The increase of anterior pelvic tilt after semitendinosus transfer to distal femur in patients with spastic diplegic cerebral palsy

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The aim of this study was to compare semitendinosus transfer to distal femur (STTX) to semitendinosus surgical lengthening (STL) regarding the increase of anterior pelvic tilt after flexed knee gait treatment. Thirty-nine patients were evaluated, and they were divided according surgical procedures at knees: STL group (22 patients/44 knees), which included patients who received medial hamstrings surgical lengthening as part of multilevel approach, and STTX group (17 patients/34 knees), which was represented by patients who underwent orthopedic surgery including a STTX instead of STL. In the present study, the mean anterior pelvic tilt increased in all groups after treatment and STTX was not effective to prevent it in a medium-term follow-up. ***J Pediatr Orthop B*** **28:327–331 Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.**

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Introduction

The knee flexion deformity (KFD) is frequently observed in patients with spastic cerebral palsy (CP), and it can compromise standing and gait [1]. The spasticity and progressive contracture of hamstrings are one of the causes of KFD and crouch gait in CP [2,3].

Consequently, surgical lengthening of the hamstrings is the present standard procedure for correction of KFD in CP, with satisfactory short-term outcomes. However, previous reports showed deterioration of the results in a long-term follow-up, and resultantly, the weakness of hamstrings as hip extensors was implicated in it [2].

In addition to this, Zwick *et al.* [4] described in 2002 an increase of anterior pelvic tilt (APT) after this procedure, as a result of the loss of hip extensors strength. Moreover, hamstrings' weakness has been considered a potential cause of the increase in APT by many authors [5–8].

Ma *et al.* [9] described the semitendinosus transfer to distal femur (STTX) to preserve hip extensor power and to avoid the increase of APT after correction of KFD in CP. They reported an improvement of knee extension in the stance after STTX, with no deterioration of APT, in a case series composed of 19 patients with CP. Nevertheless, the comparison between STTX and semitendinosus surgical lengthening (STL) was not performed.

Thus, the purpose of this study was to compare STTX and STL regarding the increase of APT after flexed knee gait treatment in patients with CP. The study hypothesis was based at the assumption that STTX was effective to prevent the increase of APT after KFD correction in CP.

Materials and methods

This was a retrospective cohort study approved by the local ethic committee. All candidates for orthopedic surgery for walking improvement were analyzed previously in the gait laboratory, and the combination of mild fixed knee flexion (< 15°) and the increase of knee flexion in stance phase (>10°) was an indication for KFD correction using soft tissue procedures in our hospital. The definition of minimum knee flexion in stance phase higher than 10° as an inclusion criterion was based on our gait laboratory normal database, and it represents a value higher than normal mean plus one SD.

According to our treatment protocol in Cerebral Palsy Clinic, the STL and STTX were both part of soft tissue procedures which could be used in this scenario, and the choice of surgical technique (STL or STTX) was defined by surgeons, according their preference and background.

Two surgeons from our hospital have performed systematically STL instead of STTX because they consider it a faster and less demanding procedure and they believed that postoperative results were similar despite the technique applied. On the contrary, two other surgeons, also from our hospital, have used STTX based on the hypothesis that this procedure could preserve some power of hip extensors. Based on the fact that these four surgeons have not changed their soft tissue approach for correction of mild KFD during

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the last 15 years, we enrolled in the study only patients treated by them.

A search was done at CP clinic database considering the following inclusion criteria: (a) diagnosis of spastic diplegic CP without previous hamstrings surgical lengthening (HSL), (b) GMFCS levels I–III, (c) fixed knee flexion deformity (FKFD) lower than 15° in the preoperative physical examination, (d) minimum knee flexion in stance phase (MKFS) greater than 10° in the preoperative gait analysis, (e) patients undergoing gracilis and semimembranosus surgical lengthening with concomitant STTX or STL bilaterally, and (f) preoperative and postoperative gait analyses with minimum follow-up time of 12 months.

We also decided to not include in the study patients with previous HSL because the soft tissue scar and fibrosis could compromise the STTX. In addition to this, Chang *et al.* [10] and Rethlefsen *et al.* [11] observed that primary and repeated HSL do not have similar outcomes. The revision of HSL was related to modest improvement of knee extension in stance phase and increase of APT.

