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ADDUCTOR LONGUS TENOTOMY IN THE TREATMENT OF GROIN PAIN SYNDROME IN ATHLETES: A SYSTEMATIC REVIEW

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ABSTRACT – *Objective:* The adductor related groin pain syndrome is a common overuse injury in sports which require quick accelerations and decelerations, changes of direction and kicking. If conservative treatment fails, adductor related groin pain syndrome can be surgically treated with adductor longus tenotomy. The purpose of this study was to perform a systematic review of the literature regarding the efficacy of the different types of adductor longus tenotomy available in literature.

Materials and Methods: This systematic review, was conducted in accordance with the PRISMA guidelines. After screening 191 articles, 10 were included and summarized in this study.

Results: Three different types of adductor longus tenotomy were present in the literature. Two over the three types of adductor longus tenotomy described represent a potential solution that offers athletes good prospects and a relatively quick return to sporting activity. However, one of the three types of partial tenotomy described presents a high rate of complications.

Conclusions: The adductor longus tenotomy is a valid solution in case of failure of conservative treatment. However, one of three types of tenotomy described is not recommendable until further studies completely clarify the issue of its possible complications.

KEYWORDS: Adductor related groin pain, Groin pain syndrome, Adductor tendinopathy, Surgery.

INTRODUCTION

Groin pain syndrome (GPS) is an important and frequent clinical condition both in professional and amateur athletes, particularly in sports that require quick accelerations and decelerations, changes of direction and/or kicking[1,2]. GPS is frequently associated with major time loss from sporting activity and sometimes can even be a career-ending injury[3]. In some sporting activities, like football (soccer), adductor-related GPS is one of the most common occurrences[4]. In the "Groin Pain Syndrome Italian Consensus Conference"[3] adductor-related GPS is included in category IV (i.e., musculo-tendinous causes), while in the "Doha agreement meeting on terminology and definitions in groin pain in athletes"[5] it is included in category III (i.e., adductor-related, iliopsoas-related, inguinal-related and pubic-related groin pain). The adductor longus tendon (AL) is generally the most affected structure in GPS[6,7]. Unfortunately, conservative programmes for severe chronic AL tendinopathy generally have low success rates[8-11]. For this reason, a surgical solution is often considered. In current literature, three types of AL tenotomy are substantially described: one type of total- and two types of partial-tenotomy[12,13]. However, to date, AL tenotomy seems to have resulted in mixed and unpredictable outcomes in all techniques considered[11]. The aim of the current systematic review is to analyze the outcomes of partial and total AL tenotomy in adductor-related GPS, performed on athletic populations suffering from adductor-related GPS.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines[14]. The protocol of this study was registered at the PROSPERO register for systematic reviews (number CRD42018091020).

Data Extraction and Quality Assessment

Prior to this systematic review the Cochrane Database of Systematic Reviews, MEDLINE and PEDro were consulted for systematic reviews on the comparison of different surgical techniques of AL tenotomy, in order to ensure that similar systematic reviews were not already present in literature. After this verification, two authors (BGN and ZV) independently screened the literature using a string of keywords: "adductor-related groin pain", "adductor tendinopathy", "tenotomy", "groin pain syndrome", "pubalgia", "Gilmore's groin", "groin disruption", "inguinal disruption", "sportsman's groin" and "sport hernia", fittingly connected by Boolean operators. When appropriate, medical subject headings (MeSH) and wildcard options were used. Furthermore, target journals were reviewed, in order to increase the possibility of collecting all the relevant articles. The research was conducted on 2 December 2018. Neither data restriction nor language limitation were applied. "Grey literature" (i.e., conference, abstracts, thesis and unpublished reports) was not taken into consideration. Cross-references from the selected articles were screened to verify their possible relevance. All double citations were removed. For each article, the relevant information was extracted and recorded on an ad hoc Excel spreadsheet. The details of the search strategy are shown in Table 1, while the PRISMA flow diagram of the study search and selection procedure is shown in Figure 1. The Methodological Index for Non-Randomized Studies (MINORS)[15] was used to assess the quality of each individual study considered.

Data Extraction, Synthesis and Analysis

Two authors (GNB and ZV) extracted the following data in a standardized form from studies that proved relevant:

I Study design;
II Level of evidence;
III Participants;
IV Study setting (sport type, level, gender, age);
V Diagnosis;
VI Type of surgical treatment;
VII Time loss injury;
VIII Follow-up;
IX Outcome;
X Complications.

Table 1. Search strategy used in the study.

