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Improvement of popliteal angle with semitendinosus or gastrocnemius tenotomies in children with cerebral palsy

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Objective: The aim of this study was to determine the efficacy of semitendinosus and gastrocnemius tenotomies on popliteal angle presenting knee flexion spasticity in children with cerebral palsy (CP).

Methods: The study included 44 patients (25 males, 19 females; mean age: 8.1 years, range: 4 to 14 years) with spastic CP who underwent surgery for knee flexion spasticity. A total of 78 semitendinosus tenotomies and 28 associated gastrocnemius tenotomies were performed. Popliteal angle was measured under general anesthesia before and after surgery. Patients were divided into groups according to age (younger and older than 7 years), severity of deformity and type of CP.

Results: Mean popliteal angles decreased by 14.3° (30.1%) following semitendinosus tenotomy and by 6.1° (12%) following gastrocnemius tenotomy (p=0.0001). The change in popliteal angle was not statistically significant according to age, severity of flexion spasticity, and type of CP palsy. There was a significant difference following gastrocnemius tenotomy between groups with a popliteal angle of greater or lesser than 50° (p=0.0001).

Conclusion: Semitendinosus and gastrocnemius tenotomies improved popliteal angle by 30.1% and 12%, respectively. Age, preoperative popliteal angle or anatomical disease classification did not a significantly affect popliteal angle.

Key words: Cerebral palsy; gastrocnemius; popliteal angle; semitendinosus; tenotomy.

Flexion deformity related to spasticity of the hamstring muscles is the most common knee deformity in cerebral palsy (CP).[1] Surgical lengthening of the hamstrings is the treatment of choice to improve knee function.[2-4] Lengthening procedures address the semimembranosus, semitendinosus, and biceps femoris muscles. Several surgical methods consisting of Z-plasty, fasciotomy and tenotomy have been described in the literature.[5,6] Despite successful postoperative functional results, recurvation of up to 10° has been observed as a complication.[7] Recurrence of knee flexion deformity is another common complication of this procedure, with rates of up to 40% as reported in the literature.[8,9] It is presumed that the effect of each hamstring muscle on knee flexion is

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important in order to avoid recurvation of the knee or recurrence of deformity.

It is also crucial to describe the effects of gastrocnemius tenotomy on knee motion in patients with spastic CP. The gastrocnemius muscle plays an important role in both knee flexion and ankle plantarflexion.[10-12] Its release in addition to that of the hamstring muscles may increase recurvation of the knee. Therefore, determination of the quantitative effect of semitendinosus and gastrocnemius tenotomies on popliteal angle improvement may affect surgical planning.

The aim of this study was to evaluate the effect of semitendinosus and gastrocnemius tenotomies on the popliteal angle in spastic CP and determine the factors that affect the results of these surgical procedures. The estimation of the amount of improvement in knee extension after such procedures will help in preoperative planning.

Patients and Methods

The study included a total of 44 patients (25 males, 19 females; mean age: 8.1 years, range: 4 to 14 years) with spastic CP who underwent surgery for knee flexion spasticity between August 2012 and March 2013. A total of 78 operations of 44 patients were performed. Bilateral surgery was performed in 34 patients and unilateral surgery in 10. A total of 78 semitendinosus tenotomies and 28 associated gastrocnemius tenotomies were performed.

Patients were operated by a single surgeon for knee flexion contracture and equinus deformity. Inclusion criteria were children with a diagnosis of spastic CP and a planned hamstring tenotomy and/or gastrocnemius tenotomy. Subjects were not included if they had any previously undergone open hamstring lengthening procedure or gastrocnemius tenotomy or if they had hip or fixed knee flexion contracture. Surgical indications for hamstring tenotomy were a popliteal angle greater than 30° under general anesthesia and knee flexion greater than 20° in the stance phase of gait. Surgical indications for gastrocnemius tenotomy was equinus gait and gastrocnemius spasticity that did not allow the ankle to dorsiflex to neutral while the knee was extended as described by Silfverskiöld.[13]

Patients were divided into two groups according to age at the time of the surgery. Group 1 included 22 patients younger than 7 years and Group 2, 22 patients 7 years old or older. Ten patients were hemiplegic and 34 diplegic. Patients were divided into groups based on preoperative popliteal angles: less than 50° (Group A; 42 procedures) and greater than 50° (Group B; 36 procedures).