A total of 39 patients fulfilled the inclusion criteria, and they were divided in two groups according to procedures performed at knees: STL group (22 patients/44 knees), which included patients who received STL combined to gracilis and semimembranosus surgical lengthening (procedures performed by team A) and STTX group (17 patients/34 knees), which was represented by patients who underwent orthopedic surgery including a STTX instead of STL (procedures performed by team B).

Surgical procedures were performed with patients in prone position. Patients from STL group received an intramuscular tenotomy at gracilis, a Z lengthening at semitendinosus, and fractional lengthening at semimembranosus. The approach in STTX group was similar to STL group regarding gracilis and semimembranosus; however, the semitendinosus was transferred to adductor tubercle at distal femur. STTX was carried out after the release of semitendinosus close to its insertion at tibia and the mobilization of it proximally. The insertion of adductor magnus at distal femur was identified by palpation. A right-angle clamp was used to pass the distal extremity of the released semitendinosus under the insertion of adductor magnus at adductor tubercle, and number 1 Ethibond (Ethicon Inc., Sumerville, New Jersey, USA) sutures were applied under slight tension. The semitendinosus was sutured to adductors magnus tendon and to itself.

The postoperative protocol was the same for the two groups that underwent hamstring surgery. After intervention, a long leg cast was used for 4 weeks to keep the knees in full extension during soft tissues healing. Subsequently, knee immobilizers were prescribed for night use for 12 months. The rehabilitation started after cast removal, and patients were discharged when they have attained functional and independence level as present before surgical intervention.

Clinical assessments included examination of lower limb passive joint range of motion using a calibrated goniometer. All of the patients were evaluated by a senior physical therapist and a pediatric orthopaedic surgeon, who both had more than 10 years of experience in gait analysis and management of neuromuscular conditions.

Kinematic data had previously been collected using reflective markers that are strategically placed on specific anatomical landmarks on each participant, as described by Kabada *et al.* [12]. An eight-camera Qualisys OQUS 300 system (Qualisys, Göteborg, Sweden) (500 Hz) was used for movement capture. Patients were instructed to walk barefooted in a self-selected speed through an 8 m walkway (26 feet). A minimum of six gait cycles for each assessed lower limb were collected to analyze walking variability during data collection. If the trials collected were consistent and with the same pattern, a mean of these gait cycles was obtained for analysis. In the present study, significant variability among gait cycles collected in each patient was not observed. As a consequence of it, the trial selected for analysis was the mean of collected trials. The data were processed using the software Vicon Clinical Manager (Oxford Metrics, Oxford, UK), according to the technique described by Davis [13].

Demographic, clinical, and dynamic parameters were analyzed, and the results were compared between the groups, before and after intervention. For comparison of age at surgery, follow-up time, and clinical and kinematic data among groups, the analysis of variance was applied. Two proportions equality test was used to compare the sex and GMFCS level distributions, and the surgical procedures performed at the same session of KFD correction. The paired Student *t*-test was used for the comparison of preoperative and postoperative analyses within groups. The level of significance was set at P value less than 0.05 for all statistical tests [14].

Results

Demographic data are presented in Table 1. Sex distribution, age at surgery, and follow-up time were comparable in STL and STTX groups. GMFCS level III patients were more frequent ($P=0.016$) in STTX (70.6%) than STL group (31.8%).

Table 1 shows the surgical correction of KFD using STL or STTX was performed concomitantly with other procedures in all patients, except in six lower limbs (13.6%) from STL group.

During analysis of the clinical parameters, we observed that unilateral and bilateral popliteal angle showed significant decrease in STL and TXST groups after surgery. The decrease of FKFD was observed only in STTX group after intervention (Table 2).

At kinematics, the APT increased from 15.3° to 18.9° in STL group ($P=0.008$) and from 14.5° to 19.3° ($P=0.006$) in STTX group. The reduction of MKFS (from 34.26° to 20.23°, $P<0.001$) was observed only in STTX group (Table 3).

