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Research Article

Therapeutic Lag Extension of the Knee After Quadricepsplasty in Children

Nguyen Ngoc Hung*

Surgical Department, Vietnam National Hospital for Pediatric, Ha Noi Medical University, Vietnam

***Corresponding Author:** Nguyen Ngoc Hung, Surgical Department, Vietnam National Hospital for Pediatric, Ha Noi Medical University, Vietnam.

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Abstract

Objective: Evaluating long-term follow-up of the rectus femoris lengthening for the Payr-Thompson procedure with transferring iliotibial band restores extension function.

Introduction: Retractile fibrosis of the quadriceps is a physical and social handicap in children, and often results from a past history of quadriceps intramuscular injection. The aim of this study was to evaluate the therapeutic results of fibrous quadriceps treated by distal quadricepsplasty using a transferring Iliotibial band (TITB) regain knee extension function.

Materials and Methods: This is a descriptive retrospective 21 year study from 2003 to 2020, including 103 children (113 knees) less than 9 years old. Clinical were: all of Patients knee flexion loss of motion 113 (100%), without associated Genu recurvatum or Dislocation of the patella. Quadricepsplasty with Payr or Thonpson procedure, and reconstruction knee function by transferring Iliotibial band.

Results: The pre-operative range of flexion varied from 5° to 32° with a mean range of 22.5°. The post-operative range was 75° to 140°. The improvement in the range of flexion varied from 5° to 140° with a mean gain of 95°. At the final follow-up, the mean active flexion was 123.5° (85 to 140). The final mean gain in movement was 97.6° (25 to 135). The mean pre-operative ROM was 37.9° (0° to 35°). The mean ROM achieved at operation was 115.9° (75° to 140°). Mean flexion ROM after surgery was 77.7°. Mean flexion increased from 77.7° to 108.5° following postoperative rehabilitation or a mean gain of 30.7°. Accepted result 40 (74.1%) in Variant 1; 59 (100%) in Variant 2; 109 (96.5%) in all patients Postoperative results were more acceptable for V2 than V1 (P-value: 0.0000118).

Conclusion: Quadriceps contracture is a condition quadriceps is contracted due to various causes. Various surgical options are available based on location of contracture, age, cause and duration of the contracture. Transferring Iliotibial band to quadriceps after quadricepsplasty.

Keywords: *Retractile Fibrosis of the Quadriceps; Plasty; Child; Quadriceps Contracture; Transferring Iliotibial Band*

Introduction

Neonatal quadriceps contracture is a condition first described by Hnevkovsky in 1961 [1]. In the following years, many articles related to this condition were published. Initially, quadriceps contracture was considered a congenital disease. Todd was the first to emphasize the relationship between neonatal quadriceps contracture and intramuscular injections [2]. By 1964, it was generally believed that the disease was iatrogenic [3,4].

Quadrupes contracture occurs after adhesions due to intramuscular injections into the anterolateral aspect of the thigh during infancy and childhood [2,4-6]. The first obvious signs appear at 2 years of age. Affected children are often born prematurely and require multiple hospitalizations in the first 6 months of life, during which time they receive intramuscular antibiotics (most commonly penicillin or aminoglycosides [7-9]. Quadriceps femoris is a common clinical entity in infants and young children, characterized by changes in the normal extensor mechanism of the knee joint due to fibrofatty replacement of the quadriceps muscle. It was once thought to occur as an idiopathic or congenital condition [10,11], but has since been considered a sequela of multiple injections [12,13]. Injection-induced myofibromatosis has also been reported in other muscles [14-17].

Limping, walking with stiff knees, and limited knee flexion after multiple injections of antibiotics into the quadriceps muscle in infants and young children have been reported over the past 80 years, mainly in Asian and African countries [1,18]. Common intramuscular injection sites the most common sites are the gluteus medius, deltoid, vastus lateralis, and rectus femoris. Although there have been reports of difficulty walking after thigh injections, these sites are still recommended in current practice guidelines [19,20]. Skin dimples on the anterior and lateral thighs indicate a history of intramuscular antibiotic injections in childhood, confirmed by the parents. Knee flexion below 45° causes gait problems and hinders daily activities [21]. This leads to severe disability and affects the entire individual, especially in countries such as those in Asia and Africa where people sit on the floor and squat for various purposes such as farm work or defecation.

Three treatment approaches have been used: conservative, distal quadriceps myoplasty, and proximal release. Several surgical approaches to quadriceps myoplasty have been described, such as the Thompson and Judet techniques and their modifications [22,23], and early proximal release and late distal release are recommended treatments [24]. Distal quadriceps myoplasty such as the Thompson or V-Y flap should not be performed in adults because it results in a significant permanent knee extension lag, especially when lengthening of the quadriceps tendon is required [22,23]. This extension lag can also occur in children, but because children are growing and constantly re-stretch the quadriceps muscle, it can be reversed [25]. The best method to achieve knee flexion is the Judet quadriceps myoplasty [23,26]. This is a proximal quadriceps slippage that addresses all elements of knee spasticity. There are various surgical options depending on the location of spasticity, age, cause, and duration of spasticity.