For semitendinosus tenotomy, the patient was placed in the supine position on the operating table under general anesthesia. The limb was prepared and draped free. The semitendinosus tendon was palpated on the medial side of the popliteal area, with the hip flexed at 90° and the knee in maximum extension. A percutaneous transection of the semitendinosus tendon was then performed. The popliteal angle was checked after semitendinosus tenotomy and semimembranosus or gracilis tenotomy was performed if more extension was needed.

Gastrocnemius tenotomy was performed according

Fig. 1. **(a)** Measurement of the preoperative popliteal angle. **(b)** Measurement of the postoperative popliteal angle. **(c)** Measurement of the popliteal angle using a goniometer. [Color figures can be viewed in the online issue, which is available at www.aott.org.tr]

to Strayer.[14] The patient was positioned supine on the operating table under general anesthesia. The limb was prepared and draped free. The incision was made at the posterior medial border of the calf. The fascia overlying the gastrocnemius was identified and the tendon of the gastrocnemius resected transversely.

Popliteal angle was measured under general anesthesia before (Fig. 1a) and after tenotomy. In cases requiring both semitendinosus and gastrocnemius tenotomy, surgical release was begun with the gastrocnemius tenotomy and popliteal angle was measured before and after the gastrocnemius tenotomy. The second popliteal angle measurement was the preoperative value of the semitendinosus tenotomy. While the patients were in the supine position and the contralateral limb was extended (Fig. 1b),[1,15] the ipsilateral hip and knee were flexed to 90° and the knee maximally passively extended to the point of mild resistance. The ankle dorsiflexed to neutral while the popliteal angle was measured after gastrocnemius tenotomy. A goniometer was used for the measurements (Fig. 1c).

Correlation with age, severity of the deformity and anatomical CP classification were statistically evaluated. SPSS 15 (SPSS Inc., Chicago, IL, USA) software was used for statistical analysis. The Mann-Whitney U test was used in order to compare the differences between means of two groups. The Friedman and Wilcoxon tests were used for repeated measures and the Pearson test for correlation analysis. P values less than 0.05 were accepted as statistically significant.

Results

Mean popliteal angles were 47.5°±7.6° (range: 32 to 68°) and 33.2°±7.8° (range: 15° to 50°) before and after semitendinosus tenotomies, respectively (Table 1). The mean improvement of the popliteal angle was 30.1%±10.5 (range: 23.6% to 55.7%) and it was statistically significant (p=0.0001). The mean popliteal angles were 50.9°±9.0° (range: 33° to 69°) and 44.8°±6.7° (range: 32° to 58°) before and after gastrocnemius tenotomies, respectively. The mean decrease of 12%±5.7 (range: 2.2% to 25%) was statistically significant (p=0.0001).

When the results of semitendinosus tenotomies were evaluated according to age, preoperative and postoperative mean popliteal angles were 44.8°±5.5° and 29.8°±7.2° in Group 1, respectively. The improvement of the popliteal angle was 33.5% in Group 1 and it was statistically significant (p=0.0001). In Group 2, preoperative and postoperative mean popliteal angles were 50.6°±8.3° and 36.4°±7.0, respectively. Popliteal angles improved by 28.1% in Group 2 after semitendinosus tenotomy and this difference was statistically significant (p=0.0001). The difference between popliteal angle improvements in Group 1 and Group 2 was not statistically significant (p=0.055).

For gastrocnemius tenotomies, preoperative and postoperative mean popliteal angles were 47.2°±7.7° and 42.2°±4.8°, respectively, in Group 1. Popliteal angle significantly improved by 10.6% (p=0.001). In Group 2, preoperative and postoperative mean popliteal angles were 54.6°±9° and 47.4°±7.4, respectively. The mean improvement of the popliteal angle was 13.2% in Group 2 and this difference was also statistically significant (p=0.001). The difference between popliteal angle improvements in Groups 1 and 2 was not statistically significant (p=0.069).

