper II still had significant yet improved pain after conservative treatment. It is our opinion that, if the conservative approach fails, surgical intervention might be advocated.
Radiographic assessments
The clinical diagnosis of the retro-trochanteric pain syndrome is difficult to confirm by only a clinical examination. Retro-trochanteric pain syndrome is an exclusion diagnosis and radiographic evaluation of the spine and hip is therefore necessary to exclude other pathology, which can be the primary cause of the symptoms experienced by the patients [55;77;84]. Blankenbaker et al. [85] studied patients with “trochanteric pain syndrome” using MRI and found that 88% of asymptomatic hips had abnormal findings, with a hyperintensity sign in the trochanteric area, and they therefore concluded that MRI has a high sensitivity to pathology in conjunction with “trochanteric pain syndrome”. The radiographic findings in Papers II and III are also interesting. A significant increase in minor degenerative changes in the lumbar column was found in the whole cohort in Paper III. This finding suggests that retro-trochanteric pain syndrome might be associated with early degenerative changes in the lumbar spine and, for diagnostic reasons; changes in the lumbar spine must be taken into consideration. Another explanation could be that the increase in degenerative changes in the lumbar spine is actually a normal ageing process. It is important to mention that neither at inclusion nor at the eight-year control was any pathology found in the hip joints in Papers I and III.

Before initiating conservative or surgical treatment for the retro-trochanteric pain syndrome, other treatable conditions in the hip joint and lumbar spine must be excluded. We therefore recommend performing standard radiographs of the hips and MRI or CT scans of the lumbar spine as a diagnostic algorithm for these types of patient.

Histological findings in patients with hip OA and patients with FCF
Tendon pathology has been studied in close relation to various joints and correlated to clinical and radiographic findings [32;56;85]. Histological changes in the tendon, especially the Achilles, patellar and rotator cuff tendons, have also been investigated [9;19;24;25;27]. Molloy et al. [19] analysed the supraspinatus tendon using a microarray technique and concluded that glutamate plays an important role in tendon degeneration. Svensson et al. [86] used the light microscope and reported increased amounts of GAGs, together with an increase in vascularity and collagen fibre disorientation in the patellar tendon, six years after harvesting its central third as an autograft during ACL reconstruction.

Lohr and Uhthoff et al. [87] studied the histological section of 18 human supraspinatus tendons with selective vascular injections of silicon-rubber compound enabling the visualisation of the vascular bed of the rotator cuff and concluded that a rotator-cuff tear starts
on the articular side of the tendon, with degenerative changes and insufficient vascularity. Using histochemical analysis, Hashimoto et al. [9] found calcifications in 19% of 80 ruptured rotator-cuff tendons and disorientation of the collagen fibrils in the stump of the torn rotator-cuff tendon without distinct inflammatory changes. They suggested that the pathogenesis of the cuff tear is closely associated with age-related degenerative changes in the tendons, followed by microtrauma. Movin et al. [25] detected increased amounts of GAGs in achillodynia and suggested that this was a reactive cell response to tendon insult. Riley et al. [20;21] stressed the importance of metalloproteinases and other enzymes in tendon healing, as well as the importance of an increased proportion of type III collagen, which reduces the ability of the tendon to resist tension force and thereby predisposes to a rupture of the tendon. Cook et al. [24] demonstrated cellular changes in 18 of 50 biopsies from asymptomatic patellar tendons in athletes, suggesting that the tendinosis process starts with cellular activation and proceeds through phases which increase the ground substance. The importance of substance P for the tissue changes and/or tissue repair that occur during the development of tendinosis was illustrated using immunohistochemical analysis [88]. All these findings are in line with the findings in Paper IV that degeneration is accompanied by increased amounts of GAGs and a change in tendon morphology. There are a number of studies of the processes involved in tendon injury and degeneration [9;10;19;21;23;24;73;87;89], but only a few studies have focused on the pathological changes in the tendons around the hip. Lempainen et al. [29] used histological analysis and found typical morphological changes of tendinosis in proximal hamstring tendinopathy in athletes with collagen disorientation, increased vascular proliferation, rounding of tenocyte nuclei and increased amounts of ground substance. To our knowledge, the changes in histological structure in the internal obturator tendon in patients with OA of the hip have not previously been reported in the literature. The histological analysis in Paper IV demonstrated significantly more tendon ruptures with scar tissue, increased amounts of GAGs and calcium deposits in the OA group. Furthermore, within the OA group, significantly more vascularity and deterioration in fibre structure were found in the scar tissue than in the non-scar tissue. The corresponding finding was not made in the FCF group. These findings and the lack of distinct inflammatory changes as seen in the light microscope therefore indicate that the tendons in the OA group have undergone changes similar to those described in tendons in other locations and referred to as tendinosis. It is likely that the tendon pathology increases the symptoms already experienced by osteoarthritic patients. It is worth considering whether performing a radiofrequency microtenotomy of the
small rotator muscle tendons in the hip region might reduce the symptoms experienced by patients with obturatorius internus syndrome or patients with mild intra-articular degenerative changes.

**Ultrastructural findings in patients with OA and patients with FCF**

In the OA group in Paper IV, the tendon material was irregular and altered, with collagen fibrils oriented in different directions and an increased amount of cell debris, as seen in the TEM (Figure 8). Furthermore, there were significantly fewer small and medium-sized fibrils compared with the FCF group (Figure 7). The change towards more non-collagenous ECM indicates that OA affects not only the joint itself but also the surrounding tissue. The FCF patients were about 20 years older than the osteoarthritic patients and should therefore theoretically have more degenerative findings, which could not be confirmed histologically or ultrastructurally. It is generally believed that a skewed fibril diameter distribution develops in the ageing tendon, with more small and medium-sized fibrils than the normal tendon of an adult person [90;91]. This could be the reason for the difference found in this respect and the tendon in the FCF group was actually normal for the age group. However, there are animal studies that do not confirm any alteration in collagen fibril diameter in tendons with increasing age [92;93].

To our knowledge, the finding of changes in the ultrastructural appearance in the internal obturator tendon in patients with OA of the hip has not previously been reported. The difference in age between the paper groups is unfortunate. It would have been better to use healthy age-matched controls. However, this was not possible for ethical reasons.

Paper IV can also be regarded as a model for future comparisons of the pathology found in patients with retro-trochanteric pain syndrome where the internal obturator muscle is involved and in other articular and/or peri-articular diseases in the hip region. It also provides some interesting perspectives in relation to future studies of treatment in patients with mild radiographic OA and severe symptoms; similar to what has been reported for the treatment of lateral epicondylitis, [94;95] patellar [94] and rotator-cuff tendinosis [96].

**Strengths and limitations of the studies**

The major strength of Paper I and Paper III is their randomised design, while the relatively long follow-up period is also strength of Paper III. The strength of Paper II is its relatively long follow-up period, as well as the attempt to exclude intra-articular hip problems and spinal disorders through multiple radiographic assessments. The fact that the clinical
evaluations at inclusion and at five years were performed by an independent physiotherapist is another strength, however no control group was available in this study.
The limitations of Paper I and Paper III are that they were not designed with enough power to compare the surgical group with the non-surgical group and that it was not possible to keep all the patients in the study until the long-term follow-up. The difference in age between the groups is the major weakness of Paper IV, but the strengths of Paper IV are that it was performed on humans and that both histological and ultrastructural evaluations were performed.

**Clinical relevance**
Patients with retro-trochanteric pain syndrome are often misdiagnosed and difficult to treat. Papers I, II and III show that there are both surgical and conservative options to treat these patients, with promising results in both the short and long term. The important thing, however, is to consider the possibility that these patients could have problems from the spine or from the hip joint. In Papers I, II and III, we tried to exclude these possibilities by performing MRI or CT of the lumbar spine and X-rays of the hip joints. However, in some patients, minor pathology was still found in these locations. Paper IV was an attempt to make an in-depth histological and ultrastructural analysis of the pathology in the short rotator muscle tendons of the hip joint. Paper IV actually generated more questions than answers and it might be that tendinosis in these tendons is a part of the OA disease. Further studies should focus on the possible connection between OA and tendinosis and also on possible treatment options. Might it, for example, be possible to reduce the symptoms of OA and even slow the disease process by treating the tendinosis?

Studies of microtenotomy might be indicated, with knowledge of the treatment of epicondylitis in the elbow region.

**Differential diagnoses**
Several other diagnoses must be considered for patients with retro-trochanteric pain; they include herniated discs, degenerative changes in the lumbosacral spine, spinal stenosis, OA and minor intra-articular pathology in the hip joint, such as labral tears, FAI and even symptoms of proximal claudication. Furthermore, gynaecological conditions, especially when the right side is affected, should not be forgotten [47]. In Papers I, II and III, serious attempts were made to exclude these diagnoses.

46
FUTURE PERSPECTIVES

In the future comparisons between histological and ultrastructural findings in the tendons of the short rotator muscles of the hip in patients suffering from retro-trochanteric pain syndrome with age-matched patients without such symptoms, as well as age-matched patients with intra-articular hip problems, appear to be very interesting. However, the most interesting future perspective is to relieve the symptoms of minor intra-articular osteoarthritic changes and manage the internal obturator syndrome by treating the tendinosis through either conservative programmes or tenotomy or microtenotomy of the short rotator muscle tendons of the hip.

Furthermore, it appears to be important thoroughly to analyse and classify whether the patients are suffering from spinal disorders, minor intra-articular hip problems or local nerve entrapment of the sciatic nerve in the hip region, as mentioned above.

A larger number of patients are needed for future studies; therefore there is a need for cooperating partners at other centres. It is attractive to consider the possibility of using the national hip replacement registers to compare the subjective results in terms of postoperative pain and patient satisfaction in patients who underwent the surgery using an anterior rotator tendon sparing approach and patients who underwent the same procedure using a posterior rotator tendon sacrificing approach.