Several methods of quadriceps reconstruction have been described, such as the Thompson and Judet techniques and their variations [27,28]. The most common complications are skin necrosis and delayed active extension after the Payr-Thompson procedure. Thompson quadriceps reconstruction can be complicated by skin necrosis and complete loss of extension [26,29-32].

We performed a retrospective long-term follow-up of the rectus femoris lengthening for the Payr-Thompson procedure with transferring iliotibial band restores extension function.

Materials and Methods

A retrospective study was carried out to evaluate the results of surgical techniques performed from December 2003 to August 2020 in 112 patients (158 knees) with knee stiffness. The operations were performed by single surgeon (Author) and the evaluation by three independent orthopaedic surgeons, who were not members of the department.

There were 112 patients who underwent surgery, 5 patients were lost to follow-up, 4 patients did not have enough time for follow-up; thus, 103 patients remained in this study.

Informed consent was obtained from all participants. The study had the approval of the Ethical Review Committee of our Institute and was carried out in accordance with the tenets of the Declaration of Helsinki.

They were operated separating the adherence between the vastus intermedius tendon and the rectus femoris tendon. Next, dividing the vastus intermedius tendon at the musculotendinous junction, 5 cm above the patella. If knee flexion > 90° was not achieved, the rectus femoris was detached 2 cm above the superior border of the patella, two tendons, the vastus intermedius, and the rectus femoris, being sewn together according to Nguyen NH., *et al.* [33]. When the rectus femoris was lengthened or divided it was as a last resort for gaining flexion, because that procedure diminishes the power of extension of the knee postoperatively [34]. The patients were excluded from the study due to be knee stiffness with genu recurvatum or knee stiffness with Dislocation of the patella.

There were 9 patients (12 knees) were lost to follow-up before the end of this study. The remaining 103 patients (113 knees) formed the basis of this study; there were 71 women (68.9%) and 32 men (31.1%). Thirty-one of the children (30.1%) were born prematurely. There an average age at time operation were 3 years 2 months (range 12 months to 9 years). Unilateral involvement was most common, with the left knee affected in 30 patients (29.1%) and the right knee affected in 63 patients (61.2%). Both the knees were involved in 10 patients (9.7%). In 11 patients, the condition was also associated with the triceps and deltoid muscles, likely due to a similar process.

Preoperatively, information was obtained about the type and quantity of medication that had been injected, history of trauma, age at the onset of symptoms, duration of symptoms, associated contractures, localized skin changes, pain, cosmetic problems, and changes in functional activities.

Their parents were usually aware of the difficulty their child had in squatting, kneeling, sitting cross-legged, running, or climbing stairs.

The range of movement (ROM) of the knee was measured at each visit by the surgeon who had performed the operation (SBH) using a goniometer with 30 cm movable arms and a scale marked in 1° increments.

The range of knee movement was measured first with the hip flexed and then with it extended. The stationary arm of the goniometer was placed parallel to the long axis of the femur along a line extending from the greater trochanter to the lateral condyle, and the movable arm was placed parallel to the long axis of the fibula, between the head of the fibula and the lateral malleolus.

To measure EL the examiner placed a clenched fist under the patient's heel so that the extremity was clear of the table. The patient was then asked to tighten the quadriceps muscle by pushing his knee down toward the table. With his other hand, the examiner palpated the quadriceps tendon at the superior pole of the patella to ensure that the muscle was exerting a force [35].

The quadriceps always was wasted and felt firm and fibrous. The patella was small and high. In a number of patients there were injection scars, including a dimple on the skin in the mid-part of the thigh which became more prominent with flexion of the knee (Figure 1). This was caused by adherence of the muscle to the skin and indicated the site of abscess formation following the intramuscular injection.

Operative technique

We performing operation separate two variant:

Figure 1: *Dimple in the anterolateral aspect of the thigh.*

- Variant 1 (54 knees): The operation separating the adherence between the vastus intermedius tendon and the rectus femoris tendon. Next, dividing the vastus intermedius tendon at the musculotendinous junction, 5 cm above the patella. If knee flexion > 90° was not achieved, the rectus femoris was detached 2 cm above the superior border of the patella. The proximal tendinous end of the vastus intermedius and the distal portion of the rectus femoris tendon are then overlapped and sutured together with the knee in 60° of flexion [33].
- Variant 2 (59 knees): Transferring Iliotibial band to position of the proximal tendinous end of the vastus intermedius and the distal portion of the rectus femoris tendon have been overlapped and sutured together with the knee in 20° of flexion.

Patient positioning

The patient was positioned supine on a standard operating table, placed under general anesthesia, with a sandbag behind the knee to keep it in between 5° and 10° of flexion; the anterolateral part of the thigh was exposed. We used the anterolateral approach that extended from the mid-third of the thigh to the tibial tuberosity, and a slightly curved lateral border of the patella (Figure 2). The subcutaneous tissues were undermined sufficiently to create a skin flap that would allow us to expose the quadriceps muscle, the iliotibial tract. The incision continued proximally, lateral to the rectus femoris tendon, thus fully releasing the vastus lateralis and vastus medialis. Any abnormal attachments of the iliotibial tract to the patella and to the lateral capsule were incised longitudinally. It was always necessary to detach the insertion of the vastus lateralis from the patella, separating it from the rectus femoris medially and the iliotibial tract laterally, then mobilizing it proximally (Figure 2). The vastus medialis was released for a distance of 2-8 cm in an attempt to obtain a straight-line pull.

