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The results of single-stage multilevel muscle-tendon surgery in the lower extremities of patients with spastic cerebral palsy

Spastik serebral palsili hastaların alt ekstremitelerinde tek aşamalı çok seviyeli kas-tendon cerrahisi sonuçları

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Amaç: Spastik serebral palsili hastaların alt ekstremitelerinde gelişmiş olan kontraktürlerin tedavisinde uygulanan tek aşamalı çok seviyeli kas-tendon cerrahisinin sonuçları değerlendirildi.

Çalışma planı: Spastisite nedeniyle alt ekstremitelerde gelişmiş olan kontraktürlerin tedavisi için tek aşamalı çok seviyeli kas-tendon cerrahisi uygulanan serebral palsili 23 hastanın (11 kız, 12 erkek; ort. yaş 6 yıl 3 ay; dağılım 4-17 yıl) ameliyat öncesi ve sonrası (ort. 4 yıl 9 ay; dağılım 1-8 yıl) fizik muayene bulguları ve Gross Motor Function Classification System (GMFCS) (Kaba Motor Fonksiyon Sınıflama Sistemi) sonuçları değerlendirildi. Hastaların beşi kuadriplejik, 14'ü diplejik, dördü hemiplejikti. Ameliyat öncesi dönemde 13 hasta yürürken, 10 hasta destekli ya da desteksiz yürüyemiyordu. Son kontroller sırasında hastaların ortalama yaşı 11.5 (dağılım 9-19) idi.

Sonuçlar: Tüm eklemlerde hareket açıklığının ameliyat öncesi döneme göre arttığı ve bunun hastanın postür, oturma, yürüme ve beden temizliği üzerinde belirgin iyileşme sağladığı görüldü. Yürüyemeyen 10 hastanın beşi ameliyat sonrasında yürüteç ya da koltuk değneği ile yürüyordu. Ameliyat öncesi dönemde 3.045 olan GMFCS ortalaması, ameliyat sonrası dönemde 1.864 bulundu (p<0.001). Hastaların tümünün GMFCS derecelerinde en az bir seviye iyileşme saptandı.

Çıkarımlar: Spastik serebral palside cerrahi girişimden tam yarar sağlanabilmesi için kalça, diz ve ayak bileklerindeki kontraktürlerin tümünün düzeltilmesi, gerekiyorsa simetrik ve çok seviyeli ameliyatların yapılması gerekir. Bu konuda tek aşamalı ve simetrik, çok seviyeli kas-tendon cerrahisi uygulamalarının, çok aşamalı girişimlere belirgin üstünlükleri vardır.

Anahtar sözcükler: Biyomekanik; serebral palsi/cerrahi; çocuk; kontraktür/etyoloji/cerrahi; yürüyüş; kas spastisitesi/cerrahi; hareket açıklığı, eklem/cerrahi; tendon/cerrahi.

Objectives: We evaluated the results of single-stage multilevel muscle-tendon surgery performed for the treatment of contractures in the lower extremities of patients with spastic cerebral palsy.

Methods: The study included 23 patients (11 girls, 12 boys; mean age 6 years 3 months; range 4 to 17 years) with spastic cerebral palsy, who underwent single-stage multilevel muscle-tendon surgery for the treatment of contractures in the lower extremities secondary to spasticity. Quadriplegia, diplegia, and hemiplegia were present in five, 14, and four patients, respectively. Preoperatively, 13 patients could walk, while 10 patients lacked ambulation even with support. Evaluations were based on pre- and postoperative (mean 4 years 9 months; range 1 to 8 years) physical examination findings and on the Gross Motor Function Classification System (GMFCS) scores. The patients' mean age at the last follow-up was 11.5 years (range 9 to 19 years).

Results: The range of motion of all the operated joints improved postoperatively, resulting in significant improvements in posture, sitting, gait, and hygiene of the patients. Of ten patients who could not walk, five could ambulate with the use of a walker or crutches postoperatively. The mean pre- and postoperative GMFCS scores were 3.045 and 1.864, respectively (p<0.001). All patients showed an improvement of at least one GMFCS level.

Conclusion: Surgery for spastic cerebral palsy can be most beneficial only when all contractures of the hip, knee, and ankle have been corrected. Symmetrical and multilevel operations should be performed when necessary, for single-stage and symmetrical multilevel muscle-tendon surgical applications have definite advantages over staged interventions.