Table 1 Demographic data in semitendinosus surgical lengthening and semitendinosus transfer to distal femur groups

	STL group	STTX group	*P*
Patients/sides	22/44	17/34	
Mean age at surgery	10 years + 7 months (range: 6 years + 5 months to 19 years + 5 months)	11 years + 4 months (range: 8 years + 1 months to 19 years + 7 months)	0.508
Mean follow-up time	5 years + 11 months	7 years + 2 months	0.229
Sex [*n* (%)]			
Male	15 (68.2)	14 (82.4)	0.315
Female	7 (31.8)	3 (17.6)	
GMFCS [*n* (%)]			
I	6 (27.3)	1 (5.9)	0.084
II	9 (40.9)	4 (23.5)	0.254
III	7 (31.8)	12 (70.6)	**0.016**

Bold values denotes $P < 0.005$, significant.
STL, semitendinosus surgical lengthening; STTX, semitendinosus transfer to distal femur.

Table 2 Surgical procedures performed in the same session of knee flexion deformity correction in semitendinosus surgical lengthening and semitendinosus transfer to distal femur groups

Procedures	STL group [*N* (%)]	STTX group [*N* (%)]	*P*
FDO	18 (40.9)	13 (38.2)	0.811
PATL	1 (2.3)	0 (0.0)	0.376
SPLITTP	1 (2.3)	0 (0.0)	0.376
RFTX	8 (18.2)	2 (5.9)	0.107
GL (zone I)	7 (15.9)	12 (35.3)	**0.048**
PTL	2 (4.5)	2 (5.9)	0.791
SPLATT	2 (4.5)	0 (0.0)	0.208
ATZL	2 (4.5)	0 (0.0)	0.208
POB	4 (9.1)	18 (52.9)	**< 0.001**
STA	2 (4.5)	2 (5.9)	0.791
HAL	7 (15.9)	11 (32.4)	0.087
GSL (zone II)	3 (6.8)	4 (11.8)	0.448
ISOLATED	6 (13.6)	0 (0.0)	**0.025**
LCL	2 (4.5)	2 (5.9)	0.791
TO	0 (0.0)	4 (11.8)	**0.019**
ART	0 (0.0)	4 (11.8)	**0.019**
CLO	0 (0.0)	2 (5.9)	0.103

Bold values denotes $P < 0.005$, significant.
ART, subtalar arthroereisis; ATZL, achilles tendon Z lengthening; CLO, calcaneous sliding osteotomy; FDO, femoral derotation osteotomy; GL, gastrocnemius lengthening; GSL, gastrocnemius and soleous lengthening; HAL, hip adductors surgical lengthening; ISOLATED, gracilis and semimembranosus surgical lengthening, with semitendinosus transfer to distal femur or lengthening, performed without concomitant procedures; LCL, foot lateral column lengthening; PATL, percutaneous Achilles tendon lengthening; POB, psoas lengthening over the pelvic brim; PTL, posterior tibialis surgical lengthening; RFTX, rectus femoris distal transfer; SPLATT, split transfer of anterior tibialis; SPLITTP, split transfer of posterior tibialis; STA, subtalar arthrodesis; TO, tibial derotation osteotomy.

Table 3 Comparison of clinical parameters before and after intervention in semitendinosus surgical lengthening and semitendinosus transfer to distal femur groups

	Mean	Median	SD	*N*	*P*
Hip flexion deformity					
STL					
Preoperative	7.16	7.5	6.42	44	**0.001**
Postoperative	11.93	10	8.64	44	
STTX					
Preoperative	9.12	10	7.83	34	1.000
Postoperative	9.12	7.5	8.30	34	
Fixed knee flexion deformity					
STL					
Preoperative	0.95	0	6.05	44	0.053
Postoperative	3.86	0	8.27	44	
STTX					
Preoperative	7.35	7.5	6.54	34	**0.044**
Postoperative	4.41	0	8.14	34	
Popliteal angle					
STL					
Preoperative	67.27	67.5	8.72	44	**0.026**
Postoperative	62.50	60	10.54	44	
STTX					
Preoperative	70.15	70	10.62	34	**< 0.001**
Postoperative	62.06	60	9.38	34	
Bilateral popliteal angle (hamstrings shift)					
STL					
Preoperative	58.41	60	9.51	44	**< 0.001**
Postoperative	47.61	50	11.93	44	
STTX					
Preoperative	61.03	60	11.06	34	**< 0.001**
Postoperative	50.00	50	7.98	34	

Bold values denotes $P < 0.005$, significant.
STL, semitendinosus surgical lengthening; STTX, semitendinosus transfer to distal femur.