Figure 2: *Skin incision.*

Variant 1: Lengthening the rectus femoris and vastus intermedius. We separated the adherence between the vastus intermedius tendon and the rectus femoris tendon. Next, we divided the vastus intermedius tendon at the musculotendinous junction, 5 cm above the patella. We performed knee flexion; If knee flexion > 90° was not achieved, the rectus femoris was detached 2 cm above the superior border of the patella, two tendons, the vastus intermedius, and the rectus femoris, being sewn together with using No. 2 Ethibond sutures while the knee was flexed at 60° (Figure 3) (variant 2). Finally, the remaining vastus intermedius muscle was sutured to the rectus femoris.

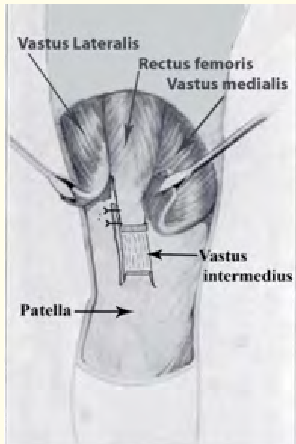


Figure 3: *The vastus intermedius and the rectus femoris, being sewn together with the knee in 20° of flexion by No. 2 Ethibond.*

Variant 2: The same variant 1 and transferring the iliotibial band. Extending incision in Variant 1 to just below the greater trochanter 4 cm. The edges of the skin are then reflected on each side by blunt dissection, fully exposing the fascia lata from the middle of the thigh to the inferior edge of the lateral surface. It is important that the reflection of the skin should be sufficiently wide to expose the insertion of the gluteus maximus into the fascia lata. A strip about half an inch in width is dissected free, to the part of the iliotibial band which is well defined. Beginning about two inches above the knee joint, the strip of the fascia lata which includes the iliotibial band is widened gradually toward the upper third of the thigh. Next step, transfer end of the iliotibial band to site the vastus intermedius and the distal portion of the rectus femoris tendon are overlapped and sutured together with the knee in 20° of flexion by No. 2 Ethibond (Figure 4). As in figure 4 transfer end of the iliotibial band to site the vastus intermedius and the distal portion of the rectus femoris tendon are overlapped and sutured together with the knee in 20° of flexion.

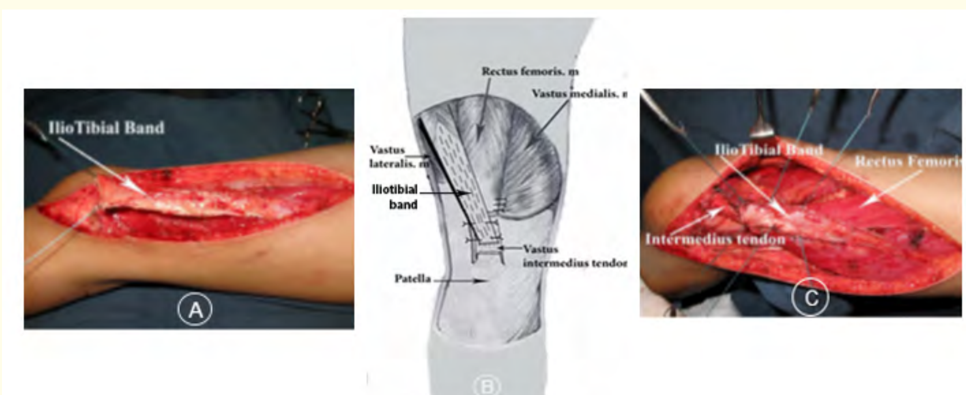


Figure 4A-4C: *A: Expose Iliotibial Band; B and C: Transfer end of the iliotibial band to site the vastus intermedius and the distal portion of the rectus femoris tendon are overlapped and sutured together with the knee in 20° of flexion.*

One surgeon (the author) performed all operations.

Postoperative rehabilitation

Postoperatively, the knee was placed in a double-capsule cast with the knee flexed at 60°. This was a long-leg cast (Figure 5). The cast could be removed easily for knee mobilization physical therapy and then be replaced after-wards.

Figure 5: *Knee was placed in a double-capsule cast with the knee flexed at 60°.*

Thereafter, the knee is kept in full extension during the night and exercised during the day on counterbalanced slings. The patient was allowed out of bed 1 day after the operation. Static quadriceps exercises and gentle knee movements (passive range of motion not > 60°, equal knee flexed at 60° were permitted, but more vigorous or extensive movements were discouraged during the first week, in order to minimize effusion or bleeding. In the first 2 weeks, a passive range of motion up to 60° and under 90° was performed with the physiotherapist. After 2 weeks, the range of motion was increased up to 90° (note: the limitations on the range of motion and weight-bearing counted only for the exercise periods, and outside of the exercise times, the cast had to be worn). After 3 weeks, the range of motion was increased to normal. The cast was removed after about 6 weeks, but without weight-bearing. After-wards, patients were allowed to bear 25% of their body weight for the first 2 weeks, and 50% of their body weight in the following 2 weeks. Full weight-bearing was allowed between the fourth and sixth weeks after cast removal

Critical results

The final results were assessed by Judet's criteria [37] with knee: excellent, if flexion was greater than 100°; good, from 81° to 100°; fair, from 50° to 80°; and poor, if less than 50° flexion, and addition of extension lag with persistent extension lag of 15°, it did not interfere with the activities of daily living or work [38]. The patients with poor results always had a considerable lag in extension. Any patients with full flexion but poor power of the quadriceps muscle (graded less than 2) were also included in the group with poor results [34].