Key words: Biomechanics; cerebral palsy/surgery; child; contracture/etiology/surgery; gait; muscle spasticity/surgery; range of motion, articular/surgery; tendons/surgery.

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Cerebral palsy is the result of a nonprogressive lesion occurring in the developing brain which results in fixed postural and motor impairment. The lesion in the brain causes problems related to muscle tone and coordination, which with time usually results in secondary joint contractures due to the power imbalance in the musculoskeletal system. [1,2]

In 80% of the patients the movement abnormality is spasticity. Spasticity which is defined as an increase of physiologic muscle tone apparent in passive motion, originates from lesions in the brain cortex. In spastic cerebral palsy, first motor neuron syndrome symptoms like hyperreflexia, clonus, and primitive reflexes are present along with an increased muscle tone. Clinical presentation of spastic cerebral palsy may be one of the following types: total body involvement (involvement of all four extremities, head, and trunk), quadriplegia (involvement of all four extremities - upper extremity involvement is as severe as involvement of the lower extremities), diplegia (lesser involvement in the upper, severe involvement in the lower extremities), hemiplegia (only one side of the body is involved), monoplegia (involvement of only one extremity). [1,3]

The main goal of orthopedic treatment of cerebral palsy should be maintaining mobility and independent ambulation of the patient. The treatment should be individualized and planned according to the patient's needs. For example, while maintaining hygiene and independent and balanced sitting is the main goal in a patient with total body involvement or quadriplegia, the main goal in a diplegic patient is maintaining improvement of gait and providing less energy consumption during walking.

Orthopedic surgery has a prominent importance in the treatment of cerebral palsy. Surgical intervention has an important role in preventing deformity development or correcting present deformities, balancing muscle strength, controlling joint movements, and gaining or improving extremity functions.

The result of assessing the static and dynamic problems in spastic cerebral palsy has shown that in order for the patient to fully benefit from surgical interventions, all the contractures of the hip, knee, and ankle joints must be corrected simultaneously.[4] Single-stage multilevel surgery in cerebral palsy designates correction of all deformities originating from bone and soft tissue abnormalities in a single operation sitting.[5] Morbidity due to correction of all deformities in a single stage is known to be less than that of staged surgical procedures.[5,6] In such cases, postoperative rehabilitation is more efficient and the postural and functional improvement gained is also maintained until the adult life.[5]

In this study, 23 patients with spastic cerebral palsy who underwent single-stage multilevel muscle-tendon surgery for the treatment of contractures in the lower extremities secondary to spasticity were included.

Methods

The study included 23 patients (11 girls, 12 boys; mean age 6 years 3 months; range 4-17 years) with spastic cerebral palsy, who underwent single-stage multilevel muscle-tendon surgery for the treatment of contractures in the lower extremities secondary to spasticity. To make the preoperative evaluation more objective, all the cases were chosen amongst patients who had no sight and cooperation problems, who had no previous operations in their lower extremities, and who had no mental retardation or extrapyramidal system involvement. Patients who were using medication which affects motor functions (baclofen, botulinum toxin, benzodiazepin) or patients who requires bony interventions for deformities were also excluded.

Sixteen patients were born before the 36th gestational week; two had prenatal complications, and five had no pathologic delivery story. Quadriplegia, diplegia, and hemiplegia were present in five, 14, and four patients, respectively. Preoperatively, 13 patients could walk, while 10 patients lacked ambulation even with support (Table 1).

Evaluations were based on pre- and postoperative (mean 4 years and 9 months; range 1 to 8 years) physical examination findings and on the Gross Motor Function Classification System (GMFCS) scores. The patients' age at the last follow-up was 11.5 years (range 9 to 19 years).

Static and dynamic conditions in the lower extremities were assessed with physical examination. Unsupported sitting, standing, and gait properties were evaluated. Toe-walking, scissoring, crouch knee gait, stiff knee gait, and patients' ambulation with or without support were observed. Toe-walking was attributed to gastrocsoleus complex contracture, scissoring to hip adductor muscle contracture, crouch knee gait to hamstring muscle contracture, stiff knee gait to rectus femoris muscle spasticity and all were assessed with special tests. Passive range of motion of the joints was assessed clinically by using a goniometer according to the neutral 0 method.[9]

Soft tissue contractures were assessed with special tests in joint examinations. Thomas and Ely tests were used to assess hip flexion contracture (Fig. 1 and 2). Iliopsoas and rectus femoris muscle contractures were diagnosed respectively when these tests were found positive. Hip abduction restriction in extension and in 90 degrees of flexion was attributed to hip adductor muscle contracture.