Table 4: In STL group, the ratio step length/lower limb length was 0.58 before surgery and 0.55 after intervention ($P = 0.382$), whereas in STTX group, it was 0.50 and 0.45 ($P = 0.105$), respectively.

The comparison of the results of treatment between groups showed that the reduction of MKFS was more significant in STTX group. The changes observed at APT did not exhibit difference among STL and STTX groups.

Table 5: Finally, after intervention, the number of limbs with FKFD was increased in STL group [from 4 (9.1%) to 11 (25%), $P = 0.047$] and decreased in STTX group [from 17 (50%) to 7 (20.6%), $P = 0.011$]. During the long-term follow-up of studied patients, 18.2% of patients from STL group and 17.6% from STTX group received additional surgical procedures for the correction of residual deformities in lower limbs, and the number of surgical procedures per patient was higher in STL group (7.25 vs. 2.67, $P = 0.002$).

Discussion

Surgical lengthening of hamstrings has been considered the standard procedure for the correction of KFD in CP. However; the outcomes can deteriorate in a long-term follow-up [2]. Zwick *et al.* [4] described an increase of APT after surgical lengthening of hamstrings. This result could be explained by the loss of hip extensors strength. The weakness of hip extensors, combined with an

Table 4 Comparison of kinematic parameters before and after intervention in semitendinosus surgical lengthening and semitendinosus transfer to distal femur groups

	Mean	Median	SD	*N*	*P*
Mean anterior pelvic tilt					
STL					
Preoperative	15.31	15.24	5.80	44	**0.008**
Postoperative	18.95	19.49	8.37	44	
STTX					
Preoperative	14.52	14.52	5.91	34	**0.006**
Postoperative	19.34	21.03	8.94	34	
Minimum hip flexion in stance					
STL					
Preoperative	3.86	4.59	8.61	44	**0.018**
Postoperative	6.83	7.46	7.01	44	
STTX					
Preoperative	11.66	9.74	10.35	34	0.524
Postoperative	12.78	12.53	11.42	34	
Minimum knee flexion in stance					
STL					
Preoperative	21.88	21.05	15.19	44	0.061
Postoperative	16.19	14.73	16.17	44	
STTX					
Preoperative	34.23	34.07	12.41	34	**< 0.001**
Postoperative	20.26	20.39	15.33	34	
Peak ankle dorsiflexion in stance					
STL					
Preoperative	6.98	10.22	15.23	44	**0.008**
Postoperative	12.81	12.16	7.19	44	
STTX					
Preoperative	5.27	10.25	20.16	34	**0.047**
Postoperative	12.73	14.24	10.76	34	

Bold values denotes $P < 0.005$, significant.
STL, semitendinosus surgical lengthening; STTX, semitendinosus transfer to distal femur.

Table 5 Comparison of the changes at clinical and kinematics parameters in semitendinosus surgical lengthening and semitendinosus transfer to distal femur groups after treatment

Parameters	Groups	Mean	SD	*N*	*P*
Hip flexion deformity	STL	4.77	8.82	44	**0.042**
	STTX	0.00	11.55	34	
Fixed knee flexion deformity	STL	2.91	9.69	44	**0.006**
	STTX	−2.94	8.18	34	
Popliteal angle	STL	−4.77	13.77	44	0.264
	STTX	−8.09	11.68	34	
Bilateral popliteal angle (hamstrings shift)	STL	−10.80	15.51	44	0.945
	STTX	−11.03	13.64	34	
Mean anterior pelvic tilt	STL	3.64	8.68	44	0.574
	STTX	4.82	9.63	34	
Minimum hip flexion in stance	STL	2.97	8.00	44	0.366
	STTX	1.11	10.05	34	
Minimum knee flexion in stance	STL	−5.68	19.59	44	**0.033**
	STTX	−13.96	11.95	34	
Peak ankle dorsiflexion in stance	STL	5.83	13.97	44	0.699
	STTX	7.46	22.93	34	

Bold values denotes $P < 0.005$, significant.
STL, semitendinosus surgical lengthening; STTX, semitendinosus transfer to distal femur.

increase of APT and lumbar lordosis, is a potential causes for recurrence of knee flexion during stance phase in gait and deterioration of the early outcomes of surgical lengthening of hamstrings [2].