	Excellent	Good	Fair	Poor
Flexion	.> 100°	> 80° - £ 100°	≥ 50° - £ 80°	< 50°
Extension lag	0° - £ 5°	> 5° - £ 15°	> 15° - £ 30°	> 30°

Table 1*: The final results were assessed by Judet's criteria [37], and addition of extension lag with persistent extension lag.*

The patients with poor results always had a considerable lag in extension. Any patients with full flexion but poor power of the quadriceps muscle (graded less than 2) were also included in the group with poor results [34].

Follow-up

All patients were examined and evaluated by three other doctors, at follow-up times of 3, 6 weeks, 3, 6 months, 1 year, and afterwards every year. At final follow-up, after an average period of 22 years, 4 months (range 19 years, 6 months to 31 years, 8 months), the average patient age was 10 years, 9 months (range 9 years, 4 months to 15 years, 6 months). The critical result according to Judet's criteria [37] (Table 1).

There were 103 patients, the mean age of the patients at time operation was 37 months (12 to 81 months). The mean follow-up was 22 years, 4 months (range 19 years, 6 months to 31 years, 8 months).

The mean age of the patients at time operation was 37 months (12 to 81 months). The mean follow-up was 22.6 years (19.4 - 31.8 years).

Statistical analysis

The paired-samples *t*-test was used for comparison between the pre-operative and the final ROM of the knee. Univariate regression analysis was performed to determine whether there was a significant association between each of the pre-operative and operation-related variables and the final gain in flexion. All analyses were performed with SPSS, version 12.0 (SPSS Inc., Chicago, Illinois) and a p-value < 0.05 was considered significant.

Result

There were 103 patients, the mean age of the patients at time operation was 37 months (12 to 81 months). The mean age at final follow-up was 23 years, 2 months old (range, 24 years, 6 months to 32 years, 7 months old). The mean follow-up was 22.6 years (19.4 - 31.8 years).

The age of 4-6 years (58.3%) was the most affected. Onset of contraction after injection was 6 months (range: 3-15 months).

Thigh amyotrophy was found in all cases of stiffness. In the case of unilateral knee stiffness, the mean difference between thighs' circumferences was 3.65 cm (range: 2.2-5.5 cm).

The Eighteen of patients there were injection scars, including a dimple on the skin in the mid-part of the thigh which became more prominent with flexion of the knee. This was caused by adherence of the muscle to the skin and indicated the site of abscess formation following the intramuscular injection.

The main complaint of these patients was inability to squat, which is a great physical and social handicap in the East. In one patient the presenting symptom was habitual lateral dislocation of the patella.

The pre-operative range of flexion varied from 5° to 32° with a mean range of 22.5°. The post-operative range was 75° to 140°. The improvement in the range of flexion varied from 5° to 140° with a mean gain of 95°.

At the final follow-up, the mean active flexion was 123.5° (85 to 140). The final mean gain in movement was 97.6° (25 to 135).

The mean pre-operative ROM was 37.9° (0° to 35°). The mean ROM achieved at operation was 115.9° (75° to 140°). Mean flexion ROM after surgery was 77.7°. Mean flexion increased from 77.7° to 108.5° following postoperative rehabilitation or a mean gain of 30.7°.

The quadriceps muscle testing scores were at least 3/5.

Motion

At the time of the final follow-up, the average maximum amount of flexion was 115° (range, 85° to 140°), indicating a mean flexion gain of 86° (range, 44° to 126°) (Table 2).

In our series, the mean maximum flexion was 112.5° (55° to 150°) and the mean ROM was 110.4° (55° to 150°), with 70.3° (5° to 110°) of mean flexion gain at a mean follow-up of 22.6 years.

	Average (Range)		
	V 1 (54 knees)	**V 2 (59 knees)**	**Total (113 knees)**
Knee flexion after 6 Months	76° (65° - 135°)	71° (60° - 130°)	73° (60° - 135°)
Knee flexion after 1 year	93° (78° - 140°)	90° (82° - 140°)	92° (78° - 140°)
Knee flexion after 2 years	104° (85° - 140°)	115° (90° - 140°)	109° (85° - 140°)
Knee flexion after 3 years	113° (94° - 140°)	118° (98° - 140°)	115° (94° - 140°)
Knee flexion end fellow-up	121° (120° - 140°)	128° (125° - 140°)	125° (120° - 140°)

Table 2: *Knee flexion.*

Knee flexion were improved from mean 73° (60° - 135°) in postoperative 6 months to 125° (120° - 140°) end fellow-up.