According to severity of the spasticity in the semitendinosus tenotomies, preoperative and postoperative average popliteal angle was 42.5°±4.2° and 29.0°±6.6°, respectively, in Group A and 53.7°±6.3° and 37.9°±6.3°, respectively, in Group B. Mean popliteal angles significantly improved by 31.8% in Group A and 29.4% in Group B (p=0.0001). The difference between popliteal angle improvements in Groups A and B was not statistically significant (p=0.242).

For patients undergoing gastrocnemius tenotomies, preoperative and postoperative average popliteal angle was 43.5°±4.9° and 39.6°±4.6°, respectively, in Group A and 57.3°±6.2° and 49.3°±4.6°, respectively, in Group

Table 1. The mean values for preoperative and postoperative popliteal angles are shown.

Patient groups	Preoperative mean popliteal angle	Postoperative mean popliteal angle
All patients	47.5°±7.6°	33.2°±7.8°
Age <7 years	44.8°±5.5°	29.8°±7.2°
Age ≥7 years	50.6°±8.3°	36.4°±7.0°
Popliteal angle <50°	42.5°±4.2°	29.0°±6.6°
Popliteal angle ≥50°	53.7°±6.3°	37.9°±6.3°
Hemiplegic group	48.9°±7.5°	31.3°±9.2°
Diplegic group	47.6°±7.7°	33.4°±7.7°

B. The improvements of the mean popliteal angles were 9% in Group A and 14% in Group B and these were statistically significant (p=0.001). The difference between popliteal angle improvements in Group A and Group B was statistically significant (p=0.022).

Average popliteal angles were 48.9°±7.5° before and 31.3°±9.2° after semitendinosus tenotomy in the hemiplegic group and 47.6°±7.7° and 33.4°±7.7°, respectively, in the diplegic group. Popliteal angles improved by 36% in the hemiplegic group and 29.8% in the diplegic group. The improvement in popliteal angles was statistically significant in both the diplegic (p=0.0001) and hemiplegic (p=0.008) groups. The difference between popliteal angle improvements in the hemiplegic and diplegic groups was not statistically significant (p=0.104).

In patients who underwent gastrocnemius tenotomies, average preoperative and postoperative popliteal angles were 50.1°±6.1° and 43.5°±2.9°, respectively in the hemiplegic group and 51.0°±9.7° and 45.1°±7.4° in the diplegic group. Angles improved by 13.2% in the hemiplegic and 11.6% in the diplegic group and these improvements were statistically significant in both groups (p=0.0001 and p=0.026, respectively). The difference between the improvement in popliteal angle between groups was not statistically significant (p=0.573).

Discussion

Knee flexion deformity is a common problem in children with CP. Surgical lengthening of the hamstrings is a treatment option for knee flexion deformity in spastic CP.[1,3,4,6] Optional surgical procedures consist of Z-plasty, fasciotomy and tenotomy of the semimembranosus, semitendinosus, and biceps femoris muscles. Nonetheless, the improvement in knee extension after each of these procedures is unclear. To our knowledge, no studies in the literature have reported on the corrective effect of semitendinosus and gastrocnemius tenotomies on popliteal angle. However, such studies would be able to play an important role in the treatment strategy of knee flexion deformity in CP. We determined an improvement of 30.1% in the popliteal angle with semitendinosus tenotomy. In addition, shortening of the gastrocnemius-soleus muscle-tendon unit induces abnormal motion in the knee joint[12,16,17] and gastrocnemius tenotomy improves extension of the knee joint.[12] This improvement was determined as an 12% decrease in the popliteal angle. Our findings also suggested that age, preoperative popliteal angle or anatomical disease classification did not have statistically significant effects on these popliteal angle improvements.

Various operative procedures have been determined to eliminate the spasticity of the hamstring muscles.[13,18-21] Baumann et al. achieved significant improvement in knee extension after hamstring tenotomy.[22] According to DeLuca et al., semitendinosus tenotomy, as a part of hamstring tenotomy procedure, provides significantly better gait performance.[2] However, recurrence rates of up to a 40% have been reported in the literature as a common complication.[7,8,23] Sharps et al. determined that the correction achieved through distal hamstring tenotomy was not maintained in up to 50% of patients.[15] We believe that inadequate lengthening of the hamstrings could cause recurrence of deformity.