Search strategy items	Details
Searched databases	PubMed/MEDLINE, Scopus, ISI, EXCERPTA MEDICA.
Searched string	(tenotomy) AND (adductor-related groin pain) AND (adductor tendinopathy) AND (groin pain syndrome OR pubalgia OR Gilmore's groin OR Gilmore's groin OR inguinal disruption OR sportsman's groin OR sport hernia).
Inclusion criteria	**P**: Articles investigating adductor tenotomy performed on an athletic population suffering adductor-related GPS. **I**: complete and partial tenotomy **C**: comparison of the outcome between the two different considered technical surgery **O**: level of post-surgery satisfaction, return to sport activity.
Exclusion criteria	**P**: Articles investigating adductor tenotomy performed for clinical frameworks other than adductor-related GPS (i.e. cerebral palsy, management of coxa vara, developmental hip dislocation etc). **I**: Articles in which the tenotomy was coupled with another surgical intervention (i.e. hernia repair) **C**: Articles that did not give enough data to allow comparison between total and partial tenotomy. **O**: Articles not focused on surgical intervention for adductor-related GPS.
Time filter	None set
Language filter	None set
Target journals	All the peer-review and indexed journal present in the considered database.

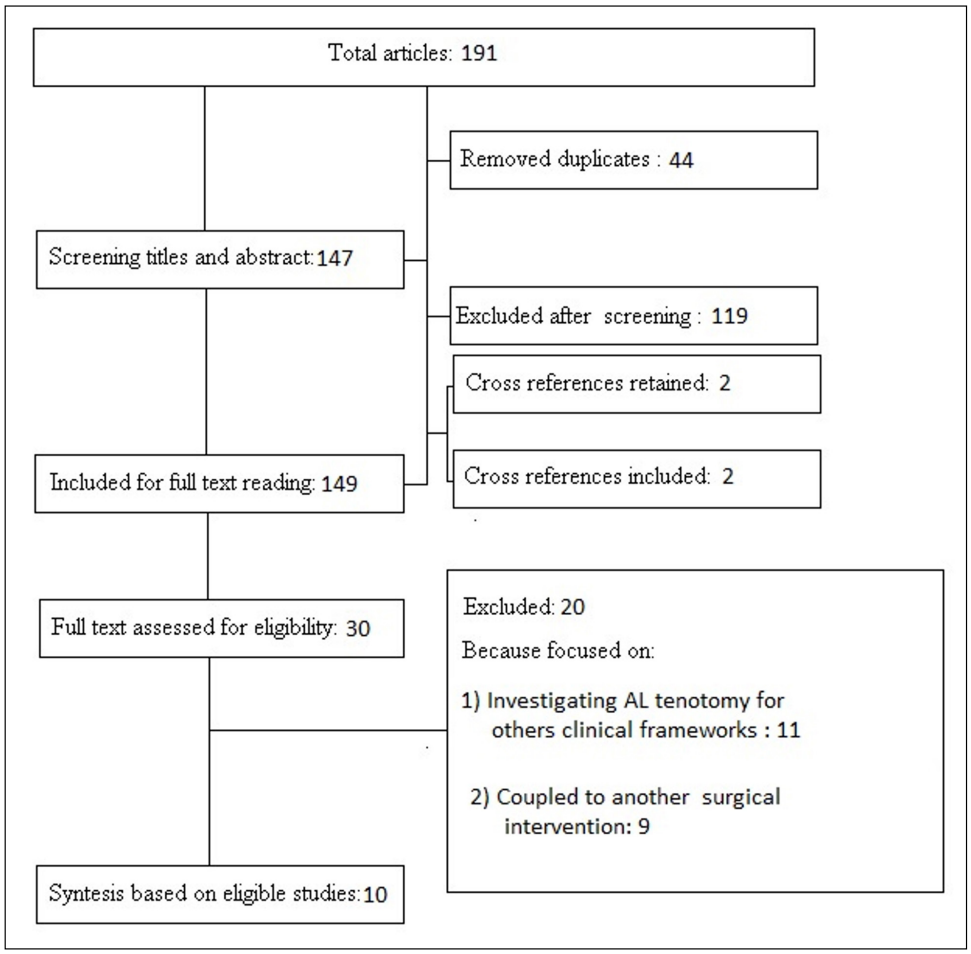

Figure 1. PRISMA flow diagram of the study search and selection procedure.

Statistical Analysis

For the data on time loss injury, descriptive standard statistical indices (average ± standard deviation) were calculated. Data were analyzed and, when possible, were treated statistically for a quantitative analysis. The effect size was computed based on the summary data provided for comparing two groups using a two-sample *t*-test. Frequency and percentage were used to describe the categorical outcomes, such as overall complications, complications due to a revision of AL tenotomy and return to sports activity. The categorical outcomes were compared with PT1, PT2 and TT to determine any statistical association using the Chi-square test. The statistical difference was set at $p<0.05$.

RESULTS

After screening 191 articles, 10 were included and summarized in this current systematic review. The characteristics of the studies considered are shown in **Supplementary Table 1**. All studies were checked to identify any potential conflicts of interest. The quality appraisal of individual studies evaluated with MINORS criteria is shown in Table 2. The average score of the quality appraisal calculated with MINORS criteria was equal to 11.55±2.1 (over a maximum score of 16).

