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HIP

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

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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

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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.

Table 1 The demographics of the patients at inclusion

Patient no.	Gender	Side	Age at inclusion (years)	Duration of symptoms (years)
1	Female	Left	49	2
2	Male	Left	64	3
3	Male	Right	45	8
4	Female	Right	42	10
5	Female	Right	52	20
6	Female	Left	38	10
7	Female	Left	62	9
8	Female	Bilat	25	5
9	Male	Right	43	2
10	Female	Left	43	7
11	Female	Left	59	8
12	Female	Left	66	3
Median (range)			47 (25–66)	7.5 (2–20)

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 thigh in a sitting position (Pace's sign) (Fig. 1), pain and weakness on forced passive internal rotation of the extended thigh (Freiberg's sign) (Fig. 2) 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.

Fig. 1 The Pace's sign. The patient is in the sitting position. During resisted abduction and external rotation of the thigh, the small rotators of the hip are stretched. The test is classified as positive if pain is registered (illustration photograph)

Fig. 2 The Freiberg's sign. The patient is in the supine position with the thigh extended. The leg and thigh are passively internally rotated by the examiner. The test is classified as positive if pain is registered (illustration photograph)

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 rotator*s* 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 scatic 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

Table 2 The radiographic findings before the treatment and 8 years after treatment

Patient no.	Side	Standard radiographs of the hips		MR/CT of the Lumbal/Sacral columna	
		At inclusion	At 8 years	At inclusion	At 8 years
Surgical group					
1	Left	No pathology	Dropped out from study	CT: no pathology	Dropped out from study
2	Left	No pathology	Dead	CT: status post laminectomi L5, hypertophic lig. flavum and narrowing at L5–S1 level on the right side. Degenerative changes L4–5 level	Dead
3	Right	No pathology	No pathology	CT: no pathology	CT: no pathology
4	Right	No pathology	No pathology	CT: minor osteoarthritis of the facet joints at levels L4–5 and L5–S1. No nerve root affection	CT: osteoarthritis of the facet joints at levels L4–5 and L5–S1. No nerve root affections
5	Right	No pathology	No pathology	CT: minor disc herniation at the L5–S1 level without nerve root affection	CT: intervertebral joint arthritis at L3–4 and L4–5 levels. At L3–4 level herniation of the disc with possible affection of the right L4 nerve root
6	Left	No pathology	No pathology	MRI: no pathology	CT: degenerative changes at the L3 level without nerve root affection
Control group					
7	Left	No pathology	No pathology of the hip joint, calcaria at the greater trochanter bilaterally	CT: minor degenerative changes at the L5–S1 levels. No nerve root affections	CT: degenerative changes at the L4–S1 levels, with facet joint osteoarthritis. At the L4 level spinal stenosis without affection of the dura or nerve roots
8	Bilat	No pathology	No pathology	MRI: no pathology	MRI: minor facet joint osteoarthritis, at the L4–S1 levels. No nerve root affections
9	Right	No pathology	No pathology	MRI: degenerative changes at the L2–S1 levels slightly narrow passage for the right L5 root	MRI: spinal stenosis at the L3–4 levels, narrowing of the passages of the right L5 root
10	Left	Calcaria at the right trochanter major, no osteoarthritis	Calcaria at the left trochanter major, no osteoarthritis	MRI: no pathology	MRI: no pathology
11	Left	Calcaria at the trochanter major bilaterally, no pathology of the hip joint	No pathology	CT: no pathology	MRI: degenerative change at the L4 level, minor central disc herniation without nerve root affection
12	Left	Minor calcaria at the right trochanter major, no osteoarthritis of the hip joint	Dropped out from study, because of severe heart disease	CT: facet joint osteoarthritis and status post laminectomi at the L4–5 levels, without nerve root affections	Dropped out from study, because of severe heart disease

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

Table 3 The classification of pain medication

No drugs	0
Paracetamol irregularly	1
Paracetamol/codein or NSAID regularly	2
Paracetamol/codein and NSAID regularly	3
Paracetamol/codein + tramadol or morphine	4