Finally, a question posed by us, but not completely answered, is how much conservative treatment compared to operative approaches can relieve the symptoms related to the described syndrome.
CONCLUSIONS

- A specific stretching programme resulted in both a short- and a long-term decrease in symptoms in patients with retro-trochanteric pain

- Surgical release of the internal obturator muscle resulted in both a short- and a long-term decrease in pain in patients with retro-trochanteric pain syndrome

- Tendon biopsy specimens from the short rotator muscle of the hip from patients with OA reveal both histological and ultrastructural degenerative changes

- Tendon biopsy specimens from the short rotator muscle of the hip in patients with FCF reveal a normal age-related histological and ultrastructural appearance.
REFERENCES


PAPER I
The internal obturator muscle may cause sciatic pain

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Abstract

Six patients suspected to have piriformis syndrome were operated in the hip region in an attempt to relieve pressure on the sciatic nerve. The piriformis muscle and tendon as well as their relationship to the sciatic nerve were found to be normal. However, the internal obturator muscle was found to be very tense, slightly hyperaemic and pressing the sciatic nerve. During Lasegue’s testing on the operating table the internal obturator and not the piriformis muscle impinged on the nerve at an early stage in the hip flexion movement. A sectioning of the tendon to the internal obturator muscle near its insertion at the trochanter was performed. Median pain score was found to be reduced from the preoperative value (8.5) to that at 6 weeks (3.5) ($P < 0.05$) and 3 (3.5) ($P < 0.05$) and 6 months (5.5) (N.S.) postoperatively. No significant reduction of pain was found in a control group of six patients followed during the same period. Three patients who needed opioids preoperatively managed without such drugs 6 months after the operation. Two patients in the operated group were at work 50 and 100% after having been out of work for 3 and 10 years, respectively.

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Keywords: Piriformis muscle; Internal obturator muscle; Sciatic nerve entrapment; Operation

1. Introduction

A syndrome was described in 1928 by Yeoman where he proposed that arthritic changes in the sacroiliac joint may cause sciatic pain due to secondary inflammatory reaction in the piriformis muscle (Yeoman, 1928). Since then a similar syndrome has been investigated in a number of studies. It has been argued that the piriformis muscle may irritate the sciatic nerve due to an anatomical abnormality such as an hypertrophic muscle (Mullin and De Rosayro, 1990; Sayson et al., 1994; Benson and Schutzer, 1999). Robinson (1947) has been credited with introducing the term piriformis syndrome (Solheim et al., 1981; Mullin and De Rosayro, 1990; Benson and Schutzer, 1999) and entrapment and irritation of the sciatic nerve in the hip region has largely been ascribed to influence from the piriformis muscle. Anatomical variations such as a bipartite piriformis muscle (Chen, 1994) and the piriformis muscle lying anterior to the nerve (Sayson et al., 1994) have been described as irritating the sciatic nerve. Operating to relieve the nerve from the pressure of the tense muscle has resulted in immediate pain relief (Chen, 1994; Sayson et al., 1994; Benson and Schutzer, 1999). In the latter report, Benson found adhesions between the piriformis muscle and the sciatic nerve. In the present study, a problem which seemed similar to those described by others (Mullin and de Rosayro, 1990; Durrani and Winnie, 1991; Sayson et al., 1994; Benson and Schutzer, 1999) was diagnosed in a number of patients. These were recruited for a small prospective, randomised study with intervention and control groups. The complaints included problems such as buttock pain and tenderness extending from the sacrum to the greater trochanter, and pain radiating to the lower extremity. The sciatic nerve was suspected to be irritated.

2. Methods

2.1. Patients and control subjects

Twelve patients, three male and nine female, mean age 51 (25–79) years with pain in the buttock, radiating pain distal to the knee, and intolerance to sitting for more than about 40 min, were included in a prospective, randomised study. The patients were randomly allocated using sealed opaque envelopes to either operative or conservative treatment. The duration of their problems had been between
3 and 7 years. All of them had pain and tenderness when examined with deep digital palpation over the small external rotators at the back of the hip, and also over the sciatic nerve at the trochanteric region (Table 1). The preoperative examination included test for pain and weakness on resisted abduction and external rotation of the thigh in a sitting position (Pace’s sign), pain and weakness on forced passive internal rotation of the extended thigh (Freiberg’s sign), and buttock and leg pain during passive straight leg raising (Lasegue’s sign). Three of the patients had been through back surgery because of sciatic pain, in two cases affecting the actual and in one case the opposite extremity. All patients had been through long periods of conservative treatment with either physiotherapy or injections with local anaesthetic agents combined with steroids after diagnosis of problems in the small external rotators in the hip. None of the operated patients was able to work. All patients provided written informed consent, and the study protocol was approved by the institutional ethical review board.

All three authors took part in the preoperative clinical examinations, they planned and performed the operations together, and also made the postoperative assessments together.

2.2. Pain in the two groups

Pain was registered using a 0–10 point numerical rating scale preoperatively and at 6 weeks, 3 and 6 months postoperatively (Table 2). The use of analgesic and anti-inflammatory drugs for each patient was expressed by increasing points with increasing amount of drugs. Zero points meant no drug, one point paracetamol irregularly, two points paracetamol/codeine or NSAID regularly, three points paracetamol/codeine and NSAID regularly, and four paracetamol/codeine and additionally either buprenorphin, tramadol or morphine. These evaluations were done at the start of the study and at 6 months in both the operative and control groups (Table 2). The number of days off sick was registered for both groups.

All patients went through radiological examination of the pelvis and hip, and CT scan or MRI of the back did not reveal actual spinal pathology giving any indication for back surgery.

2.3. Surgical procedure

An explorative operation was done using a posterolateral approach in the hip region. The fascia lata was split, the external rotators and the sciatic nerve were identified (Fig. 1). An examination of the anatomy as well as the relationships between structures during passive flexion, internal rotation and Lasegue’s test were performed during the operation. Prophylaxis against infection was cefalotin 2 g given intravenously before the operation. Weight bearing supported by crutches was allowed immediately after surgery. A liberal gradual increase in activity guided by

<table>
<thead>
<tr>
<th>Table 1</th>
<th>History, symptoms and clinical findings in patients with suspected piriformis syndrome allocated to two different groups, one operated and one control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pas no</td>
<td>Gender</td>
</tr>
<tr>
<td>Operated</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>F</td>
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<tr>
<td>2</td>
<td>M</td>
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<tr>
<td>11</td>
<td>M</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
</tr>
</tbody>
</table>

the patients themselves was allowed. All patients were re-examined at 6, 12 and 24 weeks postoperatively. No new approach for treatment was begun in the control group during the observation period.

2.4. Statistical evaluation

Wilcoxon Signed Ranks Test was used to test the outcome of the treatment on pain. $P < 0.05$ was considered statistically significant.

3. Results

In this study all patients had buttock pain with sciatica, and also tenderness when palpating the sciatic notch (Table 1). Two of them had been through trauma to the actual gluteal region. A total of 92% had difficulties sitting more than 40 min because of pain. Pace’s sign was positive in four and Freiberg’s sign was positive in all the operated patients (Table 1).

At operation the sciatic nerve was found to pass anterior to the piriformis muscle in all cases, with no part of the nerve passing through this muscle. As for the superior gemellus and internal obturator muscles, the sciatic nerve passed behind these. The internal obturator muscle was very tense, slightly hyperaemic and hypertrophic, and it was found to lie in close contact with the sciatic nerve (Fig. 1). The nerve was slightly flattened where the obturator muscle was lying against it, and was also slightly hyperaemic. As far as the operating team could observe during the Lasegue manoeuvre performed on the operating table, the internal obturator and not the piriformis muscle impinged on the nerve at an early stage in the hip flexion movement. These relationships between the internal obturator muscle and the sciatic nerve were defined as pathological. To relieve the tension on the sciatic nerve from the obturator muscle, a sectioning of the tendon to the internal obturator muscle was performed at its insertion on the greater trochanter in all cases operated. An immediate release of the tension in the sciatic nerve during Lasegue’s test was observed after the sectioning of the tendon (Fig. 2).

At the start of the study all of the patients in the operative group had a serious pain problem, as the median pain score was 8.5 (Table 2). A reduced median scoring was seen both at 6 weeks (score 3.5) ($P = 0.043$), 3 (score 3.5) ($P = 0.046$) and 6 months (score 5.5) ($P = 0.058$, N.S.)
postoperatively in the operated group when comparing to the preoperative values (Fig. 3). No significant reduction of pain was found in the control group at any point of time in the follow up period (Fig. 4).

There was an obvious tendency towards less consumption of drugs in the operative group at 6 months. It was for example found that two patients on a combination of drugs including opioids before the operation used no drugs at all at 6 months (Table 2). Such a tendency towards less drug consumption was not found in the control group in the observation period (Table 2). Two patients in the operated group (Table 2, patients number 5 and 6) were back at work 6 months postoperatively, one at 50% and the other at 100%, after having been unable to work for about 3 and 10 years, respectively.

4. Discussion

Six patients with buttock pain with additional sciatica were operated for a suspected entrapment of the sciatic nerve in the hip region. All of them were found to have a pathologically tense internal obturator muscle, which was in an abnormally close contact with the sciatic nerve, especially during Lasegue’s test performed on the operating table. After sectioning the internal obturator tendon at the greater trochanter, these patients reported less pain both at 6 weeks, 3 and 6 months postoperatively compared to the preoperative status. At 6 weeks and 3 months these differences were significant ($P < 0.05$ and $P < 0.05$, respectively). In the control group there was no significant reduction of pain at any point of time in the follow up period.

There was a tendency towards less consumption of drugs in the operated group at 6 months. Therefore, the operation had reduced pain postoperatively.

At the start of the study the pain was described as relatively intense, as four of the patients chose the extreme of either nine or ten on the numerical rating scale. Three patients in the operated group used some mixture of analgesic drugs which included opioids. It is interesting that, postoperatively, none were using opioids in the operated group, and three in this group did not use any analgesic drugs at all. The two patients in the control group who used opioids still used them after 6 months.

One of the most successfully operated patients had been out of work for about 3 years, and returned to work at 50% postoperatively with reduced pain and no analgesic.
drugs. Another had been unable to work for the last 10 years, and was at work 100% 6 months postoperatively. This patient had a reduction of pain from 7 to 0 on the numerical rating scale, and used no analgesic drugs even though she had been on opioids preoperatively. None of the patients in the control group were found to have increased their capacity for work, and no significant reduction in pain nor any reduction in the amount of analgesic drugs was found in this group. Two patients in the control group had a period of quite remarkable spontaneous but incidental improvement as found on the numerical rating scale in the observation period (patient number 7 and 8) (Table 2). This illustrates that some of these patients have periods of temporary recovery from their symptoms.