Popliteal angle was used to assess hamstring spasticity; hamstring muscle contracture was diag-

Table 1. Patients' data.

Case No	Involvement	Age at surgery	Follow up (years)	Surgical procedure
1	Diplegic	8	2	Bilateral rectus release,adductor myotomy,medial hamstring lenghtening,achilles tendon lenghtening
2	Diplegic	17	2	Bilateral rectus release,adductor tenotomy,medial hamstring lenghtening
3	Diplegic	6	5	Left iliopsoas release,bilateral medial hamstring lenghtening,achilles tendon lenghtening
4	Diplegic	4	5	Bilateral adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
5	Diplegic	6	4	Bilateral medial hamstring lenghtening, achilles tendon lenghtening
6	Diplegic	12	6	Bilateral medial hamstring lenghtening, achilles tendon lenghtening
7	Quadriplegic	5	6	Bilateral rectus release,iliopsoas release,adductor myotomy,medial hamstring lenghtening, achilles tendon lenghtening
8	Diplegic	7	4	Bilateral iliopsoas release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
9	Diplegic	6	5	Bilateral iliopsoas release, adductor myotomy, medial hamstring lenghtening, vulpius
10	Diplegic	8	5	Bilateral iliopsoas release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
11	Hemiplegic	6	5	Right medial hamstring lenghtening, achilles tendon lenghtening
12	Hemiplegic	4	5	Right medial hamstring lenghtening, achilles tendon lenghtening
13	Hemiplegic	5	8	Left medial hamstring lenghtening, achilles tendon lenghtening
14	Quadriplegic	4	5	Bilateral iliopsoas release,rectus release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
15	Diplegic	4	6	Bilateral rectus release,adductor myotomy,medial hamstring lenghtening,achilles tendon lenghtening
16	Quadriplegic	5	5	Bilateral iliopsoas release,rectus release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
17	Quadriplegic	7	5	Bilateral iliopsoas release,rectus release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
18	Quadriplegic	5	6	Bilateral iliopsoas release,rectus release, adductor myotomy, medial hamstring lenghtening, achilles tendon lenghtening
19	Diplegic	10	1	Bilateral rectus release, medial hamstring lenghtening,right achilles tendon lenghtening,left vulpius
20	Diplegic	4	6	Bilateral medial hamstring lenghtening,right vulpius,left achilles tendon lenghtening
21	Diplegic	5	6	Bilateral medial hamstring lenghtening, vulpius
22	Hemiplegic	4	6	Right medial hamstring lenghtening, achilles tendon lenghtening
23	Diplegic	7	5	Bilateral medial hamstring lenghtening, achilles tendon lenghtening

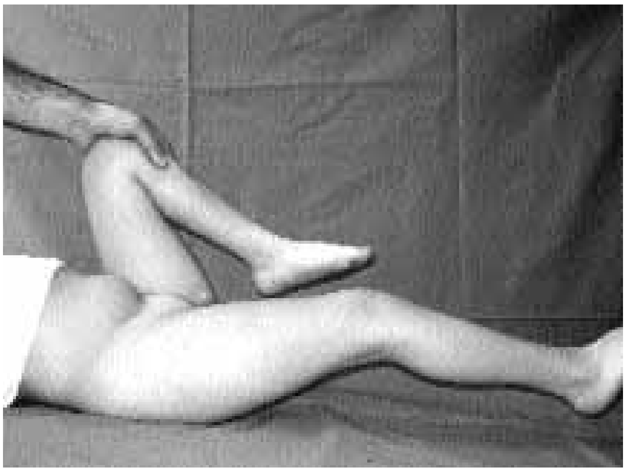

Figure 1. Thomas test

Figure 2. Ely test

nosed when this angle was below 130 degrees.[1] Popliteal angle was measured with the patient supine and the hip in 90 degrees of flexion, the knee is extended passively. The angle between the posterior aspects of the thigh and leg determines the popliteal angle degree (Fig 3).