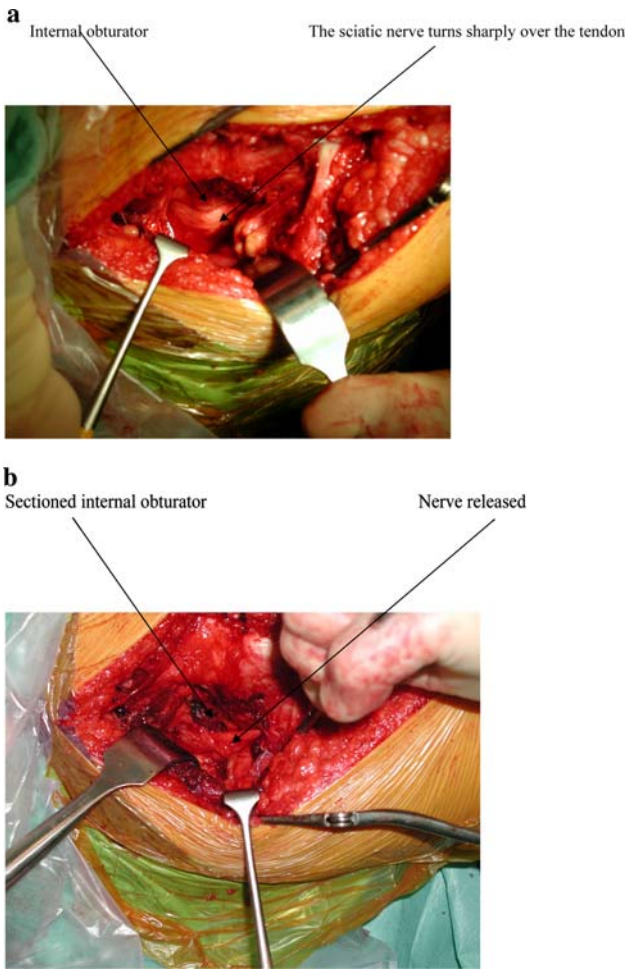

Fig. 3 **a** The sciatic nerve and the internal obturator tendon as found during operation for retro-trochanteric pain syndrome. The internal obturator tendon is tense and hypertrophic, lying in close contact with the sciatic nerve, which turns sharply over the tendon. **b** After sectioning of the internal obturator tendon the sciatic nerve is released from the tendon. Used and modified with permission from IASP® (International Association for the Study of Pain®), originally published by Meknas et al. [13]

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 re-operations 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

Table 4 The clinical examination tests at inclusion, after 6 months and after 8 years

	At inclusion		At 6 months		At 8 years	
	Surgical group ($n = 6$)	Control group ($n = 6$)	Surgical group ($n = 6$)	Control group ($n = 6$)	Surgical group ($n = 4$)	Control group ($n = 5$)
Lasegue (positive)	5/6	5/6	1/6	5/6	1/4	0/5
P-values versus inclusion			0.08 (n.s.)	1.0 (n.s.)	0. 16 (n.s.)	0. 046
Tenderness at palpation	6/6	6/6	6/6	6/6	4/4	5/5
Freiberg's sign positive	6/6	4/6	1/6	4/6	1/4	1/5
P-values versus inclusion			0.03	1.0 (n.s.)	0.08 (n.s.)	0.16 (n.s.)
Pace's sign positive	4/6	4/6	1/6	4/6	3/4	2/5
P-values versus inclusion			0.08 (n.s.)	1.0 (n.s.)	0. 56	n.s.
Walking problems Yes/No	6/6	6/6	3/6	4/6	2/4	3/5
P-values versus inclusion			0.08 (n.s.)	0.16 (n.s.)	0. 16 (n.s.)	0. 16 (n.s.)
Limping Yes/No	5/6	4/6	2/6	4/6	2/4	1/5
P-values versus inclusion			0.08 (n.s.)	1.0 (n.s.)	n.s.	0. 32 (n.s.)
Sitting problems Yes/No	6/6	5/6	4/6	6/6	3/4	4/5
P-values versus inclusion			0.16 (n.s.)	n.s.	n.s.	1.00 (n.s.)

Table 5 The VAS at inclusion, 6 months and 8 year

	Surgical group			Control group		
	At inclusion	At 6 months	At 8 years	At inclusion	At 6 months	At 8 years
Median (range) VAS for pain	8.5 (7–10)	6.5 (0–10)	4 (1–7)	7.5 (4–9)	7 (49)	6 (0–7)
Mean (SD) VAS for pain	8.3 (1.2)	5.5 (3.9)	4.0 (2.6)	6.8 (1.9)	6.5 (1.8)	4.0 (3.2)
P-values versus inclusion		0.10 (n.s.)	0.03		0.81 (n.s.)	0.06 (n.s.)

The VAS for pain was significantly decreased ($P = 0.03$) in the surgical group at 8 years compared with the findings at the time of inclusion. The corresponding was not found in the control group

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 lumbal 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 lumbal columna, and for diagnostic reasons, changes in the lumbal 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].