This study had only two patients with a history of trauma, differing from an earlier study (Benson and Schutzer, 1999) in which all patients, with similar symptoms to those described in this report, had suffered some form of trauma. Excessive exercise has also been mentioned as a reason for a similar syndrome (Beauchesne and Schutzer, 1997), but there is no proof of that in our study. Anatomical variations affecting the piriformis muscle together with the sciatic nerve have been mentioned as an etiology for syndromes affecting the external rotators (Mullin and de Rosayro, 1990; Durrani and Winnie, 1991; Sayson et al., 1994; Chen, 1994) but such variations were not found in any of the patients in our study. As in other reports, a hypertrophic (Rask, 1980; Jankiewicz et al., 1991) or spastic muscle (Solheim et al., 1981; Sayson et al., 1994) was found to cause the pain by affecting the sciatic nerve.

The symptoms and clinical findings in the two groups were similar to those previously described for the piriformis syndrome. All patients had buttock pain with sciatica, and 11 of them had difficulties with sitting (Sayson et al., 1994). Also a limp has been described in the piriformis syndrome (Solheim et al., 1981), and this was found in nine cases in our study. When examined, all patients had pain with deep digital palpation in the region at the insertion of the piriformis where also the internal obturator muscle inserts. They also reported about pain during palpation of the area for the sciatic nerve passing the great sciatic notch (Durrani and Winnie, 1991; Benson and Schutzer, 1999). Freiberg’s sign was found positive in ten of the 12 patients, and Pace’s sign was positive in eight cases (Solheim et al., 1981; Jankiewicz et al., 1991; Durrani and Winnie, 1991). Both the piriformis and the internal obturator muscles are external rotators. Passive internal rotation, which stretches the piriformis muscle, will in most cases also stretch the internal obturator muscle. If such stretching triggers pain because of tendinitis, both the piriformis and internal obturator muscles may therefore be sources of pain during passive internal rotation of the hips. In this study a pathology in or around the internal obturator muscle was not suspected in the operative group before the explorative procedure, as symptoms and findings preoperatively did not vary from what could be suspected in cases of a piriformis syndrome. The pathological findings around the internal obturator tendon were described peroperatively, and the functional testing with moving the hip joint was important to determine how much the internal obturator muscle pinched the sciatic nerve in certain positions. In the operative group one patient was found with Lasegue’s sign negative preoperatively, but on the operating table all patients had an impact from the obturator tendon on the sciatic nerve at an early stage in the movement when doing this test.

The treatment options for the syndrome affecting the piriformis muscle have been described as rectal massage (Mullin and De Rosayro, 1990; Jankiewicz et al., 1991), physical therapy (Mullin and de Rosayro, 1990) injections of anaesthetic agents together with steroids (Mullin and de Rosayro, 1990; Durrani and Winnie, 1991), and surgical release of tendons (Solheim et al., 1981; Sayson et al., 1994; Benson and Schutzer, 1999). In our small number of patients, the short time result seemed to be most striking, as the pain had been reduced at 6 weeks. The improvement of pain on the numerical rating scale was no longer significant at 6 months, but the reduction in the use of analgesic drugs in the operative group is impressive also at 6 months.

Thus, a formerly undescribed pathology affecting the internal obturator muscle and its relationships to the sciatic nerve seems to be responsible for much of the pain and diffuse neurological symptoms which were first ascribed to a piriformis syndrome in this study.

In conclusion a syndrome clinically similar to the piriformis syndrome has been described. Peroperatively the internal obturator tendon was found to make contact with the sciatic nerve. Sectioning the internal obturator tendon reduced pain postoperatively as measured by the numerical rating scale. There was an obvious tendency towards reduction in the amount of analgesic drugs consumed in the operative group 6 months after operation. Also, two of the operated patients had commenced employment after relatively long time out of work.

Acknowledgements

We would like to thank The Clinical Research Unit at Tromso University Hospital for excellent assistance in this study.

References


PAPER II
A 5-year prospective study of non-surgical treatment of retro-trochanteric pain

Khaled Meknas · Jüri Kartus · Jan Inge Letto · Magne Flaten · Oddmund Johansen

Abstract Diffuse retro-trochanteric pain occasionally radiating to the lower extremity could be caused by the piriformis or internal obturator muscle syndromes. Thirteen patients, with retro-trochanteric pain were included in the study. All patients suffered from a diffuse, but intense and often radiating hip pain. The median duration of the symptoms was 8 (1–20) years. The patients were treated by a specific supervised stretching programme with special emphasis on the internal obturator muscle. The duration of the stretching programme was 4 weeks. At inclusion, the median pain on the visual analogue scale (VAS) was 6.0 (3–7). The VAS for pain decreased to 4.0 (0–7) \( p = 0.01 \) at 12 weeks. Five years after treatment, the VAS for pain was still significantly lower than at inclusion, 4.0 (0–7) \( p = 0.018 \). A significant reduction in the number of positive Freiberg’s tests and in the number of patients limping was also observed, both at 3 months and at 5 years after treatment. It appears that a supervised stretching programme renders significant short and long term decrease in symptom for patients with retro-trochanteric pain.

Keywords Retro-trochanteric pain · Piriformis · Internal obturator muscle · Physical therapy

Introduction

Diffuse and occasionally radiating pain affecting the lower extremity is often caused by spinal pathology. Examples are the classic sciatic disease and spinal stenosis. In some cases, no clear clinical or radiological spinal, hip, or knee pathology can be found. It has been claimed that soft tissue pathology in the hip might cause diffuse and sometimes radiating pain \([1–3, 9, 15, 18]\). The concept was launched by Yeoman already in 1928 \([21]\), who proposed that arthritic changes in the sacroiliac joint can produce sciatica. The concept “piriformis syndrome” was later introduced by Robinson in 1947 \([16]\). The incidence for “piriformis syndrome” among patients with low back pain varies widely and has been reported to be between 5 and 36% \([5, 15]\).

The aetiology for this type of symptoms is not clearly known, although it has been argued that the pain syndrome may be caused by trauma to the pelvis or buttock \([3, 12]\), in addition to anatomical abnormalities of the piriformis muscle \([3, 4, 9, 17]\), such as the bipartite piriformis muscle \([6, 17]\) or as a recurrent problem after spinal surgery \([4]\). Benson et al. \([3]\) found adhesions between the piriformis muscle and the sciatic nerve. Cox et al. \([7]\) argued that the gemelli-obturator internus muscles and the associated bursa should be considered as possible sources of retro-trochanterically located sciatic like pain. Overuse of the...
piriformis muscle was suggested to contribute to the "piriformis syndrome" by Mayrand et al. [12]. The "piriformis syndrome" has also been reported following hip replacement [19]. A fusion of the piriformis with the obturator internus was confirmed in 48 of 112 cadavers in an anatomical study by Windisch et al. [20], which makes the problem even more complex. There are no laboratory or radiographical methods to diagnose the syndrome [1, 10] and a simple palpation test with tenderness over the insertion of the external rotators behind the trochanter major appears to be the main diagnostic sign [10, 13, 18].

Pain and weakness on forced passive internal rotation of the extended hip (Freiberg’s sign), and pain and weakness on resisted abduction and external rotation of the thigh in sitting position (Pace’s sign) are also the important findings. A number of methods exist for the treatment of the "piriformis syndrome" in the hip region. These include physical therapy [7, 11, 12], injection of anaesthetic agents with or without steroids [4, 14] and surgical release of the tendon [3, 13, 18]. Dezawa et al. [8] even described an arthroscopic technique for the release of the piriformis tendon. In a previous study by Meknas et al. [13], 12 patients suspected to have the “piriformis syndrome” were randomised to either operative or non-operative treatment. During the operative procedure, an unexpected pathology in terms of a tense internal obturator muscle compressing the sciatic nerve was observed, whereas no anatomical abnormality or other pathology affecting the piriformis muscle were found. A significant pain reduction was found immediately after surgical release, and it remained significantly reduced at both 6 and 12 weeks post-operatively. However, the reduction in pain did not reach statistical significance at 6 months. In the present study, an attempt has been made to reduce the tension in the internal obturator muscle/tendon by conservative means.

The hypothesis of the present study was that a specific supervised stretching programme aimed at relaxing the small external hip rotator muscles would render long term reduction of symptoms in patients with retro-trochanteric pain.

Patients and methods

Thirteen patients (1 male and 12 females) with a mean age of 49 (36–61) years, who had localised retro-trochanteric pain in the hip region, which diffusely spread down the lower extremity, were included in the study. The median duration of the symptoms was 8 (1–20) years (Table 1).

All patients had been through previous attempts of conservative treatment such as physical therapy, non steroid anti-inflammatory drugs, and injections of local anaesthetic agents in combination with corticosteroids. None of the patients had previously undergone an extended period of physical therapy aimed at stretching and relaxing the internal obturator muscle. All patients had to wait for minimum 6 months between inclusion in the study and the start of the treatment. During that time period, no patient improved spontaneously and their symptoms remained unchanged. Before inclusion in the study, all patients underwent a thorough clinical examination, standard radiography of the hip and pelvis. Furthermore, magnetic resonance imaging (MRI) using a Philips Interia 1.5 Tesla (Royal Philips, Electronics Amsterdam Netherlands) was performed in six patients, while computerized tomography (CT) using a Siemens Somatom Sensation (Siemens AG, Erlangen Germany) of the lumbar spine was performed in seven patients at inclusion. At 5 years, the corresponding was performed in seven patients using MRI and four patients using CT. Two patients had dropped out from the study.

Patients with pathology such as osteoarthritis of the hip, spondylolisthesis, significant nerve root affections and disc herniations in the lumbar spine were excluded from the study.

Rehabilitation programme

All patients were hospitalized at the Rehabilitation Centre of North Norway for a supervised rehabilitation programme for 4 weeks. They participated in two daily treatment sessions of approximately 30 min each. The exercise programme in the present study aimed at reducing the tension of the internal obturator muscle. The exercise programme was designed to be simple to teach, remember and perform both at the clinic and subsequently at home without supervision. It aimed at stretching the muscles around the hip by separate active and passive abduction, flexion and extension exercises (Fig. 1a–d). During abduction and flexion of the hip, the knee was kept extended (Fig. 1a, c). During extension of the hip, the patient grasped around the ankle and helped to force the knee into flexion, while keeping the body in an upright position (Fig. 1b). Two additional exercises were also included for the treatment of the small external rotators. One was a combined forced passive internal rotation with additional pressure towards hip flexion and adduction (Fig. 1d). The other was direct massage of the insertion of the small external rotators by a therapist. All exercises were performed for 15–30 s at a time and repeated 5–15 times depending on the ability of the patients to tolerate the stretching. If the pain was intolerable, that specific exercise was discontinued and the patient moved on to the next exercise. In the next session, a new attempt to tolerate that specific exercise was made. The patients were not denied access to other training activities, as they were accommodated at the rehabilitation centre, but
they were formally instructed and motivated only for the specific programme.