Ankle dorsiflexion was evaluated with the Silverskiöld test[1] (Fig 4). If the ankle can be dorsiflexed with the knee bent to 90 degrees of flexion but cannot be dorsiflexed with the knee extended, it is determined that the gastrocnemius is tight, but the soleus is not contracted.

Iliopsoas tendon release was performed for hip flexion contracture, percutaneous adductor tenotomy or open adductor myotomy for adductor contracture depending on the severity of the contracture, and release in the proximal region of the rectus femoris muscle for tightness determined with the Ely test. Percutaneous adductor tenotomy was performed if hip abduction was between 35-45 degrees and open myotomy if abduction was less than 35 degrees. When adductor tenotomy was performed, the tendon of the adductor longus muscle was released percutaneously in the region of pubic ramus

Figure 3. Popliteal angle

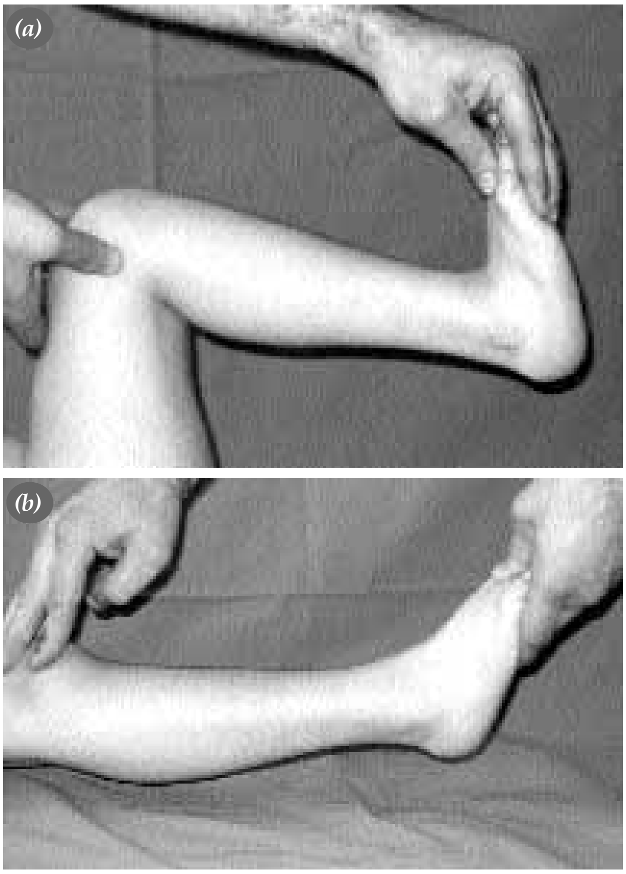

Figure 4. (a,b) Silverskiöld test

attachment. When open adductor myotomy was performed, the adductor longus muscle along with the adductor brevis muscle was released with myotomy.

Medial hamstring release was performed for hamstring contracture and a value more than 130 degrees for popliteal angle was aimed. While tendon lengthening was performed with Z-plasty in the distal gracilis and semitendinosus muscles, the semimembranosus muscle was lengthened by aponeurosis recession. While the dynamic equinus deformity with a positive Silverskiöld test was managed by the Vulpius procedure[1] in which the aponeurosis of the gastrocnemius muscle was released, the fixed equinus deformity with a negative Silverskiöld test was managed by the Achilles tendon was lengthened by Z-plasty. Every patient had undergone at least two of these procedures.

Abduction pillow was used in the bed after adductor tenotomy in the postoperative period. Patients who had undergone medial hamstring lengthening along with Achilles tendon was lengthening or the Vulpius procedure were placed in a long-leg cast with the knees in full extension and the ankles in 0 degrees of dorsiflexion. The patients were discharged in mean 2.3 days postoperatively. The casts were removed in the fourth postoperative week and an ankle-foot orthosis (AFO) or a knee-ankle-foot orthosis (KAFO) was used as night splints for an additional four weeks. The patients were permitted to walk and the families were shown physiotherapy exercises and followed monthly by the physician and the physiotherapist.