	Variant 1 (54 knees)		**Variant 2 (59 knees)**	
	Number (%)	**Average (Range)**	**Number (%)**	**Average (Range)**
Extension lag after 6 Months	22 (40.7)	38° (25° - 46°)	21 (35.6%)	36° (27° - 41°)
Extension lag after 1 year	18 (33.3)	28° (21° - 37°)	17 (20.8)	26° (20° - 32°)
Extension lag after 2 year	14 (25.9)	23° (18° - 35°)	6 (10.2)	15° (12° - 18°)
Extension lag after 3 year	9 (16.7)	21° (14° - 35°)	3 (5.1%)	10° (12° - 15°)
Extension lag end fellow-up	4 (7.8)	19° (14° - 34°)	2 (3.4)	9° (8° - 10°)

Table 3*: Extension lag.*

Extension lag were improved from 38° to 19° in variant 1, and 36° to 9° in variant 2. At end follow-up, Extension lag mean 19°, 2 knees with > 30° in Variant 1; and Extension lag mean 9° in Variant 2 (Table 3).

	V 1 (54 knees)	V 2 (59 knees)	Total (113 knees)
Excellent	31 (57.4%)	47 (79.7%)	78 (69.1%)
Good	19 (35.2%)	12 (20.3%)	31 (27.5%)
Fair	2 (3.7%)	0	2 (1.7%)
Poor	2 (3.7%)	0	2 (1.7%)

***Table 4**: Find results.*

Accepted result 40 (74.1%) in Variant 1; 59 (100%) in Variant 2; 109 (96.5%) in all patients.

Postoperative results were more acceptable for V2 than V1 (P-value: 0.0000118).

***Figure 6:** Extension lag 34.1° in variant 1.*

***Figure 7:** Extension lag 5.0° in Variant 2.*

At end follow-up, Extension lag mean 19˚, 2 knees with > 30˚ in Variant 1 (Figure 6); and Extension lag mean 9˚ in Variant 2 (Figure 7).

The results of surgical quadricepsplasty (Table 4).

Complications

There were not skin necrosis or sutures anomalies after operation. Four cases (3.5%) of femoral metaphyseal fractures occurred during rehabilitation exercises with the arrest of the process and immobilisation in flexion by plaster In terms of outcome, all patients had a rating of power in the quadriceps muscle above 3/5 at the end of the rehabilitation. There were 21 cases (18.6%) of poorly looking postoperative scars; with Hematoma in 1 (0.9%) and without Femoral nerve tear, Quadriceps tendon tear. Loss of active extension 2 knees with > 30° in Variant 1.

Discussion

Anatomic consideration

It is believed that the vastus lateralis fascia plays a very important role in hip flexion contractures and other common deformities of the lower limb, and there are certain anatomical reasons that need special consideration.

In addition to abducting the hip, the vastus lateralis fascia performs an additional function, namely tensing the vastus lateralis muscle. In this function, the vastus lateralis fascia always works in conjunction with another vastus lateralis fascia, i.e. the gluteus maximus. The anatomical relationship between these structures is so close that a proportional functional relationship can be assumed.

The vastus lateralis originates from the anterior part of the lateral lip of the iliac crest and from the lateral surface of the anterior superior spinous process and part of the lateral border of the inferior notch.

Its origin lies between the gluteus medius muscle laterally and the sartorius muscle medially. It becomes tendinous approximately 13 cm from its origin and merges with the superficial layers of the vastus lateralis muscle. Gray describes the integration of the structures of the lateral thigh as follows: "The vastus lateralis muscle forms a uniform covering over the entire region of this limb, but its thickness varies in different parts; thus it is thicker in the upper and outer parts of the thigh, where it receives fibrous expansion from the gluteus maximus, and the taut femoris fascia is inserted between its layers… and again becomes stronger around the knee, receiving fibrous expansion from the biceps tendon laterally, from the sartorius laterally, and from the quadriceps anteriorly". Laterally, the vastus lateralis muscle receives most of the tendon insertions of the gluteus maximus and becomes proportionally thicker.

The vastus lateralis fascia originates from the anterior part of the upper part of the pelvis, corresponding to the origin of the femoral fascia, and passes over the lateral thigh in two layers, one superficial and one underlying this muscle. The superficial layer is a continuation of the gluteus maximus tendon and the superficial layer is a continuation of the fascia femoris tendon, but receives some fibers from the fascia covering the gluteus medius. These layers at the lower end of the muscle merge into a thick and strong band. This band continues downwards under the name of the iliotibial band, to attach to the lateral tuberosity of the tibia. It should be noted that the fascial band is attached to the femur over its entire length by septa between the muscles originating from it, of which the lateral septa are stronger. Points of practical importance in this described anatomy from the point of view of the deformities under consideration are: First, the majority of the insertion of the gluteus maximus is on the vastus fascia and not on the femur. This suggests that it is both a tensor of the vastus fascia and an extensor of the thigh. Second, the gluteus maximus, being a tensor of the fascia, is closely related to a separate tensor fascia and these extend down the thigh as a separate thick band (iliotibial band), which has its main insertion on the tibial tuberosity. When discussing the relative functions of these structures, Gray says: "The femoral fascia is a tensor of the broad fascia. In the upright position, acting from below, it stabilizes the pelvis on the femoral head.