**Clinical examination**

The patients underwent clinical examination by two independent therapists, not involved in the treatment programme, at the start of the study ($n = 13$) and at 5 years ($n = 11$). At 3 months ($n = 13$) the examination was performed by the principle investigator (KM). The pain was classified using a VAS graded from 0 to 10, where 0 indicated no pain, and 10 indicated the worst possible pain. The patients were tested for pain and weakness on resisted abduction and external rotation of the thigh in a sitting position; the Pace’s sign, which was categorically classified by the patient as positive (pain) or negative (no pain) (Fig. 2).

Correspondingly the Freiberg’s sign for pain and weakness on forced passive internal rotation of the extended thigh was used and it was also categorically classified by the patient as positive (pain) or negative (no pain) (Fig. 3).

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Gender</th>
<th>Side</th>
<th>Age at inclusion (years)</th>
<th>Duration of symptoms (years)</th>
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<td>1</td>
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<td>Right</td>
<td>36</td>
<td>1</td>
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<tr>
<td>2</td>
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<td>Left</td>
<td>49</td>
<td>2</td>
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<td>Right</td>
<td>68</td>
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<td>Left</td>
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<td>8</td>
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<tr>
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<td>2</td>
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<tr>
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<td>Female</td>
<td>Left</td>
<td>41</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>Right</td>
<td>55</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>Bilat</td>
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<td>Left</td>
<td>56</td>
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<tr>
<td>13</td>
<td>Female</td>
<td>Right</td>
<td>57</td>
<td>8</td>
</tr>
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</table>

**Table 1** Demographics of the patients

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**Fig. 1** The stretching exercises in flexion (a), extension (b), abduction (c) and in combined flexion, adduction and internal rotation (d) position. An exercise was performed 15–30 s at a time and repeated 5–15 times under supervision of the physiotherapist.
Buttock and leg pain during passive straight leg rising performed by the examiner (Lasegue’s sign) was classified by the patient as positive if radiating pain before 60° of hip flexion occurred.

Limping and tenderness at palpation were performed and categorically classified by the examiner and the patient, respectively, as either positive or negative. The sitting and walking abilities were classified by the patients according to five graded scales (Table 2).

Statistics

All values are reported as median values unless otherwise indicated.

The Wilcoxon paired samples rank sum test was used for the longitudinal comparisons. A \( p \) value of less than 0.05 was considered statistically significant.

Results

Before the start of the treatment, the median VAS for pain was 6.0 (3–7). The VAS for pain was significantly lower both at 12 weeks (\( p = 0.01 \)) and at 5 years (\( p = 0.018 \)) compared with before the treatment (Table 3).

Six out of 13 patients had a positive Lasegue’s test at inclusion; at 3 months, the test was negative in all 13 patients, and three patients had a positive Lasegue’s test at 5 years [\( p = 0.014, p = 0.16 \) (n.s.), respectively] (Table 3). Significantly, fewer patients had a positive Freiberg’s sign at 3 months and 5 years (\( p = 0.025, p = 0.018 \), respectively) than at inclusion (Table 3).

Significantly, fewer patients were limping at both follow-up occasions (\( p = 0.014, p = 0.014 \), respectively) compared with before the treatment (Table 3).

There was no significant reduction of pain at palpation of the external rotator muscles and the Pace’s sign at 5 years compared with before the treatment. (Table 3). An associated significant improvement at both follow-up occasions in the ability to sit and walk without pain following treatment was also found (Table 3). The individual radiographic findings before the start of the treatment and at 5 years are reported in Table 4. At inclusion, 10/13 patients had minor degenerative changes or minor herniated discs without nerve root affection. The corresponding findings at 5 years were observed in 8/11 patients (n.s.).

At 5 years, a tumour was found in the uterus in one of the patients when examined by MRI. The tumour was not seen on the MRI at inclusion. The patient has been referred to the Department of Gynaecology at her local hospital.

Discussion

The most important conclusion of this study is that a supervised stretching programme rendered long term decrease in symptom in patients with diffuse and radiating pain of the hip and thigh. The exercise programme in the present study aimed at reducing the tension of the internal
obturator muscle, which we previously have found tense with impact on the sciatic nerve during explorative surgery on patients with symptoms and findings very similar to the present group of patients. In a prospective randomised study by Meknas et al. [13], a significant and immediate reduction of pain lasting for 3 months was found in the surgical group, but not in the control group. However, after 6 months, the pain reduction in the study by Meknas et al. [13] was no longer significant. The reason for this is uncertain. One explanation could be that the operative procedure might have caused secondary scar formation close to the sciatic nerve. Non-operative procedures do not cause scar formation problems and therefore, the present study was performed as an attempt to treat the internal obturator muscle without sectioning it.

A number of methods exist for the treatment of the “piriformis syndrome” with variable result; however, no particular treatment has resulted in long term improvement. Cox et al. [7] suggested that the distraction and manual stretching of the gemmeli-obturator internus and piriformis muscle are successful for treating retro-trochanteric pain. Keskula et al. [11] described the importance of stretching exercises for the “piriformis syndrome”, and Mayrand et al. [12] considered chiropractic care and muscle stretching beneficial. Benzon et al. [4] recommended an injection technique with special placement of the needle to avoid damage to the sciatic nerve, and Mullin et al. [14] reported significant pain relief after injection of corticosteroids and local anaesthetics in 12 patients with a follow-up period of 9–24 months.

In two case reports, Solheim et al. [18] found complete pain relief immediately after surgical release of the piriformis muscle with 11 and 10 months of follow-up, respectively. In a technical note, Dezawa et al. [8] reported good results in six patients operated with an arthroscopic release of the piriformis tendon.

The 6 month observational phase proceeding the treatment period in the present study revealed no improvement of symptoms. The clinical improvement was seen only after the stretching programme. This elucidates that the decrease of symptoms seen after the stretching programme was not a pure placebo effect. Finding methods to relax the piriformis muscle has been extensively studied. Even though it is an external rotator, the piriformis muscle has been found to rotate the femur internally when the hip is in flexion. In the present study, we chose not to perform the stretching exercises in external rotation. Assuming that a tense internal obturator muscle caused the problems, a different procedure was chosen. To our knowledge, there has been no description of a change of action for the internal obturator muscle from external to internal rotation [11]. The patients in the present study reported most pain during passive internal rotation, which therefore was considered as an efficient stretching manoeuvre for the obturator muscle. Maximum stretching of the internal obturator muscle was thought to be obtained by passive internal rotation with simultaneous flexion and adduction of the hip. Direct massage of the tendons of the small external rotators at their insertion at the trochanter by a physical therapist was also part of the treatment programme. The rational for this procedure is not thoroughly known, but one could assume that a mechanism similar to acupuncture could cause a relief of pain.

### Table 2 The classification of walking and sitting abilities

<table>
<thead>
<tr>
<th>Ability to walk</th>
<th>Scale</th>
<th>Ability to sit</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can walk without problem</td>
<td>1</td>
<td>I can sit without problem</td>
<td>1</td>
</tr>
<tr>
<td>I can walk 1 km without pain</td>
<td>2</td>
<td>I can sit 1 h without pain</td>
<td>2</td>
</tr>
<tr>
<td>I can walk 1/2 km without pain</td>
<td>3</td>
<td>I can sit 1/2 h without pain</td>
<td>3</td>
</tr>
<tr>
<td>I can walk only with crutches</td>
<td>4</td>
<td>I can sit only 10 min because of pain</td>
<td>4</td>
</tr>
<tr>
<td>I cannot walk</td>
<td>5</td>
<td>I cannot sit at all</td>
<td>5</td>
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</table>

### Table 3 The median VAS for pain and the clinical examination tests at inclusion, 3 months and 5 years after treatment

<table>
<thead>
<tr>
<th></th>
<th>At inclusion</th>
<th>3 months</th>
<th>5 years</th>
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<tbody>
<tr>
<td>VAS for pain median (range)</td>
<td>6.0 (3–7)</td>
<td>4.0 (0–7)</td>
<td>4.0 (0–7)</td>
</tr>
<tr>
<td>p values</td>
<td>0.01</td>
<td>0.018</td>
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<tr>
<td>Lasegue’s test (positive)</td>
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<td>0/13</td>
<td>3/11</td>
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<tr>
<td>p values</td>
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<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Tenderness at palpation</td>
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<td>11/11</td>
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<tr>
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<td>Freiberg’s sign positive</td>
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<td>0/11</td>
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<tr>
<td>p values</td>
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<td>0.018</td>
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<tr>
<td>Pace’s sign positive</td>
<td>9/13</td>
<td>6/13</td>
<td>5/11</td>
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<tr>
<td>p values</td>
<td>0.16 (n.s.)</td>
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<tr>
<td>Walking ability median (range)</td>
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<tr>
<td>p values</td>
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<td>0.023</td>
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<tr>
<td>Limp</td>
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<td>3/13</td>
<td>3/11</td>
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<tr>
<td>p values</td>
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<tr>
<td>Sitting ability median (range)</td>
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<td>2 (1–3)</td>
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<tr>
<td>p values</td>
<td>0.034</td>
<td>0.034</td>
<td></td>
</tr>
</tbody>
</table>

p values indicate comparison with inclusion values.

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In the present study, we also added exercises to stretch other muscles around the hip, like the adductor group and the hip extensors. This was done because in some cases, we have seen cramp-like states in multiple muscles associated with retro-trochanteric pain.

A critical point is to get the patients to continue the stretching exercise for an extended period of time. At the rehabilitation centre, the exercises were performed according to the programme, managed by physical therapists associated with the study. Since the exercises were limited in number, it was our intention that the exercises could be remembered and used by the patients after the initial treatment period. Unfortunately, we have no data to what extent the patients actually continued the exercise programme.

However, a significant reduction of pain was still found after 5 years compared to the pre-treatment values. Furthermore, the Freiberg’s sign as well as the ability to sit and walk without pain were also still improved at 5 years. In the present study, the median duration of the symptoms was 8 (1–20) years. This suggests that the patients had suffered a long time from their symptoms and the disease was already in a chronic stage. The chronic nature of retro-trochanteric pain is probably the reason to why the patients still had significant but improved pain, as measured using the VAS at 5 years after the initial treatment period.