GMFCS[7] scores were calculated and compared between the preoperative period and the last follow-up visit to measure the functional improvement obtained. In this system, the patients are classified into five levels by a scoring system based on age; the first group designates the best functional status and the fifth the worst. The patients in Level 1 can walk unlimited distances without support, but have problems with fine motor skills. The patients in Level 2 can walk unlimited distances without support, but have limitations outside home and in crowds. These patients have problems walking on rough surfaces and in crowds. The patients in Level 3 can walk with a gait support (orthosis, walker, crutches), but have significant problems outside home and in crowds. The patients in Level 4 have limitations in ambulating on their own, they can walk short distances with gait supports on smooth surfaces, and usually they are carried by others. The patients in Level 5 do not have the ability to ambulate independently and they need to be carried by others, usually they cannot sit without support.

Paired t-test was used in the statistical analysis of the evaluation results.

Results

When passive range of motion values of the joints at physical examination at the last follow-up were compared with the preoperative values, all patients showed an improvement at all levels.

Pre- and postoperative values of passive range of motion of the hips, knees, and ankles which were operated on were given in Table 2.

While hip abduction values measured in extension and 90 degrees of flexion showed significant improvement ($p<0.001$), no significant improvement was observed in hip flexion, adduction, internal and external rotation values ($p<0.05$).

While knee extension values showed significant improvement ($p<0.05$), no significant improvement was observed in flexion values ($p>0.05$). Popliteal angle values showed significant improvement ($p<0.001$).

While a significant increase ($p<0.001$) was observed in ankle dorsiflexion values measured with the knee in extension and 90 degrees of flexion, a significant decrease ($p<0.05$) was observed in plantar flexion values.

Of ten patients who could not walk, five could ambulate with the use of a walker or crutches postoperatively. Remaining five patients who could not walk postoperatively could sit without support and personal hygiene had improved.

The mean pre- and postoperative GMFCS scores were 3,045 and 1,864, respectively ($p<0,001$). Improvement was statistically significant and all patients showed an improvement of at least one GMFCS level. Five patients who were Level 5 preoperatively became Level 4 postoperatively; five patients who were Level 4 became Level 3, eight patients who were Level 3 became Level 2, two patients who were Level 3 became Level 1, and

Table 2: Passive range of motion of hip, knee and ankle and popliteal angle values preoperatively and postoperatively

		Preoperative		Last follow-up		
	Function (°)	Mean	SD	Mean	SD	*p*
Hip	Flexion	120	4.05	118.30	6.94	>0.05
	Extansion	-9.62	9.73	0	0	>0.05
	İnternal rotation	40.58	17.56	39.46	17.83	>0.05
	External rotation	41.90	15.00	40.31	21.00	>0.05
	Adduction	28.79	3.00	28.62	4.35	>0.05
	Abduction in extansion	24.84	10.35	33.89	6.86	<0.001
	Abduction in 90° flexion	40.86	13.53	51.83	10.39	<0.001
Knee	Flexion	140	0.00	140	0.00	>0.05
	Extansion	-4.62	9.61	0	0	<0.05
Ankle	Dorsiflexion					
	Knee in 0° extansion	-16.79	9.96	6.07	8.81	<0.001
	Knee in 90° extansion)	-7.18	9.89	16.47	11.57	<0.001
	Plantar flexion	45.48	4.00	42.16	5.90	<0.05
Popliteal Angle		91.12	16.35	122.65	24.77	<0.001

three patients who were Level 2 became Level 1.

With subjective evaluation all patients stated that they are better functionally. Likewise, families stated that their children improved significantly both cosmetically and functionally after surgery, that the children are ambulating better in daily life, and that they are happy with the results.

Discussion

At school age in industrialized countries, the prevalence of cerebral palsy is about 2 per 1000 live births and the most common type is spastic diplegia (6). Most of the patients with cerebral palsy develop contractures and deformities due to muscle power imbalance in their musculoskeletal systems. Although complete recovery of these patients is impossible due to the brain lesion, orthopedic surgical interventions performed to provide, maintain, or improve musculoskeletal system function help significantly to life quality of the patient. These surgical interventions may be minor like percutaneous adductor tenotomy to prevent dislocation of the hips due to adductor contracture or major operations with high morbidity rates like multilevel spinal fusion to provide the patient a balanced sitting in a wheelchair. The goal of orthopedic surgical interventions in cerebral palsy patients is to provide a balanced spine and pelvis; hips and knees that can be extended in the stance phase and knees that can be flexed and ankles that can be dorsiflexed in the swing phase of the gait, and plantigrade feet.