Table 2. Quality appraisal of individual studies evaluated with MINORS criteria.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total	Q9	Q10	Q11	Q12	Total
Akermark and Johansson[12]	2	2	2	1	0	2	2	0	**11**					
Atkinson et al[20]	2	2	1	1	0	2	2	1	**11**					
Dojčinović et al[6]	2	2	1	1	1	2	2	1	**12**					
Maffulli et al[17]	2	2	1	1	1	2	2	1	**12**					
Mei-Dan et al[10]	1	1	0	2	0	0	2	1		2	0	2	2	**13**
Sansone et al[21]	2	2	1	1	1	2	2	2	**13**					
Schilders et al[11]	2	2	2	2	0	2	2	2	**14**					
Robertson et al[16]	2	2	2	2	0	2	2	2	**14**					
Garvey and Hazard[19]	1	1	1	1	0	2	0	1	**7**					
De Queiroz et al[18]	1	2	1	1	0	2	2	1	**10**					

Maximum score for non-randomized studies is 16, maximum score for randomized studies is 24.
The scores are: 0 - not reported, 1 - reported but inadequate, 2 - reported and adequate.

Study Design

Among the selected articles, one[10] was a case-control study (Level of evidence: III), five[11,16-19] were case series (Level of evidence: IV), two[12,20] were observational cross-sectional studies (Level of evidence: IV), one[21] was a retrospective case series (Level of evidence: IV) and one[6] was an observational prospective study (Level of evidence: IV).

Participants and Study Setting

In the different studies, a total of 411 subjects were considered in the study groups (SG) and 59 subjects in the control groups (CG) (467 men and 3 women in total), whose average age was 27.5±3.9 years (range 13-56 years). With reference to the sports activities, 239 subjects (58.2%) practiced soccer, 74 (18.0%) Gaelic football, 31 (7.5%) Australian football, 15 (3.6%) hurling, 9 (2.2%) rugby, 8 (1.9%) hockey, 6 (1.5%) athletics, six (1.5%) martial arts, 5 (1.2%) cricket, 5 (1.2%) tennis and racket sports, 3 (0.7%) indoor soccer, 2 (0.5%) orienteering, 1 (0.2%) bandy, 1 (0.2%) basketball, 1 (0.2%) cross country skiing, 1 (0.2%) handball, 1 (0.2%) lacrosse, 1 (0.2%) swimming, 1 (0.2%) triathlon and 1 (0.2%) weight lifting. Among the subjects considered, 393 (95.6%) played field-based ball sports.

The terminology used for the classification of the sport level practiced by the subjects was rather heterogeneous and confusing, since 73 (17.8%) subjects were classified as professionals, 16 (3.9%) as competitive athletes, 112 (22.2%) as amateurs, 133 (32.4%) without a distinction between categories, and 77 (18.7%) were not classified at all.

Diagnosis

In four studies[11,16,18,19] (40%), the diagnosis of inclusion was "chronic adductor dysfunction/tendinopathy" and in the other six studies[6,10,12,17,20,21] (60%) it was "chronic/recalcitrant/long standing GPS".

Types of Surgical Treatment

In six studies[6,10,12,17,20,21] (60% of the studies comprising 226 subjects, 55% of all the considered subjects), the patients underwent AL total tenotomy (TT). Among all patients subjected to total tenotomy, 16 (7.1%) subjects underwent a unilateral tenotomy of the affected side only, while 162 (71.7%) subjects underwent a bilateral tenotomy and for the remaining 48 (21.2%) subjects, this information was not reported.

In four studies[11,16,18,19] (40% of the studies comprising 185 subjects, 45% of all the considered subjects), the patients underwent a partial tenotomy of the AL. Among all patients subjected to partial tenotomy, 142 (76.7%) had unilateral tenotomy at the affected side only, 40 (21.6%) subjects underwent bilateral tenotomy and for the remaining three (1.6%) subjects this information was not reported. In the studies in question, partial tenotomy (PT) was performed with two different surgical techniques called PT1 and PT2, respectively (described in the details under).

Types of Rehabilitation

In seven studies[6,10,11,17,18,20,21] (70%) the rehabilitation programme was based on early stretching avoiding hip adduction, and in the remaining three studies[12,16,19] (30%) the rehabilitation program was not specified.

Follow-Up

The average of follow-up in the 10 studies was 29.0±38.8 months (range 0.5-300).

Time Loss Injury

Time loss injury, i.e., the time necessary for full recovery and therefore missed in training and competition, was on average 13.1±3.1 weeks. In two studies[19,21], the time loss injury value was not reported.

Time loss value for TT, PT1 and PT2 groups was equal to 12.9±3.3, 9.2±4.6 and 15.5±7.1 weeks, respectively.