Knee recurvation has been observed as another unfavorable effect of hamstring lengthening.[4,20] Drummond et al. reported a recurvation rate of up to 30% after hamstring tenotomy.[24] Dhawlikar et al. reported 8% recurvation after hamstring tenotomy and emphasized that there is no accurate way to predict postoperative recurvation.[23] Those undesirable effects and difficulties indicate that the amount of surgical correction plays an important role in the treatment. However, there is no objective guide to show how much correction can be achieved through tenotomy of each hamstring tendon. We examined popliteal angle improvement, which can be achieved with semitendinosus tenotomy, because percutaneous determination of the semitendinosus tendon has a higher reliability than that of other parts of the hamstrings. Our study determined that a mean popliteal angle improvement of 14.3° (30.1%) can be achieved with semitendinosus tenotomy.

Ankle equinus, one of the most common deformities in spastic CP, is commonly treated with gastrocnemius tenotomy.[25] The gastrocnemius muscle is a secondary flexor of the knee joint.[10,11,17] Previously, while it has been shown that tenotomy of the gastrocnemius muscle improves extension of the knee joint,[12] no quantitative data about the effects of this procedure has been presented in the literature. Furthermore, gastrocnemius tenotomy can cause overcorrection of knee flexion deformity if it is performed together with hamstring tenotomy. We determined that a mean popliteal angle improvement of 6.1° (12%) can be achieved with gastrocnemius tenotomy. We believed that this result may help surgeons to avoid overcorrection of knee flexion deformity in cases in which semitendinosus tenotomy was planned in addition to gastrocnemius tenotomy.

Phelps reported that only 15% of operative procedures in patients younger than 14 years of age were successful.[26] However, many other authors concur that age does not significantly affect operative outcome of hamstring tenotomy.[7,15,23] Our analysis also showed that the

effect of age on the amount of popliteal angle correction was not statistically significant. Mean popliteal angle improved by a mean of 33.5% in patients younger than the age of seven and by 28.1% in those seven years old or older following semitendinosus tenotomy. The angle improved by 10.6% and 13.2% in patients younger and older than the age of seven, respectively, following gastrocnemius tenotomy.

There was no statistically significant relationship between the severity of flexion deformity and the magnitude of popliteal angle correction. However, Damron et al. performed 117 hamstring tenotomies (proximal, distal or combined) with a follow-up of 3.4 years and reported that the severity of preoperative flexion deformity was related with improvement in postoperative range of motion.[7] We had similar results in this study and found that the popliteal angle improvement was more for semitendinosus tenotomy when preoperatively popliteal angle was greater than 50°. However, this improvement percentage was statistically insignificant. Furthermore, the popliteal angle improvement was statistically significant for gastrocnemius tenotomy in patients with a preoperative popliteal angle greater than 50°.

Popliteal angle measurement is widely used for clinical assessment of hamstring spasticity and has good intraobserver reliability.[27,28] The anterior pelvic tilt is counterbalanced by hamstring contraction, which is expressed by an increased popliteal angle. Although there are some concerns regarding proper popliteal angle measurement technic, all measurements were performed by a single experienced author before and after tenotomies using the same method to decrease some bias. Therefore, the effect of anterior pelvic tilt remained constant, increasing the objectivity.

The relatively small number of patients with gastrocnemius release may be considered a limitation of this study. Further studies with a larger group of patients are necessary for greater reliability. In addition, long-term results, complications and loss of improvement in extension were not included in this study. However, the purpose of this study was to evaluate intra-postoperative improvement after the procedure in order to assist in preoperative planning.

In conclusion, both semitendinosus and gastrocnemius tenotomy appeared to improve popliteal angle in patients with CP. We believe that this data can help surgeons in the preoperative planning for the treatment of knee flexion deformity in CP. In this manner, overcorrection or recurrence can be avoided.

Conflics of Interest: No conflicts declared.

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