The surgical interventions in cerebral palsy patients are usually carried out for the restricted range of motion of the joints due to the contractures which developed because of spasticity and the resulting gait disorders. Since diplegic and quadriplegic patients cannot walk before the age of four, surgery should be avoided before four years of age.[2,10,11] Conservative means must be tried before four years of age. There were no patients younger than four years among our patients.

Whatever the type and severity of involvement is, the fact that a better posture and a more efficient gait can be obtained by muscle-tendon lengthening operations when contractures have developed in cerebral palsy have been proved by many studies.[1,5,6,12,13] However, in order that the patient can benefit fully from surgery, all contractures in the hip, knee, and ankle should be released (4); when necessary, symmetrical and multi-level operations should be carried out. For example, bilateral hamstring contractures in a diplegic patient must be released bilaterally; unilateral intervention would not improve the patient's function. Likewise, if hamstring and gastrocsoleus contractures causing crouch knee gait and equinus in the ankle are present in a hemiplegic patient, releasing only one of the contractures would not improve function sufficiently. On the contrary, surgery in only one level would interfere with the patient's gait which had obtained a balance within itself preoperatively.

There are different opinions on timing and priority of the interventions when more than one intervention is needed. There are pro- and anti-multi-level surgery surgeons.[14] For example, it was reported that in patients with flexion contractures both in the hips and knees releasing in both levels would not be right, because only a small number of patients would need hamstring release after iliopsoas release and in the rest of the patients sufficient improvement can be obtained by physiotherapy only.[15] Still, other authors argue that if a patient suffers from adduction and flexion contractures in the hip, flexion contracture in the knee, and equinus in the ankle, first the adductor and iliopsoas release should be performed; if sufficient improvement could not be obtained by physiotherapy than gastrocsoleus release would be performed one year later, and finally hamstring release may be performed if crouch knee gait persists.[14,15]

However, these multi-stage single-level surgical interventions may lead to many medical, psychological, social, and economic problems. This case was defined as "the birthday surgery" [1]. With this saying, a cerebral palsy patient with multi-level involvement who would have an operation in one level every year, and whose gait would not improve due to the other contractures in other levels and would need further surgery in these levels the following year, thus spending a certain period of time in the hospital every year was defined. The child would not go to school and live a normal childhood within this period of time. Releasing all contractures simultaneously would be ideal. Furthermore, releasing all involved joints in one stage, and when required performing tendon transfers and corrective osteotomies in the same sitting would provide the lower extremity joints a more balanced posture and a better functional gain.[5,6] Gait analysis studies also showed that significant improvement could be obtained after single-stage multi-level surgery. [5,6,13]

We have observed significant improvement postoperatively in our patients who underwent single-stage multi-level surgery for treatment of contractures in the lower extremities. This improvement was confirmed both by the patient's and his/her family's subjective evaluation and by the clinical improvement obtained in the passive range of motion of the joints and the improvement obtained in gait. Furthermore, these observational and clinical examination findings were also supported by the GMFCS evaluation.

While passive hip range of motion values in extension and abduction showed significant improvement ($p<0.001$) when compared to preoperative values, other hip range of motion values showed no difference ($p<0.05$). The iliopsoas tenotomy performed to correct the flexion contracture of the hip was reported to cause a loss especially in active flexion strength and range of motion which in turn leads to insufficient clearance of the foot off the ground in the first half of the swing phase, thus creating difficulty in climbing the stairs and running.[6] Although we have not observed this phenomenon in our patients, passive hip flexion had decreased a little which was statistically insignificant. This condition was also reported in other studies [5] ; in order to maintain the hip flexion strength, lengthening of the psoas muscle by intrapelvic intramuscular tenotomy was proposed instead of iliopsoas tenotomy.[5,6,16]

While knee extension values showed significant improvement ($p<0.05$), no significant improvement was observed in flexion values ($p>0.05$) which were within the normal range preoperatively. Other studies also revealed similar changes in hip and knee range of motion values. [6,12] An improvement of 31.5 degrees was obtained between the pre- and postoperative popliteal angle values ($p<0.001$). This result is in accordance with the highest popliteal angle change, which is 33 degrees, reported after distal hamstring lengthening.[6]