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

Patient no.	Level of pain medication at inclusion	Level of pain medication at 6 months	Level of pain medication at 8 years	Level of work at inclusion	Level of work at 6 months	Level of work at 8 years
Surgical group						
1	3	3	–	Sick leave	Sick leave	–
2	4	0	–	Retired	Retired	–
3	4	2	3	Sick leave	Sick leave	Sick leave
4	3	1	1	Sick leave	Sick leave	Sick leave
5	3	0	1	Sick leave	Work 50%	Work 50%
6	4	0	0	Sick leave	Full work	Work 50%
Control group						
7	3	3	0	Sick leave	Sick leave	Retired
8	1	1	0	Full work	Full work	Full work
9	4	4	3	Sick leave	Sick leave	Sick leave
10	1	1	2	Full work	Full work	Retired
11	3	2	2	Retired	Retired	Retired
12	2	2	–	Sick leave	Sick leave	–

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.

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References

1. Barton PM (1991) Piriformis syndrome: a rational approach to management. Pain 47:345–352. doi:10.1016/0304-3959(91)90227-O
2. Beauchesne RP, Schutzer SF (1997) Myositis ossificans of the piriformis muscle: an unusual cause of piriformis syndrome. A case report. J Bone Joint Surg Am 79:906–910
3. Benson ER, Schutzer SF (1999) Posttraumatic piriformis syndrome: diagnosis and results of operative treatment. J Bone Joint Surg Am 81:941–949. doi:10.1302/0301-620X.81B6.10474
4. Benzon HT, Katz JA, Benzon HA, Iqbal MS (2003) Piriformis syndrome: anatomic considerations, a new injection technique, and a review of the literature. Anesthesiology 98:1442–1448. doi:10.1097/00000542-200306000-00022
5. Boyajian-O'Neill LA, McClain RL, Coleman MK, Thomas PP (2008) Diagnosis and management of piriformis syndrome: an osteopathic approach. J Am Osteopath Assoc 108:657–664
6. Chen WS (1994) Bipartite piriformis muscle: an unusual cause of sciatic nerve entrapment. Pain 58:269–272. doi:10.1016/0304-3959(94)90208-9
7. Cox JM, Bakkum BW (2005) Possible generators of retrotrochanteric gluteal and thigh pain: the gemelli-obturator internus complex. J Manipul Physiol Ther 28:534–538. doi:10.1016/j.jmpt.2005.07.012
8. Dezawa A, Kusano S, Miki H (2003) Arthroscopic release of the piriformis muscle under local anesthesia for piriformis syndrome. Arthroscopy 19:554–557. doi:10.1053/jars.2003.50158
9. Durrani Z, Winnie AP (1991) Piriformis muscle syndrome: an underdiagnosed cause of sciatica. J Pain Symptom Manage 6:374–379. doi:10.1016/0885-3924(91)90029-4

10. Jankiewicz JJ, Hennrikus WL, Houkom JA (1991) The appearance of the piriformis muscle syndrome in computed tomography and magnetic resonance imaging. A case report and review of the literature. Clin Orthop Relat Res 262:205–209
11. Keskula DR, Tamburello M (1992) Conservative management of piriformis syndrome. J Athl Train 27:102–110
12. Mayrand N, Fortin J, Descarreaux M, Normand MC (2006) Diagnosis and management of posttraumatic piriformis syndrome: a case study. J Manipul Physiol Ther 29:486–491. doi:10.1016/j.jmpt.2006.06.006
13. Meknas K, Christensen A, Johansen O (2003) The internal obturator muscle may cause sciatic pain. Pain 104:375–380. doi:10.1016/S0304-3959(03)00045-9
14. Mullin V, de Rosayro RM (1990) Caudal steroid injection for treatment of piriformis syndrome. Anesth Analg 71:705–707. doi:10.1213/00000539-199012000-00023
15. Pace JB, Nagle D (1976) Piriform syndrome. West J Med 124:435–439
16. Robinson DR (1947) Piriformis syndrome in relation to sciatic pain. Am J Surg 2:255–258
17. Sayson SC, Ducey JP, Maybrey JB, Wesley RL, Vermilion D (1994) Sciatic entrapment neuropathy associated with an anomalous piriformis muscle. Pain 59:149–152. doi:10.1016/0304-3959(94)90060-4
18. Solheim LF, Siewers P, Paus B (1981) The piriformis muscle syndrome. Sciatic nerve entrapment treated with section of the piriformis muscle. Acta Orthop Scand 52:73–75
19. Uchio Y, Nishikawa U, Ochi M, Shu N, Takata K (1998) Bilateral piriformis syndrome after total hip arthroplasty. Arch Orthop Trauma Surg 117:177–179. doi:10.1007/s004020050224
20. Windisch G, Braun EM, Anderhuber F (2007) Piriformis muscle: clinical anatomy and consideration of the piriformis syndrome. Surg Radiol Anat 29:37–45. doi:10.1007/s00276-006-0169-x
21. Yeoman W (1928) The relation of the sacroiliac joint to sciatica. Lancet 2:1119–1122. doi:10.1016/S0140-6736(00)84887-4