In the present study, the patients were informed of the rational behind the approach, as this was supposed to motivate them better. The patients were also informed of

| Patient no. | Involved side | Standard radiographs of the hips | MR/CT finding of the lumbal/sacral column
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At inclusion</td>
<td>At 5 years</td>
<td>MRI: no pathology</td>
</tr>
<tr>
<td>1</td>
<td>Right</td>
<td>No pathology</td>
<td>CT: low intervertebral disc L5-S1. No nerve root affection</td>
</tr>
<tr>
<td>2</td>
<td>Left</td>
<td>No pathology</td>
<td>MRI: minor affection of the L5 root at the lateral recess</td>
</tr>
<tr>
<td>3</td>
<td>Right</td>
<td>No pathology</td>
<td>MRI: minor bilateral affection of the L4 roots at the lateral recess</td>
</tr>
<tr>
<td>4</td>
<td>Left</td>
<td>Minor calcia on the greater trochanter bilateral</td>
<td>MRI: minor bilateral affection of the L4 roots at the lateral recess</td>
</tr>
<tr>
<td>5</td>
<td>Right</td>
<td>No pathology</td>
<td>CT: no nerve root affections. Low intervertebral discs on multiple levels</td>
</tr>
<tr>
<td>6</td>
<td>Left</td>
<td>No pathology</td>
<td>CT: no pathology</td>
</tr>
<tr>
<td>7</td>
<td>Right</td>
<td>Minor degenerative changes in the left hip joint</td>
<td>MRI: facet joint osteoarthritis on level L3-5. No nerve root affection</td>
</tr>
<tr>
<td>8</td>
<td>Bilat</td>
<td>No pathology</td>
<td>MRI: no pathology</td>
</tr>
<tr>
<td>9</td>
<td>Left</td>
<td>No pathology</td>
<td>MRI: minor herniated disc at the L5-S1 level without nerve root affection</td>
</tr>
<tr>
<td>10</td>
<td>Right</td>
<td>No pathology</td>
<td>CT: no nerve root affection. Facet joint osteoarthritis on multiple levels</td>
</tr>
<tr>
<td>11</td>
<td>Right</td>
<td>No pathology</td>
<td>MRI: post-operative changes after laminectomy, without nerve affection nor other pathology</td>
</tr>
<tr>
<td>12</td>
<td>Right</td>
<td>No pathology</td>
<td>CT: minor left sided disc protrusion at the L5/S1 level No nerve root affection</td>
</tr>
<tr>
<td>13</td>
<td>Right</td>
<td>No pathology</td>
<td>MRI: no nerve root affection. Minor protrusion of the L5-S1 disc</td>
</tr>
</tbody>
</table>

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the relatively extended period of treatment needed, and for the need of continued treatment after discharge from the clinic. One problem in the clinical setting could be that these types of patients often get a mixture of treatment algorithms for both back and hip problems.

Larger and controlled studies should be set up to thoroughly evaluate the treatment of this type of pathology. The present study was not a randomized trial and no control group was available, which is of course a weakness in addition to the low number of patients. One further limitation of the present study is that the hips were only evaluated using standard radiographs. Pathology in the hip, such as labral tears or femuro-acetabular impingement can best be diagnosed using MRI which was not performed in the present study.

However, one strong aspect of the present study was that all patients had to wait for minimum 6 months between inclusion in the study and the start of the treatment. During that time period, no patient improved and their symptoms remained unchanged. A further strength is that the clinical evaluations at inclusion and at 5 years were done by an independent physical therapist. As in the present study, we recommend that, in future studies, patients with other pathology in the spinal columna and the hip joint should be excluded. A close collaboration between patients, doctors and physical therapists is also recommended to manage and stick to the specific stretching programme.

Retro-trochanteric pain caused by the piriformis- or internal obturator syndrome is often underdiagnosed or overlooked in the clinical setting, because the symptoms may be similar to lumbal spine disorders, such as disc herniations or spinal stenosis [5]. Therefore, it is important to recognize the problem in an early stage and to start a treatment programme to prevent the disease from proceeding into a chronic stage.

Conclusion

A specific stretching programme resulted in both short and long term decrease in symptoms in patients with retro-trochanteric pain. The hypothesis of the study could thus be verified.

Acknowledgment The authors thank Prof. James Mercer, Ph.D., Department of Medical Physiology, Institute of Medical Biology, Faculty of Medicine, University of Tromsø, Norway for assistance with language editing.

References

PAPER III
Surgical release of the internal obturator tendon for the treatment of retro-trochanteric pain syndrome: a prospective randomized study, with long-term follow-up

Khaled Meknas · Jüri Kartus · Jan Inge Letto · Anders Christensen · Oddmund Johansen

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Abstract Twelve patients with clinical signs of retro-trochanteric pain syndrome were randomized to either operative treatment or a control group. Six patients were operated on with sectioning of the tendon to the internal obturator near its insertion to the trochanter major. There was no significant pain decrease in either group at 6 months. However, at 8 years, the decrease in pain was significant in the surgical group ($P < 0.03$) but not in the control group. Three patients in the surgical group who needed pain medication with opioids preoperatively managed without such drugs at 8 years. Two patients in the surgical group were working half time at the 8 year follow-up. Before the start of the study the patients had been out of work for 3 and 10 years, respectively. At inclusion 4/12 patients had minor degenerative changes at the L3–L5 level as seen on computerized tomography or magnetic resonance imaging. At 8 years, the corresponding change was found in 7/9 patients ($P = 0.025$). In conclusion, at 8 years after surgical release of the internal obturator muscle, the patients had a significant decrease in pain compared with the finding at inclusion. The corresponding was not found in the control group.

Keywords Piriformis · Internal obturator muscle · Retro-trochanteric pain syndrome · Surgery · Radiology

Introduction Retro-trochanteric pain has been attributed to as the “piriformis syndrome” and can often be unrecognized or misdiagnosed. In 1928, Yeoman described a syndrome where he proposed that arthritic changes in the sacroiliac joint may cause sciatic pain due to secondary inflammation of the piriformis muscle [21]. The concept “piriformis syndrome” was later introduced by Robinson in 1947 [16].

The syndrome is characterized by buttock and lower extremity pain caused by a hypertrophic or inflamed muscle, which increases the pressure from the small external rotators of the hip towards the sciatic nerve [2, 3, 6, 13, 15]. The aetiology of the syndrome is not clearly known, although it has been argued that the pain may occur secondary to blunt trauma to the buttock or gluteal region [3, 12]. Anatomical abnormalities of the piriformis muscle or the sciatic nerve as bipartite piriformis muscle and piriformis muscle lying anterior to the nerve have been described as irritating the sciatic nerve [3, 4, 6, 9, 17]. It has also been described that the cause could be a recurrent problem after spinal surgery [4]. Benson et al. [3] found adhesions between the piriformis muscle and the sciatic nerve. Cox et al. [7] argued that the gemelli-internal obturator muscles and the associated bursa should be considered as possible sources of retro-trochanterically located sciatic-like pain. Overuse of the piriformis muscle was suggested to contribute to the “piriformis syndrome”
by Mayrand et al. [12]. The “piriformis syndrome” has also been reported following hip replacement [19]. There are no laboratory or radiographical methods to establish a diagnosis of the syndrome [1, 10]. Windisch et al. [20] argued that the variations of the piriformis muscle were not mentioned in radiological text books, which are of importance for the interpretation of ultrasonographic and magnetic resonance tomography images. In an anatomical cadaver study, the authors found that 48 of 112 cadaveric specimens had a fusion of the piriformis and the internal obturator muscles [20].

The role of the internal obturator in retro-trochanteric pain syndrome is not especially well described in the literature and suggested treatment options for this type of pathology are seldom seen. A palpation test with tenderness over the insertion of the external rotators behind the trochanter major appears to be the main diagnostic sign [10, 13, 18]. Pain and weakness on forced passive internal rotation of the extended hip (Freiberg’s sign) and pain and weakness on resisted abduction and external rotation of the thigh in sitting position (Pace’s sign) are also important findings. A number of methods exist for the treatment of the “piriformis syndrome” in the hip region. These include physical therapy [7, 11, 12], injection of anaesthetic agents with or without steroids [3, 14], and surgical release of the tendon [6, 13, 18]. Dezawa et al. [8] described an arthroscopic technique for the release of the piriformis tendon.

In 2003, Meknes et al. [13] reported significant short-term pain reduction both at 6 and 12 weeks after surgery in patients with radiating pain in the buttock after sectioning the internal obturator muscle. However, at 6 months, the reduction in pain was no longer statistically significant. The aim of the present study was to perform a long-term clinical and radiographic follow-up of the patients in the randomized study by Meknas et al. [13]. The hypothesis of the study was that surgical release of the internal obturator muscle would render a long-term decrease in pain in patients with retro-trocanterically located pain in the buttock.

**Patients and methods**

Twelve patients, three males and nine females, mean age 47 (25–66) years with retro-trochanteric pain in the buttock, radiating distal to the knee and intolerance to sit more than 40 min, were included in a prospective, randomized trial. At inclusion the patients were randomly allocated by sealed envelopes to either operative treatment or a control group. The median duration of symptoms was 7.5 (2–20) years (Table 1), and all patients had undergone various conservative treatments with either physiotherapy or injections with local anaesthetic agents combined with steroids before inclusion in the study.

At inclusion, 6 weeks, 12 weeks, 6 months and at 8 years the patients were tested for pain and tenderness when examined with deep palpation over the small external rotators dorsal to the trochanter major and over the sciatic nerve in the same region. The clinical examinations also included tests for pain and weakness on resisted abduction and external rotation of the extended thigh (Freiberg’s sign) (Fig. 1) and buttock and leg pain during passive straight leg raising (Lasegue’s sign). Furthermore, an evaluation of limping and of problems at walking and sitting was performed. All the above tests were categorically classified by the patient as positive (pain/problems) or negative (no pain/no problems). The 6- and 12-week results have been reported in a previous publication by Meknas et al. [13].

Patients with obvious spinal pathology, cancer or severe organic diseases, patients older than 70 years and patients who suffered from mental illness preventing them from following simple rehabilitation instructions were excluded from the study. At inclusion and at 8 years, the patients underwent standard antero-posterior radiographs of the pelvis and hips, and lateral view of the hips (bilaterally) and either CT using a Siemens Somatom Sensation (Siemens AG, Erlangen Germany) or MRI using a Philips Intera 1.5 Tesla (Royal Philips, Electronics Amsterdam Netherlands) of the lumbar spine (Table 2).