The only difference of the surgical technique performed in our patients from the examples given in the literature[5,6] is that routine distal transfer of the rectus femoris muscle was not performed in patients who underwent hamstring lengthening. Rectus femoris muscle spasticity that causes insufficient knee flexion leading to stiff knee gait during the swing phase can be overcome by transferring the rectus femoris tendon distally to the hamstrings.[17] While some surgeons argue that in the case of cospasticity of the hamstring and rectus femoris muscles, distal transfer of the rectus femoris muscle must always be performed along with hamstring lengthening in order to overcome stiff knee gait, [5,6,18] others prefer distal transfer of the rectus femoris muscle only in patients whose stiff knee gait persists even after hamstring lengthening and postoperative rehabilitation.[19] Defenders of the second opinion argue that routine transfer of the distal rectus femoris muscle is unnecessary, because in reality distal transfer of the rectus femoris muscle does not obtain power transfer to the hamstrings, but only the deforming force of the rectus femoris muscle on the flexors is eliminated.[19-21] We, too, share this opinion and do not perform routine transfer of the distal rectus femoris muscle in patients who undergo hamstring lengthening. Furthermore, since most of our patients undergo proximal rectus femoris muscle release, the deforming force of the rectus femoris muscle on the flexors is mostly eliminated thus rendering distal transfer unnecessary.

While a significant increase ($p<0.001$) was observed in ankle dorsiflexion values measured with the knee in extension and 90 degrees of flexion, a significant decrease ($p<0.05$) was observed in plantar flexion values. Dorsiflexion of the ankle which preoperatively had an equinus deformity will undoubtedly improve gait function significantly. On the other hand, the decrease obtained in plantar flexion values would not affect gait adversely, because the plantar flexion value which was 45 degrees preoperatively became 42 degrees postoperatively.

The significant increase obtained in ankle dorsiflexion helps lifting the foot off the ground in the swing phase of the gait, thus preventing sweeping of the foot. However, one of the main factors in the improvement of gait is the knee extension obtained by the hamstring release simultaneous with the ankle dorsiflexion in the heel strike which is the first phase of stance.[5] This also can be shown as an example of the advantages of single-stage multi-level muscle-tendon surgery.

The weak side of our study is the lack of support of our observations and findings by pre- and postoperative gait analysis. The benefits of gait analysis are certain: The objective data obtained facilitates cerebral palsy studies, standardize the indications, and makes measurements of the improvements obtained in the postoperative period possible. However, this should not mean that reaching successful results in cerebral palsy surgery is not possible without gait analysis. In spite of all the advances in technology, the main means at the decision step is the clinical interpretation which the surgeon reaches by observation and physical examination.[19]

On the other hand, it is apparent that the patients should be evaluated by at least an observational gait scale.[19] We have evaluated our patients with the GMFCS which is a clinically proven system. [22] The improvement obtained by the evaluation using this system was statistically significant ($p<0.001$) and all patients showed an improvement of at least one GMFCS level. Of the patients who had undergone single-stage multi-level surgery, five who could not walk before walked postoperatively; five who could not sit without support before sat unsupported; 10 who could only ambulate with the use of a gait support walked unsupported; three who had a hard time ambulating outside home walked better.

Like our surgical application, the success obtained by multi-level botulinum applications[23] and the fact that the most experienced clinics in cerebral palsy surgery and gait analysis are giving up multi-stage surgery in favor of single-stage surgery which they were against previously[15,23] also encourage us in our current applications.

However, the cases must be thoroughly evaluated before single-stage multi-level surgery. For this reason, the patients must be examined more than once in different days and the contradicting points in evaluation must be solved before the operation. The observational gait analysis should be repeated over and over and the findings drawn from this analysis should in accordance with the passive physical examination findings. The inexperienced surgeon in this regard should evaluate the patients with experienced pediatric orthopedic surgeons and reach a mutual opinion. Physical examination should be repeated under general anesthesia and the surgical plans must be changed when necessary.

The surgical procedures performed should be minimally invasive as much as possible and the preoperative plan should be reevaluated during the operation; after an intervention in one level is finished, physical examination should be repeated before proceeding to another level.

Consequently, we believe that single-stage multilevel surgery has significant advantages over multistage surgery in the treatment of cerebral palsy.

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