Outcome

As with the terminology used for the classification of the practiced sport level, there was an excessive heterogeneity in the terms used for classifying outcome.

Indeed, 207 subjects (50.4%) judged the outcome as "excellent", 84 (20.4%) as "good", 110 (26.8%) as "improved", 3 (0.73%) as "fair" and seven (1.70%) as "deterioration" compared to pre-surgery.

Complications

Complications occurred in 26 patients (6.3% of the total patients) for whom: 11 patients (42.3%) underwent a revision of AL tenotomy, four (15.4%) suffered of dysuria, three (11.5%) had superficial wound infection, two (7.7%) had sub-cutaneous hematoma, two (7.7%) complained of unilateral adduction weak-

ness, one (3.8%) had persistent pain for two months post-surgery, one (3.8%) complained of numbness around the wound, one (3.8%) presented a painful scar and one (3.8%) reported painful intercourse.

The percentage of complications for PT1, PT2 and TT groups are subdivided in 2 sub-groups: 1) overall complications and 2) complications due to revision of AL tenotomy.

Results of Statistical Analysis

The time loss injury value for PT1, PT2 and TT groups was of 9.2±4.6, 15.5±7.7 and 12.9±3.3 weeks, respectively. The statistical significance of the difference in the average is shown in Figure 2.

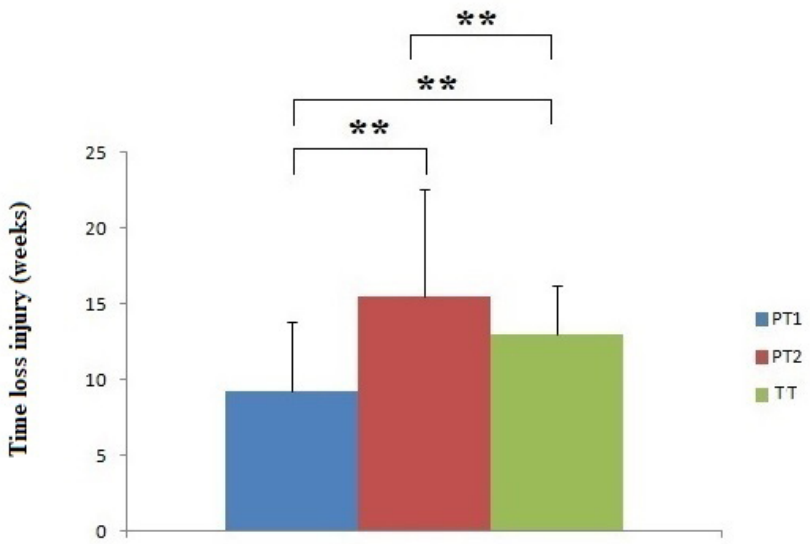

Figure 2. The statistical significance of the difference in the average concerning the time loss injury for PT1, PT2 and TT. (**): $p<0.001$.

The percentages of overall complications for PT1, PT2 and TT groups were of 33±46.7%, 8.0±7.5% and 9.5±8.3%, respectively. The statistical significance of the difference in the average is shown in Figure 3.

The percentages of complications due to a revision of AL tenotomy for PT1, PT2 and TT groups were of 33±46.7%, 1.4±1.9 and 0.7±1.0%, respectively. The statistical significance of the difference in the average is shown in Figure 4.

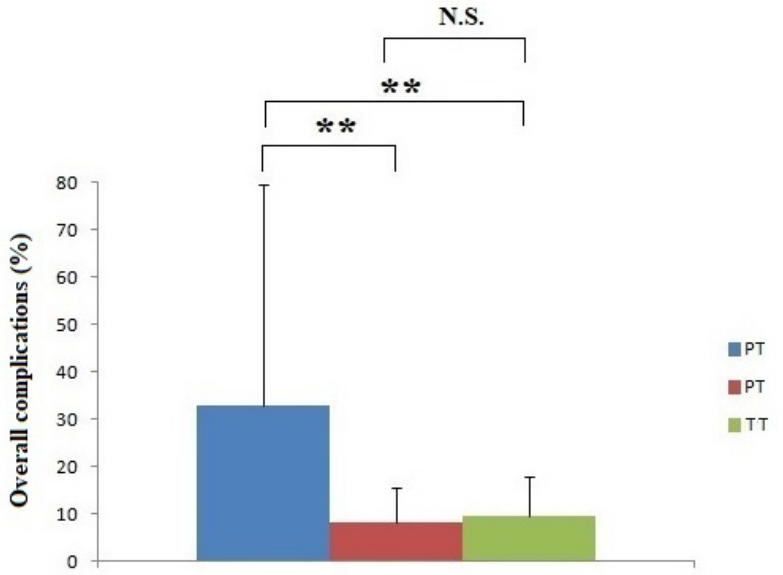

Figure 3. The statistical significance of the difference in the average concerning the percentage of overall complications for PT1, PT2 and TT. (**): $p<0.001$; N.S.: not significant.