The clinical examinations at 8 years as well as all radiographic assessments were performed by independent observers who were not involved in the treatment of the patients.
In the present study, pain was registered using the visual analogue scale (VAS) preoperatively, at 6 months and at 8 years. The use of analgesic and anti-inflammatory drugs and the level of work for each patient at inclusion, 6 months and at 8 years were registered and classified according to Tables 3 and 6. All patients provided written consent, and the study protocol was approved by the National Committee for Research Ethics in Norway.

Surgical treatment and regimen in the control group

An explorative operation was done using a postero-lateral approach in the hip region. The fascia lata was split, the external rotators and the sciatic nerve were identified (Fig. 3a, b). An examination of the anatomy as well as the relationships between structures during passive flexion, internal rotation, and the Lasegue’s test were performed during the operation. The sciatic nerve was found to pass anterior to the piriformis muscle in all cases in the surgical group, with no part of the nerve passing through this muscle. As for the superior gemellus and internal obturator muscles, the sciatic nerve passed behind these in all cases in the surgical group. The internal obturator muscle was found tense, hyperaemic and in close contact with the sciatic nerve (Fig 3a). The nerve was flattened and slightly hyperaemic. When performing the Lasegue manoeuvre on the operating table, the internal obturator, and not the piriformis muscle, impinged on the sciatic nerve at an early stage during hip flexion. To relieve the tension towards the sciatic nerve from the internal obturator muscle, sectioning of the tendon was performed at its insertion to the greater trochanter. An immediate release of the tension towards the sciatic nerve during the Lasegue’s manoeuvre was observed after sectioning of the tendon (Fig 3b). Prophylaxis against infection was administered intravenously using 2 g of Cefalotin (ACS Dobfar Generics Luxembourg) just before the operation. Weight bearing supported by crutches was allowed immediately after surgery. A gradual increase in activity as tolerated by the patients was allowed. The patients underwent no formal sessions of physiotherapy. No new approaches for treatment were initiated in the control group during the observation period.

Statistical methods

The power analyses was performed before the start of the long-term follow-up using the knowledge from the short term study by Meknas et al. [13]. The decrease in pain in the treatment group as measured with the VAS was the primary variable. It was hypothesized that there would be a mean long-term decrease in the pain score of 3 on the VAS.
with a standard deviation of 1.5 compared with the pre-operative values. With the alpha value set at 0.05 and the power at 80%, the required sample size would be four patients in the treatment group. Based on these calculations, it was decided to proceed with the long-term follow-up.

Mean (SD) values are reported for the VAS and median (range) values for the other variables. The repeated
measures ANOVA test and the Fisher’s post hoc test were used to analyse the change over time in terms of the VAS for pain within the study groups. For all other ordered variables within group comparisons were made using the Wilcoxon test. Dichotomous variables were analysed using the Fisher’s exact test.

Results

The demographics of the patients are presented in Table 1. At inclusion, there were no significant differences between the study groups in terms of gender, age and duration of symptoms. At inclusion, all patients underwent both clinical examinations and radiographic examinations of the hips and either CT or MRI of the lumbar spine (Tables 2, 4). At 6 months, all patients underwent clinical examinations (Table 4). At 8 years, one patient in the surgical group had died and one patient in each group was lost to follow-up. The remaining four patients in the surgical group and five patients in the control group underwent clinical (Table 4) and radiographic (Table 2) examinations at 8 years. No per or postoperative complications or reoperations were registered during the period of the study.

At 8 years, a significant decrease in pain was found in the surgical group but not in the control group (Table 5).

All clinical examination tests at inclusion, 6 months and 8 years are presented in Table 4. At 8 years, the Lasegue’s test was significantly better compared with the findings at inclusion in the control group.

All individual radiographic findings at inclusion and at 8 years are presented in Table 2. At inclusion and at 8 years, no pathology was found in the hip joints in neither group. Minor degenerative changes were found at the L3–L5 level in 4/12 patients at inclusion. At 8 years, the corresponding changes were found in 7/9 patients ($P = 0.025$).

The level of pain medication decreased significantly in the whole study cohort at 6 months ($P = 0.03$) and at 8 years ($P = 0.02$) compared with the levels at inclusion. If the study groups were analysed separately, the decrease was only significant in the surgical group at 6 months ($P = 0.04$) (Table 6).

Two patients in the surgical group were working full and half time, respectively, at 6 month follow-up; both patients still worked half time at 8 years. Before the start of the study the patients had been out of work for 3 and 10 years, respectively (Table 6).

Discussion

Twelve patients with diffuse retro-trochanterically located radiating pain in the hip and thigh region were enrolled in this prospective randomized study.

The principal finding of the present study was that a significant decrease in pain was found in the surgical group but not in the control group, 8 years after sectioning of the internal obturator tendon. Meknas et al. [13] have previously reported that patients with symptoms and findings similar to the “piriformis syndrome” had a remarkable and significant decrease in pain during the first months after
surgical release of the internal obturator muscle tendon. A corresponding finding was not seen in the control group. However, after 6 months, the decrease in pain was no longer significant. The reason for this is unknown. One explanation could be that the operative procedure included sectioning of the internal obturator tendon, and also exploration of the sciatic nerve, which might have caused secondary scar formation.

The radiographic findings are also interesting. A significant increase in minor degenerative changes in the lumbar columna was found in the whole study cohort. This finding suggests that retro-trochanteric pain syndrome might be associated with early degenerative changes in the lumbar columna, and for diagnostic reasons, changes in the lumbar columna must be taken into consideration.

A number of methods exist for the treatment of the “piriformis syndrome” with variable results; however, no particular treatment has resulted in long-term improvement. Cox et al. [7] suggested that distraction and manual stretching of the gemmeli-internal obturator and piriformis muscles are successful for treating “retro-trochanteric pain syndrome”. Keskula et al. [11] described the importance of stretching exercises for the “piriformis syndrome” and Mayrand et al. [12] considered chiropractic care and muscle stretching beneficial. Benzon et al. [4] recommended an injection technique with special placement of the needle to avoid damage to the sciatic nerve and Mullin et al. [14] reported significant pain relief after injection of cortico-steroids and local anaesthetics in 12 patients with a follow-up period of 9–24 months.

In two patients, Solheim et al. [18] found complete pain relief immediately after surgical release of the piriformis muscle with 11 and 10 months of follow-up, respectively. In a technical note, Dezawa et al. [8] reported good results in six patients operated with an arthroscopic release of the piriformis tendon. To our knowledge, there are no other randomized studies on surgical treatment of retro-trochanteric pain syndrome found in the literature except the study by Meknas et al. [13].

Anatomically, the internal obturator muscle is deep to both the piriformis muscle and the sciatic nerve and it runs parallel to the piriformis in its attachment to the trochanter major. Because of its proximity, similar pathway and similar function, most treatments for patients with “piriformis syndrome” would affect the internal obturator muscle as well [5].
In an anatomical cadaver study, Windisch et al. [20] found that 48 of 112 cadaveric specimens had a fusion of the piriformis and the internal obturator muscles. Their finding is in line with the present observation that the internal obturator muscle can cause symptoms similar to those of the “piriformis syndrome”. There is some confusion in the literature since retro-trocanterically located pain has been given different names such as “piriformis syndrome”, “internal obturator syndrome”, “small external rotator syndrome”, or other similar names. We suggest that the syndrome consisting of symptoms and findings as described in the present study should be named “retro-trochanteric pain syndrome” in the future.

Larger and controlled studies should be set up to thoroughly evaluate the treatment of this type of pathology. The present study was a randomized trial which is of course a strength of the study. One more strength of this study is that independent examiners performed the long-term clinical examinations and all radiographic assessments.

A weakness of the study is the small number of patients involved and that the study was not designed with enough power to compare the surgical treatment group with the control group. In addition, the patients did not undergo Lauenstein radiographs or MRI evaluation of the hip. Although it is unlikely, there is a possibility that the patients could have suffered from femuro-acetablular impingement or labral tears in their hip joint.

**Conclusion**

Surgical release of the internal obturator muscle resulted in long-term decrease in pain in patients with retro-trochanteric pain syndrome. Thus, the hypothesis of the present study could be verified.

**Acknowledgment** The authors thank Prof. James Mercer, Ph.D., Department of Medical Physiology, Institute of Medical Biology, Faculty of Medicine, University of Tromsø, Norway for assistance with language polishing.

**References**


**Table 6** Levels of pain medication and work at inclusion, 6 months and 8 years

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Level of pain medication at inclusion</th>
<th>Level of pain medication at 6 months</th>
<th>Level of pain medication at 8 years</th>
<th>Level of work at inclusion</th>
<th>Level of work at 6 months</th>
<th>Level of work at 8 years</th>
</tr>
</thead>
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<td></td>
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</tr>
<tr>
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<td>3</td>
<td>3</td>
<td>–</td>
<td>Sick leave</td>
<td>Sick leave</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0</td>
<td>–</td>
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</tr>
<tr>
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<td>4</td>
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<td>Sick leave</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
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<tr>
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<td>3</td>
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<td>1</td>
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<td>Work 50%</td>
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<td>4</td>
<td>0</td>
<td>0</td>
<td>Sick leave</td>
<td>Full work</td>
<td>Work 50%</td>
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<td>Control group</td>
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<td></td>
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PAPER IV
Ultrastructural and Histological Characteristics of the Internal Obturator Tendon in Hip Osteoarthritis and Fracture of the Collum Femoris
Could tendinosis be involved in osteoarthritis?

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Abstract

Background: There is limited information available in terms of the histological and ultrastructural changes in the tendons in the hip and gluteal region for patients with different clinical conditions.

Methods: Ten patients median age 60 (48-75 years) with osteoarthritis of the hip and ten patients median age 82.5 (60-90 years) who had suffered a Fracture of the Collum Femoris (FCF; Garden III or more) underwent an open biopsy procedure in conjunction with a total hip replacement.

Results: The histological evaluation revealed that all the tendon samples in the osteoarthritis group had limited areas of scar tissue; the corresponding finding was made in 50% of the patients in the FCF group (p = 0.02). There were more GAGs (p = 0.023) and calcium deposits (p = 0.001) in the samples from the osteoarthritis group than in the FCF group. The ultrastructural evaluation revealed fewer small and medium-sized fibrils (p = 0.001) and more non-collagenous extracellular matrix (ECM) (p = 0.003) in samples of the osteoarthritis group compared with the FCF group.

Conclusion: The tendon samples from the internal obturator tendon in the osteoarthritis group revealed a more degenerative appearance with more scar tissue and a change in fibril diameter distribution, as well as more non-collagenous ECM compared with the FCF group.