Lag extension of the knee with daily active and restore power extension

Loss of knee extension is a serious condition that causes significant disability, including the inability to run, climb stairs, drive, and even walk unassisted. Most cases are medical in origin, but trauma and malignancy can also occur.

Reconstructive options after loss of quadriceps function are not well described despite their disabling effects. Nerve grafts are widely used, but the proximal limb stump can be difficult to identify and access. Our group and others have pioneered nerve transfers from the obturator to the femoral nerve to restore function. However, many patients have end-stage target muscle atrophy or have injuries or pathologies involving the quadriceps that preclude nerve transfers. More aggressive options, including functional free flaps, have been described, but not everyone tolerates them.

In patients unsuitable for nerve- or microvascular-based reconstruction, pedicled muscle transfers remain an option. These methods have been performed for decades in the upper limb with excellent results, although they have not been well characterized in the lower limb. Optimally, the donor muscle can replace and synergize with the recipient muscle, as the donor muscle functions in a straight line of pull. The donor muscle also requires strength and displacement to match the desired movement, which limits lower limb reconstruction due to the greater biomechanical demands of the donor muscle compared to the upper limb.

Previous attempts to use muscle transfers in the lower limb have focused on plantar flexion at the Achilles tendon and assistance of the intact quadriceps femoris by the knee flexors, rather than restoring knee extension function. Previous attempts to restore knee extension function have used the knee flexors and required extensive transposition and training of antagonist muscles with a spiral line of pull, resulting in suboptimal results.

We propose the Iliotibial Band as a muscle that is potentially more suited to knee extension. Because of its location and function, it works in conjunction with the quadriceps femoris and requires less surgical dissection and transposition, and provides a straighter line of pull than the hamstrings. Furthermore, it remains functional in isolated femoral nerve palsy. Its relatively larger size compared to other options described, such as the gracilis or sartorius, and its attrition profile suggest that it can withstand the large loads required to replace quadriceps femoris function without compromising hip adduction, making it a more ideal choice when used alone or in combination with other muscles. We describe the Iliotibial Band as a muscle transfer to restore knee extension in patients who are too late for nerve-based reconstruction, along with other donor muscles, such as the gracilis, sartorius, or vastus lateralis (TFL), to maximize stability and strength. We detail the anatomical considerations of this transfer and report the outcomes of patients who have undergone this procedure.

Cause fibrotic quadriceps muscle

Quadriceps femoris contractures in children can be congenital or secondary to various causes. This study discusses quadriceps contractures, which were caused by injections into the thigh muscle and resulted in progressive painless limitation of knee flexion [37]. All children had severe disease from the first weeks of life and had received intramuscular injections into the thigh. All patients noted a dimple in the thigh [4]. The mechanism by which these injection-induced contractures develop remains speculative. In neonates and young children, the muscle mass is small, and in most preterm infants in the study, the muscle mass was even smaller [39]. Due to the volume of drug injected, muscle and capillary compression may result in significant muscle ischemia [13]. Experimental trauma from a single intramuscular injection appears to cause disruption of muscle fibers with subsequent local necrosis and fibrosis [40]; local toxicity of the drug may also play an important role [10]. It is interesting to note that the muscle damage following injection differs from that caused by vascular injury. Unlike the elliptical forearm MI [41], in which Volkman contracture develops immediately, thigh contracture is significantly delayed after injection therapy. In our study, the age of admission ranged from 1 to 9 years. Williams [42] has suggested that injection-induced contracture may be related to the uneven growth of muscle and bone. Initially, healthy distal muscle fibers can compensate for bone growth, and therefore, no obvious impact on the knee is seen for several years after injection. Subsequently, contractures reach a point where healthy muscle can no longer lengthen in proportion to bone growth and become evident. The discrepancy between bone and muscle growth cannot be the sole cause of the patient's worsening condition. If this type of contracture is left untreated, secondary changes may occur in the soft tissues, cartilage, and bones of the adjacent joint [43]. Some authors have observed good results achieved through surgical reimplantation of the thigh muscle to mobilize the knee. The adductor muscle is usually asymptomatic, and any symptoms are due to its potential for nerve compression [44,45] or localized compartment syndrome during exercise [5]. In some cases, it can mimic a soft tissue tumor [46-48]. We believe that the progressive limitation of knee flexion in our patient was due to the lack of elasticity of the adductor muscle, which becomes a ligament as the femur grows. The muscle belly is short compared to its long tendon [49].

Surgical Quadricepsplasty

Quadriceps reconstruction is a major operation; the ability to achieve a successful range of knee flexion depends on both the surgeon and the patient. To achieve a good outcome, preparation begins preoperatively with patient education on knee exercises; the postoperative period is continued with meticulous debridement and hemostasis, followed by adherence to a strict postoperative physical therapy regimen combined with the patient's strong will and ability to prevent quadriceps inhibition, allowing for strengthening and strengthening of the quadriceps and hamstrings. Patients should be warned of a slight extension lag that may be experienced during follow-up.

Among the quadriceps reconstruction techniques, the Thompson and Judet techniques are the most common. The most obvious difference between the two techniques is the location of the quadriceps release: the release is at the insertion site in the Thompson technique [37].