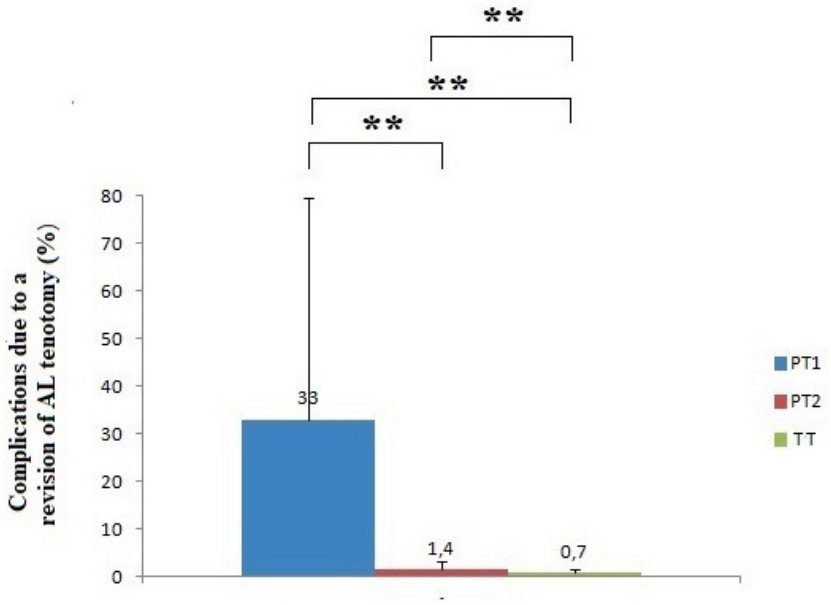

Figure 4. The statistical significance of the difference in the average concerning the percentage of complications due to a revision of AL tenotomy for PT1, PT2 and TT. (**): $p<0.001$.

The PT1, PT2 and TT interventions were associated with an improvement in symptoms and a return to sporting activity in 98.8±1.6%, 95.5±6.4% and 88.2±8.6% of the cases. The statistical significance of the difference in the average is shown in Figure 5.

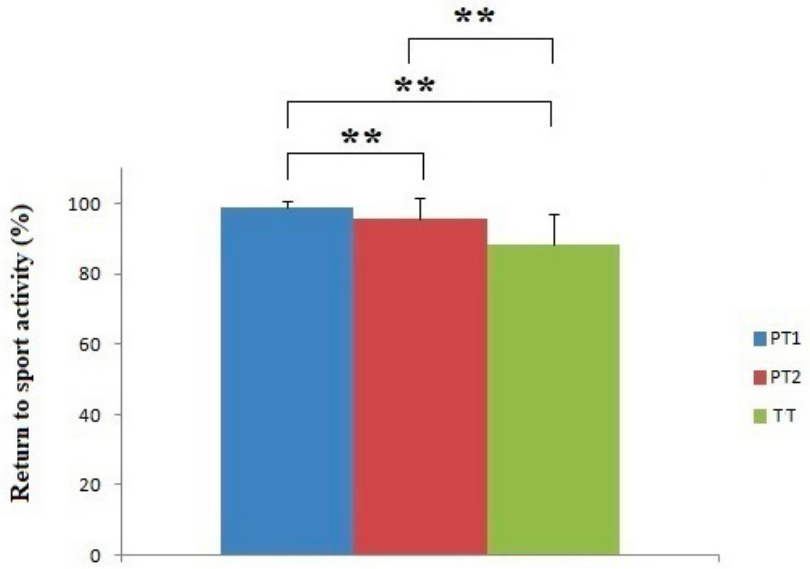

Figure 5. The statistical significance of the difference in the average concerning the percentage of return to sport activity values for PT1, PT2 and TT. (**): $p<0.001$.

DISCUSSION

The AL arises as a flat and narrow tendon from the anterior surface of the pubic bone, medial to the pubic tubercle and is distally inserted on the aponeurosis into the linea aspera of the femur[22]. Proximally, it presents a poorly vascularized fibrocartilaginous enthesis[23,24]. It is innervated by the obturator nerve. Several anatomical studies show that the AL anterior origin is tendinous, while the posterior origin is muscular[24-26]. Indeed, at its origin, AL is composed of ~38% tendon and ~62% muscle tissue. About ~1.0 cm from the origin, the tendon percentage is ~34%, while at ~2.0 cm from the origin the tendon represents ~27% of the total cross section[25] (Figure 6). AL is the muscle belonging to the adductor mus-

cle complex most often implicated in the adductor-related GPS[3,5,27]. It has been hypothesized that AL's strong involvement in the adductor-related GPS etiology may be referred both to its poor entheseal blood supply[24] and by the fact that AL proximal insertion undergoes strong mechanical stress during the transmission of the force generated by muscle contraction[22,28].