One of the purposes of STTX is to preserve the strength of semitendinosus as a hip extensor and to prevent the increase of APT postoperatively. In 2006, Ma *et al.* [9] reported an improvement at knee extension during physical examination and stance phase in gait in a series of cases: of which, 19 patients with CP had undergone gracilis and semimembranosus surgical lengthening, combined with STTX. In addition, they mentioned no deterioration of APT after a mean follow-up time of 25 months.

In another report by Sung *et al.* [15], they analyzed a group of patients who had received single-event multilevel surgery in lower limbs, including STTX; after a long-term follow-up, there was no increase in APT observed. However, the comparison between STTX and STL regarding its effects at clinical and kinematic parameters was not done in these studies.

Dreher *et al.* [16] compared the conversion of biarticular to monoarticular muscle (including STTX) with musculotendinous lengthening in spastic diplegic CP. After a follow-up time of 9 years, they reported an increase of APT at 30% of the patients of both.

Feng *et al.* [17] and De Mattos *et al.* [18] compared the results of the transfer of semitendinosus and gracilis to distal femur to the lengthening of medial and lateral hamstrings. The improvement of knee extension in stance phase and the increase of APT were noted in both studies, irrespective of the techniques applied for the correction of KFD. The authors believed that the inclusion of biceps femoris in the treatment plan in most patients analyzed could be a possible explanation for the raise of APT after surgery. Feng *et al.* [17] mentioned that an increase of APT is inevitable when crouch gait is corrected, as the oblique femur becomes more vertical during stance, thereby rotating the pelvis into more of an anterior tilt.

In the present study, comparison between STTX and STL using clinical and kinematic parameters was carried out. Similar increase of APT was observed in all groups after intervention, and STTX was not able to prevent the increase of APT in the groups of patients analyzed.

The determination of the position of the pelvis in sagittal plane seems to be determined by multiple factors, including posture changes after KFD correction and crouch gait treatment, as the increase of APT was described previously after distal femoral extension osteotomy and patellar tendon advancement [19,20].

In addition to this, the surgical lengthening performed at gracilis and semimembranosus in all patients of this study could be related with some degree of hip extensors weakness and also be a cause of the increase of APT in long-term follow-up.

In 2006, Arnold *et al.* [7] reported that the examination of the muscle-tendon lengths and velocities allows individuals who walk with abnormally short or slow hamstrings to be distinguished from those who do not, and thus may help to identify patients who are at risk for unsatisfactory postsurgical changes in knee extension or APT. As a consequence of it, we believe that the use of muscle-tendon lengths modeling prior STTX or STL can be helpful to predict the results at APT.

Moreover, Rutz *et al.* [21] described in 2010 the preoperative botulinum toxin test injectons before muscle lengthening in CP to filtering out patients with risk of deterioration after soft tissue procedures. The authors observed that the use of the botulinum toxin test before surgery reduced the percentage of patients with deterioration of the function after surgical muscle lengthening from 18 to 0%. We also believe that this test could be applied before medial hamstrings procedures to identify patients with higher risk of increase APT after intervention.

Second, we also observed that the reduction of FKFD and knee flexion in stance phase were statically significant only in STTX group; however, owing to different magnitude of these parameters among groups before intervention, these findings may not be clinically relevant.

Although, the present study has limitations. There was a prevalence of GMFCS level III in STTX group and as a consequence of it, mean FKFD and minimum knee flexion in stance phase were higher in this group than STL group before treatment. These data suggest that patients who had undergone STTX had more severity than those who received STL, and it might have influenced the results regarding the improvement of knee extension.

In addition to this, the psoas surgical lengthening was performed more frequently in STTX than STL group. Despite this fact, the increase of APT was observed in all groups after intervention. Amazingly, the higher prevalence of psoas surgical lengthening over the pelvic brim in STTX group did not influence the results.

Dispite these facts, the present study is the first to compare STTX to medial HSL regarding the effects at APT. The current literature is scarce about the topic addressed, and the results obtained may add new information for the management of KFD in CP.

Conclusion

The APT increased in both groups after treatment, and STTX was not effective to prevent it in a medium-term follow-up, rejecting the study hypothesis.

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Conflicts of interest

There are no conflicts of interest.

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