Therefore, the Judet quadriceps myoplasty requires a much wider dissection and cannot be performed with a tourniquet. On the other hand, the Thompson technique has inherent weaknesses, such as delayed wound healing, infection, and extension lag due to separation of the rectus femoris from the rest of the quadriceps through an anterior midline incision [50,51], which is the main reason why improvements to this technique have been sought, and proximal release in the early stage and distal release in the later stage are the recommended treatments [21] (See table 2).

The Thompson quadriceps myoplasty [52] and its variants [23] involve complete separation of the rectus femoris from the vastus lateralis, release of the vastus lateralis and vastus lateralis from the patellar attachment, and lengthening of the rectus femoris when necessary. These procedures can result in significant extensor weakness and extension lag [19,23]. Extension lag after quadriceps femoris myoplasty has been widely reported in the literature with rates ranging from 8° to 61.1° [19,22,23,37,51-57]. The length of the rectus femoris muscle has been implicated as a causative factor [19]. All patients with extension lag gradually improved their extension strength and reduced lag with quadriceps stretching and strengthening exercises. The extension lag resolved between three months and ten years postoperatively [34,43,56-60]. In this study, extension lag remained at 34° in two cases 21 years postoperatively (See table 3).

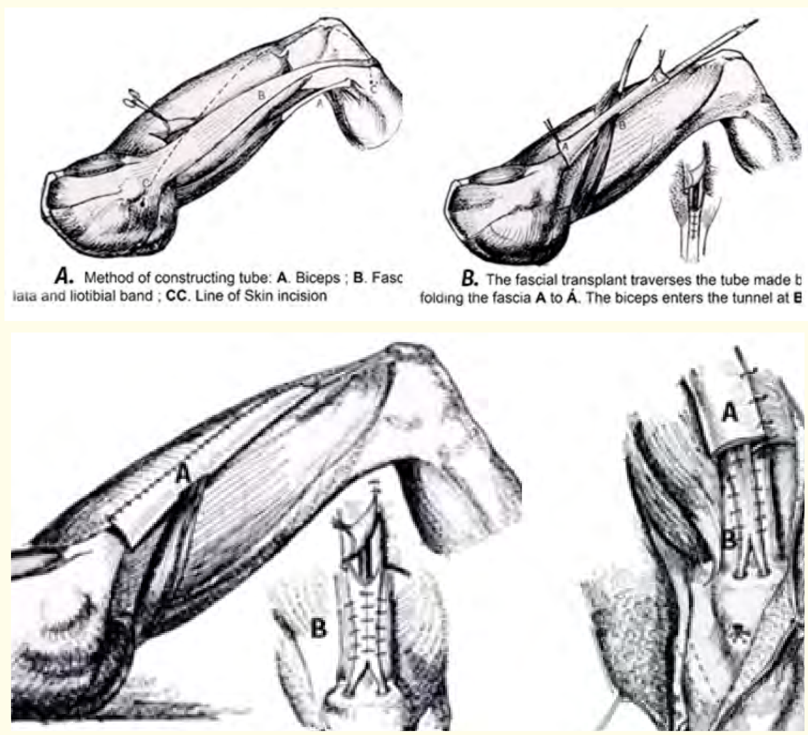
Despite some complications, most of our patients achieved significant improvement in knee flexion after quadriceps femoris myoplasty at two or more years of follow-up. We recommend that surgeons consider lengthening the rectus femoris if the desired degree of knee flexion cannot be achieved with gentle passive manipulation after release of periarticular adhesions to avoid disruption of the extensor muscles. If full flexion and extension cannot be maintained, full extension should be the primary goal [30]. We agree with Hesketh's opinion that the original Thompson technique should be used in surgery [61]. It is important not to use a tourniquet, as many large vessels are cut during dissection, especially in the peripatellar region, and these must be seen and fixed. Diathermy is most useful for dividing the vastus lateralis muscle and treating multiple small bleeding points, especially in areas with severe scarring. In the first two cases, blood transfusions are required, but with careful hemostasis, this is no longer necessary. Hematomas can significantly slow progression. We agree with Gbenou [62] that when lengthening the quadriceps femoris, the proximal vastus intermedius tendon head and the distal rectus femoris tendon are then overlapped and sutured together with the knee at 60° flexion to reduce the risk of creating an extension lag and that even in cases with a preoperative 90° flexion angle, V-Y reconstruction of the rectus femoris should not be performed [21]. According to Wang., *et al*. [63], surgical lengthening of the suture at 90° of knee flexion can lead to significant impairment of the extensor mechanism and extension lag.

Techniques for reconstructing the knee extensor mechanism have been described since the late 19th century [63] with modern techniques originating from those originally developed in polio patients [65,66].

The need for knee extension rehabilitation is uncommon, but the inability to control active extension is a potentially devastating problem that occurs after quadriceps resection in patients with sarcoma, femoral nerve dysfunction, trauma, paralysis, and chronic complex tendon ruptures [65-67].