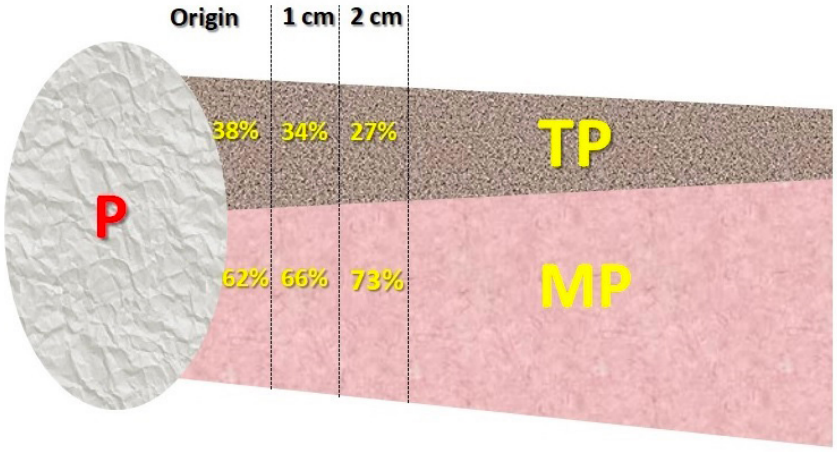

Figure 6. AL sagittal schematic view. At its origin AL is composed of ~38% tendon and ~62% muscle tissue. At ~1.0 cm from the origin, the tendon percentage is ~34% and muscle tissue ~66% while at ~2.0 cm from the origin, the tendon represents ~27% and the muscle tissue ~73%. P: pubis bone; TP: tendinous part; M: muscle part.

AL tenotomy was described for the first time by Akermark and Johansson[12] for cases of chronic adductor-related GPS, at the 1981 AOSSM annual meeting. AL tenotomy can be performed in cases of chronic adductor-related GPS, refractory to conservative treatments, in young and athletic populations playing field-based ball sports[2,29,30].

Three different adductor tenotomy techniques are described in literature:

AL Partial Tenotomy (PT1 Technique)

This type of AL partial tenotomy (PT1) is performed under general anesthesia following antibiotic prophylaxis. The patient is positioned in a so-called "frog-leg position". A transverse incision is made below the scrotum and the AL fascia is divided to identify the AL tendon. The procedure continues with a tenotomy (performed 2-4-cm from the tendon origin) (Figure 7) of the anterior tendinous fibres[19,31,32].

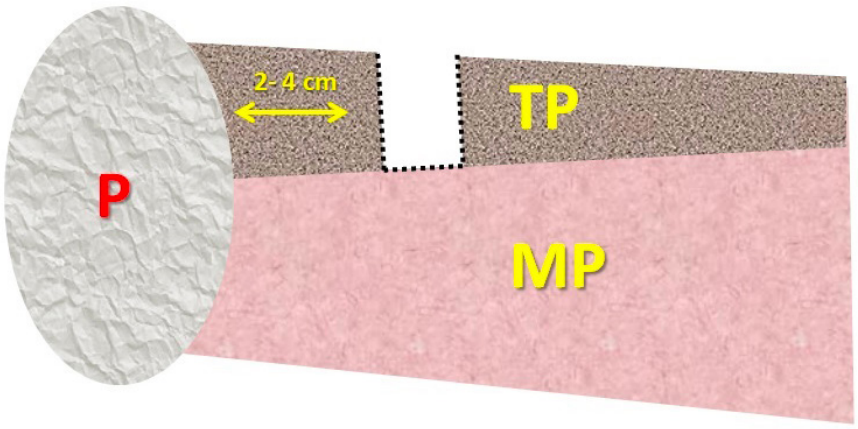

Figure 7. Sagittal schematic view of the PT1 technique. In the PT1, the partial tenotomy is performed 2–4 cm from the tendon origin on the superficial fibers of the tendon. The AL direct muscular attachments to the pubis are left intact. P: pubis bone; TP: tendinous part; M: muscle part.

The AL direct muscular attachments to the pubis are left intact[33]. Once the tenotomy is completed, the wound is sutured after accurate hemostasis. After surgery, a compressive bandage is applied. The patients may leave the hospital either the same day or the day after surgery. The compressive bandage is generally removed 2 days after the operation.

AL Partial Tenotomy (PT2 Technique)

In this variant of AL partial tenotomy (PT2)[16,34], the AL tendon release is performed just below the pelvic attachment. The remaining part of the surgical procedure corresponds to that previously described (Figure 8).