Clinical relevance: Theoretically, the pathology in the short rotator muscle tendons could contribute to the symptoms experienced by patients with osteoarthritic hips. Therefore, treatment of the tendinosis in patients with mild and moderate osteoarthritis might be an option to decrease the symptoms.

Level of Evidence: Case control study, level of evidence, 3.

Key words: Osteoarthritis; internal obturator tendon; tendinosis; histology; ultrastructure.
INTRODUCTION
Tendon disorders and overuse injuries in sports and repetitive occupational activities are major problems in the general population, as well as being difficult to treat. “Tendinopathy” is a term that is commonly used in chronic tendon disorders when the patient seeks help as a result of pain. The term “tendinosis” is a histological confirmation of degenerative changes without inflammatory cells but with changes such as collagen fibril disorientation, rounding of tenocyte nuclei, increased ground substance and hypervascularity in the histological specimens [1-3].
A better understanding of the cellular interaction during tendon degeneration may help to increase the opportunity to treat the condition.
The morphological changes in tendinopathies have been analyzed in several studies involving the shoulder [4-6], elbow [3] and patellar tendon [7;8]. However, there is limited information in the literature in terms of the ultrastructural and histological changes in the tendons in the hip and gluteal region. Lempainen et al. [9] confirmed histological tendinosis using histological analysis in 103 cases of proximal hamstring tendinopathy in athletes. Grimaldi et al. [10] used magnetic resonance imaging (MRI) and showed a significantly smaller piriformis muscle in patients with hip osteoarthritis compared with patients with non-osteoarthritic hips, while Broadhurst et al. [11] found an abnormal piriformis morphology in a significant number of patients with chronic buttock pain using ultrasonography.
Lequesne et al. [12;13] studied the correlation between MRI findings and clinical and surgical findings in refractory greater trochanteric pain syndrome. They found tears in the gluteus medius and minimus tendons and they introduced the term “hip rotator cuff syndrome”. Pathology in the short rotators of the hip is regarded as a possible source of retrotrochanterically located sciatic-like pain, as reported by Cox et al [14] and it was suggested that overuse of the piriformis muscle contributed to the “piriformis syndrome” [15].
Meknas et al. [16;17] demonstrated a favorable short- and long-term outcome after the surgical release of the internal obturator tendon in patients with retrotrochanteric pain syndrome. Recently the approach towards symptoms from the hip joint has become more active. The possibility to perform hip arthroscopies and address pathology such as the CAM lesion and femuro acetabular impingement syndrome has increased the possibility to treat symptoms from the hip joint before it will be subjected to joint replacement surgery [18;19]. Theoretically, the pathology in the short rotator muscle tendons could contribute to the symptoms experienced by patients with osteoarthritic hips. Therefore, treatment of the tendinosis in patients with mild and moderate osteoarthritis in the hip joint might be an option to decrease the symptoms.
Based on this consideration the aim of the present study was to examine the histological and ultrastructural appearance of the short rotators around the hip, especially the internal obturator muscle tendon, in patients with osteoarthritis of the hip joint compared to the patients who had suffered of a fracture of the collum femoris (FCF).
The hypothesis of the study was that the tendon samples from the patients with osteoarthritis in the hip would reveal a degenerated fiber structure, an increased amount of glycosaminoglycans (GAGs), as well as an altered extracellular matrix (ECM) and fibril diameter distribution, compared with the samples from the patients with FCF.

PATIENTS AND METHODS
The material in this case control study consisted of tendon samples from the short external rotators of the hip, e.g. the internal obturator muscle, obtained in an open fashion at the time of total hip replacement in 10 consecutive patients (4 male, 6 female) with osteoarthritis of the hip; the median
age was 60 years (48-75). Samples from 10 consecutive patients (2 male, 8 female) with FCF (Garden III or more), median age 82.5 years (60-85), who also underwent a total hip replacement, served as controls. A minimum of two samples were obtained from each patient. All the patients gave their written consent and the National Committee for Research Ethics approved the study protocol.

**Histological analysis**
The samples for light microscopy were fixed in 4% formalin, embedded in paraffin blocks and sectioned at 4-5μm. The sections were stained with hematoxylin and eosin (H&E) to evaluate the fiber structure, cellularity and vascularity. Alcian Blue/Periodic Acid Schiff (AB/PAS) was used to detect sour/neutral mucins for glycosaminoglycans. Furthermore, the Perl, van Gieson and van Kossa stains were performed to identify hemosiderin, collagen and calcium deposits respectively. The biopsies were evaluated by two independent, experienced pathologists (SES, LJ). The fiber structure, cellularity, vascularity and the presence of GAGs were classified according to a semi-quantitative scoring system (Table 1) [20]. The staining for hemosiderin and calcium deposits was dichotomously classified as positive/negative.

**Ultrastructural analysis**

The ultrastructure was assessed using a transmission electron microscopy (TEM) analysis; the specimens were fixed in 8% formaldehyde in Hepes buffer. The biopsies were cut into small cubes and half the material was immersion-fixed in McDowell’s fixative for electron microscopic studies [21]. After primary fixation, the tissue was washed with Sorensen’s phosphate buffer, post-fixated in 1% aqueous OsO4, washed and “en block” stained with 2% uranyl acetate, dehydrated in a graded series of ethanol, embedded in an Epon substitute (AGAR: AGAR 100, MNA, DDSA) and DNP-30 with propylene oxide as a transitional solvent, according to standard procedures. Semi-thin and ultra-thin sections were cut using a Leica Ultracut S (Vienna, Austria) on glass or diamante knives (Diatome, Biel, Switzerland). Ultra-thin sections were mounted on formvar-coated 100 mesh copper grids and contrasted with 5% uranyl acetate followed by Reynold’s lead citrate [22]. Micrographs were obtained using a Jeol JEM 1010 (Tokyo, Japan) with a Morada camera system (Olympus Soft Imaging Systems, Münster, Germany).

For sampling, two blocks from each patient were sectioned and mounted on carbon-coated formvar films on copper grids. Micrographs for measuring the fibril diameters were obtained at random, from

---

**Table 1. Evaluation of biopsy samples with a semi-quantitative 4-point scoring system**[20]

<table>
<thead>
<tr>
<th></th>
<th>Grad 0</th>
<th>Grad 1</th>
<th>Grad 2</th>
<th>Grad 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber structure</td>
<td>Straight, parallel, packed fibers, with slight waviness</td>
<td>Slight separation of fibers, increased waviness</td>
<td>Separation of fibers, deterioration of fibers</td>
<td>Complete loss of fiber structure and hyalinization</td>
</tr>
<tr>
<td>Cellularity</td>
<td>&lt; 100 cells/high power field (HPF)</td>
<td>100-199 cells/HPF</td>
<td>200-299 cells/HPF</td>
<td>&gt; 200 cells/HPF</td>
</tr>
<tr>
<td>Vascularity</td>
<td>Vessels running parallel to the collagen fiber bundles in the septa</td>
<td>Slight increase in vessels, including transverse vessels in the tendon tissue</td>
<td>Moderate increase in vessels within the tendon tissue</td>
<td>Markedly increased vascularity with clusters of vessels</td>
</tr>
<tr>
<td>Glycosaminoglycans</td>
<td>No alcianophilia</td>
<td>Slight alcianophilia between the collagen fibers</td>
<td>Moderate increase in alcianophilia</td>
<td>Markedly increased alcianophilia forming blue lakes</td>
</tr>
</tbody>
</table>
one to three groups of cross-sections from each block. The diameter of a minimum 100 fibril was measured using the Soft Imaging System (Olympus, Münster, Germany) at a magnification of x 50,000. The relative fibril diameter distribution was calculated in percent. The diameters were grouped in 5 size classes (0-30 nm, 31-60 nm, 61-90 nm, 91-120 nm).

The morphology of the extracellular matrix (ECM) was evaluated and dichotomously classified as homogeneous or irregular at a magnification of x 3000.

The micrographs were evaluated by one independent technician (RO) with extensive experience of using the TEM.

**Statistical analysis**

Median (range) values are presented. The Mann-Whitney U test was used for comparisons between the osteoarthritis and FCF groups. The within-group comparisons were made using the Wilcoxon test and the dichotomous comparisons were made using Fisher’s exact test. A p-value of < 0.05 was regarded as statistically significant. The comparison of the fibril diameter distribution was performed at group level and involved 1,145 fibrils in the osteoarthritis group and 1,215 fibrils in the FCF group.

**Source of Funding**

Institutional support was received from the “Dr. Trygve Gythfeldt and wife's research fund”. The funding source did not play a role in the investigation.

**RESULTS**

**Histological Evaluation**

Light microscope analysis of nine representative samples in the osteoarthritis group and 8 in the FCF group demonstrated significantly more scar tissue (p = 0.02), calcium deposits (p = 0.001) and GAGs (p = 0.023) in the biopsies from the internal obturator in the osteoarthritis group than in the FCF group (Tables 2 and 3, Figure 1 A, B, C, D). The van Kossa stain revealed that calcium salts had precipitated within the areas of scar tissue in 8 of 9 specimens in the osteoarthritis group (Figure 1 C). The AB/PAS staining for GAGs was positive in 8/9 specimens in the osteoarthritis group and in 3/8 specimens in the FCF group (Figure 1 D). There was no evidence of inflammation in either group (Table 3). Furthermore, within the osteoarthritis group, there was significantly more vascularity (p = 0.04) and the fiber structure in the scar tissue had deteriorated to a significantly greater degree than in the non-scar tissue (p = 0.02) (Table 2, Figure 1 A, B). The corresponding finding was not made in the FCF group.

All the biopsies from the patients in the osteoarthritis group had limited areas of scar tissue. The corresponding finding was made in 4/8 patients in the FCF group (Table 3).

The scar tissue was composed of both thin and thick irregular collagen bundles, oriented in a more or less wavy and crosswise fashion. The scar tissue was densely fixed to the tendinous tissue, indicating a previous tendon rupture site (Fig 1 B). In and close to these previous rupture sites, the Perl’s reaction was negative, indicating that there was no bleeding and no remnants of hemosiderin present.

**Ultrastructural Evaluation**

Nine representative samples in the osteoarthritis group and ten in the FCF group were evaluated by TEM.

The distribution of fibril diameter revealed significantly fewer small and medium-sized fibrils in the osteoarthritis group than in the FCF group (p = 0.001), (Figures 2 AB and CD).