Transferring muscle for repower extension of quadriceps

Some are transferred to the quadriceps



C. A: Exposed and transferring Iliotibial band TO Quadriceps; B: Fixating distal Quadriceps and Patella. D. A: Transferring Iliotibial band; to B: with Quadriceps and Patella.

***Figure 8A-8D:** A: Some procedures transferring muscles; B: Transferring Fascia latae to Quadriceps; C: Transferring Iliotibial band to Quadriceps; D: Fixating Iliotibial band with distal Quadriceps and Patella.*

Several other muscle movements have been described, but their functional outcomes have not been independently reported (Figure 8). Among them is the vastus lateralis fascia movement described by Ober in 1933 [68]. In 1925, Spitzy proposed transposition of the iliotibial band onto the patella as a treatment for quadriceps paralysis following poliomyelitis [69,70]. His proposal was based on the fact that the musculofascial pathway spans both joints, lying anterior to the axis of motion of the hip and posterolateral to the knee. When the hip joint is lengthened, its musculofascial pathway also lengthens and stabilizes the knee. He also pointed out, like Erlacher [71], that the vastus lateralis muscle is usually not paralyzed when the thigh flexors are affected. In 1933, Ober pointed out the risk of scoliosis after hamstring transposition and proposed the use of the vastus lateralis and sartorius muscles instead [72]. In 1926, Yount proposed iliotibial band transposition [72] and in 1938 presented his series of 16 cases in which good results were obtained [73]. In half of these cases, the biceps femoris was used in conjunction with muscle bundles. Apart from isolated case reports [74,75], no other series using iliotibial band transposition as the sole treatment for quadriceps paralysis have been published. In 1940, Debrunner [76] showed that the muscle strength required to transmit the stabilizing forces of the knee joint to the ligaments is small. We performed iliotibial band transposition in 59 knees. Comparison of extension lag showed that extension lag improved from 38° to 19° in variant 1 and from 36° to 9° in variant 2. At the end of the follow-up period, the average extension lag was 19°, with 2 knees having an extension lag > 30° in variant 1; and the average extension lag was 9° in variant 2; The results of the reconstruction of the iliotibial ligament and the transferred quadriceps muscle showed that the final results were 100% acceptable (See table 4).

Parents were often aware that their child had difficulty squatting, kneeling, sitting cross-legged, running, or climbing stairs. In each case, the affected leg had a dimple in the thigh, which deepened with forceful knee flexion [77].

Gbenou., *et al*. [78] and Shivaprasad., *et al*. [79] used the increase in knee flexion and quality of walking as measures of treatment outcome. Outcomes were rated as "good" if flexion was greater than 90°, allowing normal walking and squatting, which is often necessary for toileting and farming in African and Asian countries. Outcomes were rated as "acceptable" if flexion was between 45° and 90°, gait was normal, and a comfortable sitting position was achieved. Outcomes were rated as "poor" if flexion was less than 45°, accompanied by limping and uncomfortable sitting.

Knee flexion less than 45° interferes with the patient's normal gait and causes gait problems and interferes with daily activities [80,81].

Authors in different countries have different results regarding daily activities, knee flexion angle and important postoperative outcomes (Table 5 and 6).

	Judet [37]	**Gbenou [78]**	**Petrea [82]**	**Mukherjee [34]**	**Hung (in this study)**
Excellent	Over 100°		Over 110°		>100° + ≤ 5°EL
Good	80° - 100°	Over 90°	90 - 110°	90 - 135°	80°- ≤ 100°+ > 5°- ≤ 15°EL
Satisfactory	50 - 80°	45 - 90°			
Very poor	Sub 50°	Under 45°			
Moderate			70 - 90°		
Fair				45 - 90°	≥50°- £80°+> 15°- £ 30°EL
Poor			Under 70°	Under 45°	< 50° + > 30° EL

Table 5: *Critical result.*

EL: Extension Lag.

Author	Procedure	Excellent	Good	Fair	Poor
Hněvkovsky (1961) [1]	Bennett's	0%	70%	30%	-
Bos and Chong (1976) [43]	Thompson's/Bennett's	55%	25%	20%	-
Mukherjee and Das (1968) [34]	Thompson's/Bennett's	15%	60%	10%	5%
Jackson and Hutton (1985) [60]	Thompson's	45%	45%	10%	-
Hung - Variant 1 (2020)	Payr's / Hung's	57.4%	35.2%	3.7%	3.7%
Hung - Variant 2 (2020)	Payr's / Hung's and TITB*	79.7%	20.3%	-	-

Table 6: *Compare results of surgical quadricepsplasty and it was transferred iliotibial band.*

TITB: Transferred IlioTibial Band.*

Conclusion

Quadrosis is a condition in which the quadriceps muscle is contracted due to various causes. There are different surgical options depending on the location of the contracture, age, cause and duration of the contracture. Early surgery provides better results and also helps prevent secondary changes in soft tissue, cartilage and bone. Physical therapy is the mainstay of post-operative treatment, not only to achieve maximum flexion but also to restore active extension. Transfer of the iliotibial ligament to the quadriceps muscle after quadriceps femoris surgery has been shown to produce good post-operative results.

Limitations of this Study

1. Retrospective study.
2. No similar study results for comparison.
3. The cause of the study was not clearly assessed as congenital or iatrogenic.

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