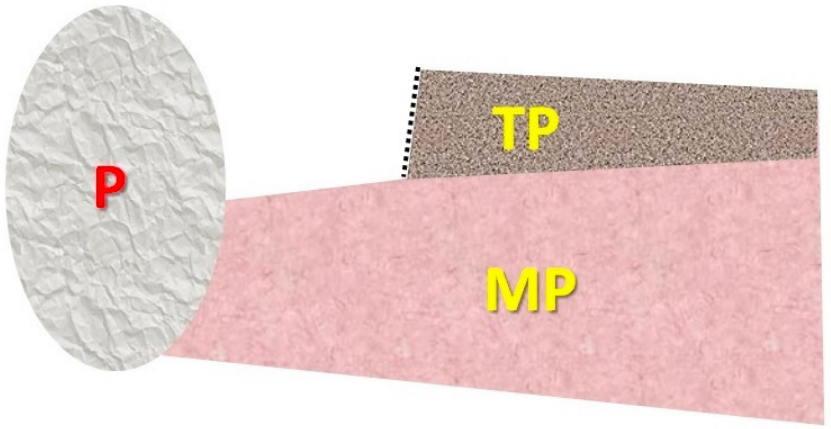

Figure 8. Oblique sagittal schematic view of the PT2 technique. In the PT2, the tenotomy is performed just below the pelvic attachment. As in PT1, the AL direct muscular attachments to the pubis are left intact.
P: pubis bone; TP: tendinous part; M: muscle part.

AL Total Tenotomy

In the AL total tenotomy (TT) technique, both the tendon and the direct muscle attachment are fully released from their pubic attachment, about 2 cm distal to its origin. The muscular fascia attaching the AL directly to the pubis is then released. Finally, the freed tendon and muscular stump are then manually displaced approximately 5 cm distally to prevent its reattachment[7,35] (Figure 9).

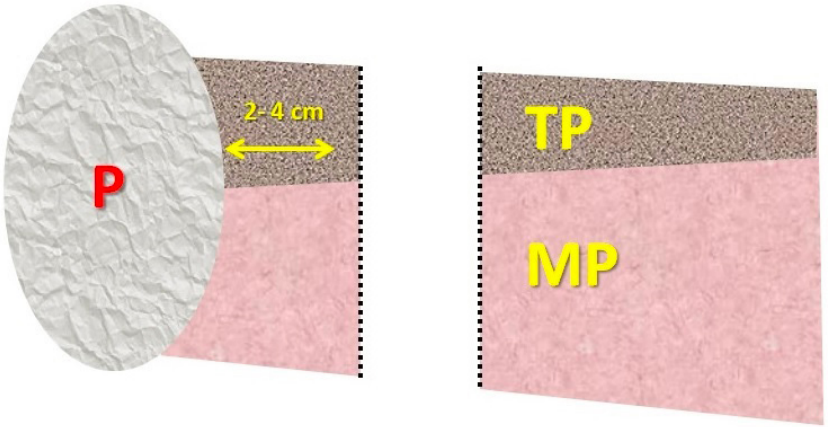

Figure 9. Sagittal schematic view of the TT technique. In the TT technique the AL tendon and the AL direct muscular attachments to the pubis are fully released at about 2 cm distally from their origin The released tendon and muscle attachment are then pushed down about 4-5 cm to prevent reattachment.
P: pubis bone; TP: tendinous part; M: muscle part.

In the studies considered in this systematic review, PT1 was investigated in 2 studies[11,19], PT2 in 2 studies[16,18] and TT in 6 studies[6,10,12,17,20,21].

The justification for an AL PT (both PT1 and PT2) is that the superficial tendon fibers of the AL tendon are subjected to a relatively greater tensile load in comparison to the direct muscle attachment fibers[11]. Furthermore, since the AL tendon/muscle ratio decreases in a proximal to distal direction[25], in performing a more distal release (2-4 cm from the tendon origin), a greater proportion of the AL muscle fibers is preserved[11].

We must remember that some authors justify the AL PT both with the "compression theory"[36] and the "stress shielding theory"[31]. The theory behind both the compression and the stress shielding theory for insertional tendinopathy is that the superficial portion of the tendon insertion undergoes greater tension than the deeper portion. Some histological studies[36] show that in tendinopathy the pathological part of the insertional tendon is the deeper portion, whilst the superficial insertional portion usually remains unaffected. The stress shielding-theory explains this situation by sustaining that the process of tendinopathy arises through a combination of overuse-underuse in which the superficial portion of the tendon bears the maximum tensile force, whilst the deeper portion is under-stimulated. This under stimulation may induce important biological changes in the tendon leading to the condition of tendinopathy[31] very similar to that observed in a tendon suffering from compression, for example the rotator cuff tendons affected by tendinopathy[36]. However, the "stress shielding theory" applied to adductor-related GPS[31] is very open to criticism: in taking into account the particular anatomy of the proximal attachment of the AL[24-26] and in considering the anatomical situation described by the above-mentioned studies, it would be more correct to affirm that, in releasing the tendon fibers, the AL PT1 and PT2 surgical techniques may well be responsible for transferring the tensile forces from the anterior, superficial, tendinous portion of the AL to its deeper muscular portion directly attached to the pubis.