All 10 samples from the FCF group displayed a normal or close to normal homogeneous ultrastructural pattern, with collagen fibrils running in the same direction. The samples from the osteoarthritis group displayed a more irregular pattern in 6/9 specimens, with pathological morphologic characteristics – e.g. the collagen fibrils were oriented in different directions and there was an
increased amount in non-collagenous ECM. In 3/9 samples, the ultrastructural pattern was more or less homogeneous (p = 0.003) as presented in Figures 3 A, B.

**Table 2.** The histologic, semi-quantitative, 4-point scoring system (0-3) for the non-scar tissue (NST) and the scar tissue (ST) in terms of fiber structure (Fiber), cellularity (Cell), vascularity (Vasc) and the presence of GAGs in the osteoarthritis group and in the FCF group.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Arthrosis Fiber NST/ST</th>
<th>Arthrosis Cell NST/ST</th>
<th>Arthrosis Vasc NST/ST</th>
<th>Arthrosis GAGs NST/ST</th>
<th>FCF Fiber NST/ST</th>
<th>FCF Cell NST/ST</th>
<th>FCF Vasc NST/ST</th>
<th>FCF GAGs NST/ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/1</td>
<td>0/0</td>
<td>0/1</td>
<td>0/2</td>
<td>1/-</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
</tr>
<tr>
<td>2</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>3</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>0/2</td>
<td>0/0</td>
<td>0/2</td>
<td>0/2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>0/2</td>
<td>0/0</td>
<td>0/2</td>
<td>0/3</td>
<td>0/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>6</td>
<td>0/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>0/0</td>
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<td>0/1</td>
</tr>
<tr>
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<td>0/0</td>
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<td>2/2</td>
<td>0/0</td>
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<td>0/2</td>
</tr>
<tr>
<td>8</td>
<td>1/2</td>
<td>0/0</td>
<td>0/1</td>
<td>0/1</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
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<tr>
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<td>0/-</td>
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<tr>
<td>10</td>
<td>0/1</td>
<td>0/0</td>
<td>0/1</td>
<td>0/2</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
<td>0/-</td>
</tr>
</tbody>
</table>

X indicates that it was not possible to evaluate the sample as there was too little tissue. Four patients in the FCF group did not have any scar tissue in their samples, this is indicated by – in the table.

**Table 3.** The characterization of calcium deposits, inflammation and scar tissue in both groups. X indicates that it was not possible to evaluate the sample, as there was too little tissue.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Arthrosis Calcium deposits</th>
<th>FCF Calcium deposits</th>
<th>Arthrosis Inflammatory cells</th>
<th>FCF Inflammatory cells</th>
<th>Arthrosis Scar tissue, % of the sample</th>
<th>FCF Scar tissue, % of the sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>30</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>95</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0</td>
<td>Few</td>
<td>0</td>
<td>95</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0</td>
<td>Few</td>
<td>0</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>0</td>
<td>X</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>70</td>
<td>0</td>
</tr>
</tbody>
</table>

p = 0.001

p = 0.02
Figure 1. A. Normal tendon from a patient in the FCF group, H&E staining, original magnification x100. B. Scar tissue from a patient in the osteoarthritis group indicating a ruptured tendon. H&E staining, original magnification x400. C. Calcium deposits (black stain at arrows) in the scar of a previously ruptured tendon in a patient in the osteoarthritis group. Van Kossa staining, original magnification x400. D. Moderately increased amount of mucin, indicating GAGs between collagen structures in a patient in the osteoarthritis group (blue stain at arrows). Alcian Blue/Periodic Acid Schiff staining. Original magnification x400.

Figure 2. A. Transmission electron micrograph showing fewer small and medium-sized fibrils in the osteoarthritis group. B. Relative distribution of the fibril diameter size in the internal obturator tendon in the osteoarthritis group. C. Transmission electron micrograph showing more small and medium-sized fibrils in the FCF group. D. Relative distribution of the fibril diameter size in the internal obturator tendon in the FCF group. Original magnification x50.000.
DISCUSSION

The principal findings in the present study were that samples from the internal obturator tendon in patients with osteoarthritic hips revealed a significantly altered pathological and ultrastructural appearance compared with tendon samples from patients who suffered a fracture of the collum femoris. In the osteoarthritis group, the tendon material was irregular and changed, with collagen fibrils oriented in different directions and an increased amount of cell debris, as seen in the TEM. Furthermore, there were significantly fewer small and medium-sized fibrils compared with the FCF group. The change towards more non-collagenous ECM indicates that osteoarthritis affects not only the joint itself but also the surrounding tissue. The FCF patients were about 20 years older than the osteoarthritic patients and should therefore theoretically have more degenerative findings, but we found the opposite. It is believed that a skewed fibril diameter distribution develops in the aging tendon, with more small and medium-sized fibrils than the normal tendon of an adult person, for example [23;24]. This could be the reason for the difference found in this respect and the tendon in the FCF group was actually normal for the age group.

The histological analysis demonstrated significantly more tendon ruptures with scar tissue, increased amounts of GAGs and calcium deposits in the osteoarthritis group. Furthermore, within the osteoarthritis group, significantly more vascularity and deterioration in fiber structure were found in the scar tissue than in the non-scar tissue. The corresponding finding was not made in the FCF group. These findings and the lack of distinct inflammatory changes as seen in the light microscope therefore indicate that the tendons in the osteoarthritis group have undergone changes similar to those described in tendons in other locations and referred to as tendinosis. It is likely that the tendon pathology increases the symptoms already experienced by os-
To our knowledge, there have been no previous reports on whether the tendinous changes around the hip are a normal pathophysiologic process in conjunction with the osteoarthritis disease, or whether the disease actually starts in the tendon and then proceeds to the joint, in a similar manner to what is known as rotator cuff arthropathy in the shoulder. It is interesting to speculate that, by intervening early in the tendinous disease, it might be possible to reduce the symptoms of osteoarthritis or even slow the process.

Tendon pathology has been studied in various joints and correlated to clinical and radiographic findings [12;25;26]. Others have focused on histological changes in the tendon, especially the patellar, Achilles and rotator cuff tendons [1;6;27;28]. Molloy et al. [4] analyzed the supraspinatus tendon using a microarray and concluded that “glutamate” plays an important role in tendon degeneration.

Lian et al. [8] used antibodies to demonstrate an increase in tendon apoptosis and tendinosis with neo-vascularization, collagen disarray and degeneration, increased amounts of GAGs and the absence of inflammatory cells in athletes with patellar tendinopathy. Scott et al. [29] used caspase-3 activity in an animal model and demonstrated the opportunity to induce apoptosis in the tendon after supraphysiological mechanical loading, but in a later study the same author reported that morphologic changes in the tendon cell in the early phase of tendinosis were not accompanied by apoptosis. However, increased amounts of GAGs appeared to be predominant. Furthermore, the substance IGF-1 appears to modulate a tenocyte response to early-stage tendon overuse injuries [30]. Svensson et al. [28] used the light microscope and reported increased amounts of GAGs, together with an increase in vascularity and collagen fiber disorientation in the patellar tendon, 6 years after harvesting its central third as an autograft during ACL construction.

Lohr and Uhthoff et al. [31] studied the histological section of 18 human supraspinatus tendons with selective vascular injections of silicon-rubber compound enabling the visualization of the vascular bed of the rotator cuff and concluded that the rotator cuff tear starts on the articular side of the tendon, with degenerative changes and insufficient vascularity.

Using histochemical analysis, Hashimoto et al. [2] found calcifications in 19% of 80 ruptured rotator cuff tendons and disorientation of the collagen fibrils in the stump of the torn rotator cuff tendon without distinct inflammatory changes. They suggested that the pathogenesis of the cuff tear is closely associated with age-related degenerative changes in the tendons, followed by microtrauma. These findings are in line with the findings in the present study that degeneration is accompanied by increased amounts of GAGs and a change in tendon morphology and ultrastructure. Movin et al. [1] detected increased amounts of GAGs in achillodynia and suggested that this was a reactive cell response to tendon insult.

Riley [5] stressed the importance of metalloproteinases and other enzymes in tendon healing, as well as the importance of an increased proportion of type III collagen, which reduces the ability of the tendon to resist tension force and thereby predisposes to a rupture of the tendon. Cook et al. [7] demonstrated cellular changes in 18 of 50 biopsies from asymptomatic patellar tendons in athletes, suggesting that the tendinosis process starts with cellular activation and proceeds through phases which increase the ground substance. While studying patients with “trochanteric pain syndrome”, Blankenbaker et al. [26] found that 88% of asymptomatic hips had abnormal findings, with a hyperintensity sign in the trochanteric area, using MRI, and therefore concluded that MRI has a high sensitivity to pathology in conjunction with “trochanteric pain syndrome”. Taken together, there is evidence in the literature of the developments during tendon injury and degeneration. However, there are only a
few studies that focus on pathological changes in the tendons around the hip. Lempainen et al. [9] used histological analysis and found typical morphologic changes of tendinosis in proximal hamstring tendinopathy in athletes with collagen disorientation, increased vascular proliferation, rounding of tenocyte nuclei and increased amounts of ground substance.

To our knowledge, the findings of deterioration in fiber structure and changes in histological structure and ultrastructural appearance in the internal obturator tendon in patients with osteoarthritis of the hip have not previously been reported in the literature. The strengths of the present study include the evaluation of both the histological and ultrastructural appearance and the fact that it was performed on humans. The weaknesses include the limited number of patients and the use of FCF patients as a control group. Due to the difference in age between the study groups, it would have been better to use healthy age-matched controls. However, this was not possible for ethical reasons. The present study can also be regarded as a model for future comparisons of the pathology found in patients with retrotrochanteric pain syndrome and patients with other articular and/or periarticular diseases in the hip region, for example. It is worth to consider that performing e.g. a radiofrequency microtenotomy of the small rotator muscle tendons in the hip region can reduce the symptoms experienced by patients with mild intraarticular degenerative changes; similar to what has been reported for the treatment of lateral epicondylitis [32], patellar [33], and rotator cuff tendinosis [34].

CONCLUSION
In conclusion; tissue samples from the internal obturator tendon in the osteoarthritis group revealed more scar tissue, more GAGs and more precipitated calcium salts in the degenerative tissue, as seen in the light microscope, as well as a change in fibril diameter distribution and more non-collagenous and irregular ECM, compared with the samples from the internal obturator in the FCF group. The hypothesis of the study was thus verified.

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REFERENCE LIST