However, the AL shows many anatomical variations[24-26] that must be taken into account when choosing the appropriate surgical technique[12,20]. Furthermore, it is important to note that TT does not involve any loss of muscle strength and power production in the lower limb[8,20]. In fact, the AL loss of strength and power production may be compensated by an increased strength and power production of the agonistic adductor muscles[12,37,38].

In all 3 techniques investigated, the most worrying and widespread complication seems to be the need to repeat the AL tenotomy. Indeed, AL tenotomy revision accounts for 100%, 17.5% and 7.3% of all recorded complications associated with the PT1, PT2 and TT surgical techniques respectively.

A revision of AL tenotomy may be necessary whenever the proximal part of the adductor longus tendon is left either intentionally rather long (as in PT1 technique)[19] or it has remained long due to a surgical error[16,20,21,32]. Indeed, a too-long tendon stump can give rise to regrowth and to the formation of a scar area that may become the anatomical location of re-injury[16,20,21,32,39-41]. The need to prevent the regrowth of the tendon stump is also confirmed by the fact that, in seven studies (70%), the rehabilitation programme was based on early stretching exercises in order to avoid the bridging of the two severed tendon stumps[6,10,17,18-21]. It should be noted that in PT1 intervention, 33±46.7% of the patients displayed recurrent AL tendinopathy due to regrowth of the tendon stumps, for which a revision of tenotomy was necessary. On the contrary, this complication arose in only 1.4±1.9% (p<0.001; CI=95%) of patients undergoing PT2 intervention and in 0.7±1.0% (p<0.001¸ CI=95%) of patients undergoing TT intervention; both of which are significantly much lower than the PT1 relapse.

Statistical analysis showed that the PT1 intervention resulted in the lowest time loss. This apparent paradox can be explained by two factors. The first is represented by the fact that PT1 is less invasive than the PT2 and TT interventions from a surgical point of view and, as a result, it allows for a quicker return-to-play. However, this prompt return-to-play is in conflict with the higher number of tenotomy revisions required in comparison to PT1 (p<0.001; CI=95%) and TT interventions (p<0.001; CI=95%). This could be because the decision to intervene with a second tenotomy is taken in the long run, a long time after the return-to-play[20,16,19,21]. In other words, PT1 intervention allows for a quicker return-to-play but is related to a higher risk of AL tenotomy revision, probably due to the excessive proximity of the two stumps of the severed tendon, which could favor their reattachment. As already mentioned, this "bridge of scar tissue" represents a weak spot where injuries can easily reoccur[16,20,21,32]. It is important to underline that the apparently most appealing technique, with speedy return-to-play, actually results to be less efficient in the long run. This must be taken into account when explaining surgical outcomes to high-profile athletes and their coaches, who often focus on the short-term return-to-play.

Comparing PT2 and TT interventions, the main points to underline are:

– In PT2 and TT groups, there is no statistical difference between the overall complications (8.0±7.5% *vs.* 9.5±8.3%), whilst the complications due to AL tenotomy revision are lower in TT group (0.7±1.0% *vs.* 1.4±1.9%, p<0.001; CI=95%).

– PT2 intervention allows for a greater outcome of return-to-play than TT (95.5±6.3% *vs.* 88.2±8.6%, $p<0.001$; CI=95%).

Here, in the light of the data analyzed in literature, PT2 and TT seem to be the most favorable interventions. Indeed, both allow for a substantial return-to-play and a low incidence of complications (risk for the patient to undergo a tenotomy revision). In any case, the PT1 intervention should be discouraged, due to the high number of complications involving tenotomy revisions.

Limitations of the Study and Further Developments

The most important limitations of this study are:

– More data (currently not present in literature due to the lack of pertinent studies) are needed to establish the clear correlation between tendon-stump re-growth and the PT1 surgical technique. Furthermore, additional in-depth investigations are necessary to establish the complications linked to the PT1 technique.
– The heterogeneity of the terms used to verify the outcome in the various studies makes a rational comparison relatively difficult to compile and not thoroughly objective.

CONCLUSIONS

AL tenotomy performed by PT2 and TT interventions are reliable techniques in the field of adductor-related GPS which allow a high percentage of athletes to return to sporting activities in a relatively short period of time. On the contrary, PT1 is not recommended, despite the relatively quick return to play, as it is associated with numerous complications.

Conflict of Interest:
The Authors declare no conflict of interest.

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Availability of Data and Materials:
The data presented in this work is available upon request from the corresponding author.

Informed Consent:
Not required by the nature of the study.

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