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Research Article

The Iliotibial Band Transfer Restores Extensor Function Post-Operative Quadriceps Plasty for Knee Stiffness in Children

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Received: November 12, 2024; **Published:** January 08, 2025

Abstract

Introduction: Quadriceps contracture is a physical and social disability in children, and is often the result of a history of intramuscular injections of the quadriceps muscle. The aim of this study was to evaluate the treatment outcomes of quadriceps fibroma treated with quadriceps myoplasty and muscle restoration using the iliotibial band (ITB) transfer method.

Materials and Methods: This is a retrospective descriptive study spanning 19 years from January 2000 to August 2018, including 146 children (185 knees). Patients were divided into two groups, from January 2000 to November 2009, in Group 1, including 70 patients (89 knees) performed with the Pary technique; and from December 2009 to December 2018, in Group 2, including 76 patients (96 knees) performed with the Pary technique and iliotibial band transfer. Final results were assessed according to the Judet criteria.

Results: The mean age at the time of surgery was 42 months (range: 22 to 162 months). The mean age at the last follow-up was 21 years, 2 months. The mean follow-up age was 18.4 years. At the last follow-up, the Extension Lag improved from 38° to 19° in Group 1 and from 36° to 9° in Group 2. At the last follow-up, the mean Extension Lag was 19° in Group 1; and Mean extension delay was 9° in Group 2. Preoperative flexion range ranged from 5° to 31° with a mean range of 23.5°. Improvement in flexion range from 5° to 140° with a mean increase of 98°. At final follow-up, mean active flexion was 123.5° (78° to 140°). Mean final range of motion increase was 96.8° (25° to 135°). Acceptable outcomes were 76 (85.4%) in Group 1; 96 (100%) in Group 2; 171 (92.4%) in all patients. Acceptable outcomes in G1 were similar to G2 (Pvalue: 0.105455); and G 2 with Excellent beter G 1 (Pvalue: 0.019132).

Conclusion: Quadriceps contracture is a condition of quadriceps contracture due to various causes. Transfer of the iliotibial ligament to the quadriceps muscle after quadriceps surgery with good postoperative results.

Keywords: *Fibrotic Contracture; Plastic Surgery; Children; Quadriceps Contracture; Iliotibial Ligament Transfer*

Introduction

Anatomy of tensor fasciae latae (cf. figure 1)

Attachments: The vastus lateralis fascia originates 5 cm anterior to the lateral border of the iliac crest, from the lateral surface of the anterior superior iliac spine and part of the inferior notch between the gluteus medius and sartorius, and from the deep surface of the vastus lateralis. Proximal attachments may extend to the superficial fascia of the gluteus medius. It descends medially and is attached to the two layers of the iliotibial line of the vastus lateralis and usually ends about one-third of the way down the thigh, although it may extend to the lateral femoral condyle.

Vascular supply: The muscle itself is supplied primarily by a large ascending branch of the lateral femoral coronary artery. The vastus lateralis fascia flap is raised on this pedicle. The superior portion of the muscle receives branches from the superior gluteal artery. The fascia surrounding the muscle is supplied superficially by the superficial iliac artery and deeply by the lateral femoral artery.

Innervation: The vastus lateralis fascia is innervated by the superior gluteal nerve, L4, 5, and S1.

The latissimus dorsi, acting via the iliotibial tract, extends the knee when the leg is rotated laterally; it may also assist in abduction and internal rotation of the thigh, although its role as an abductor is controversial. The muscle helps maintain upright posture while minimizing the energy expenditure of muscle action: when the subject is standing, it acts from below to stabilize the pelvis on the femoral head and, via the iliotibial tract, stabilizes the femoral condyles on the tibial condyles while the knee extensors are relaxed. Some authors have suggested that the iliotibial tract is more important in stabilizing the pelvis than the latissimus dorsi. The muscle assists the gluteus medius in abduction at the hip. Postural control is its primary function.

During the last 20° of extension, the pull of the iliotibial tract is anterior to the axis of knee flexion and the latissimus dorsi is therefore the weak extensor. Flexion beyond 20° causes the iliotibial tract to pass behind the flexor axis, rendering the muscle a weak flexor.

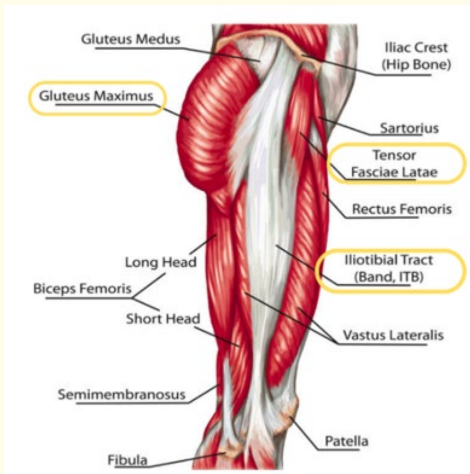

Figure 1: *Anatomy of the iliotibial tract.*

Spastic quadriceps femoris in infancy was first described by Hnevkovsky in 1961 [1]. In the following years, many articles were published on the condition. Initially, spastic quadriceps femoris was considered a congenital disease. Todd in 1861 was the first to emphasize the relationship between spastic quadriceps femoris in infancy and intramuscular injections [2]. By 1964, it was generally believed that the disease was iatrogenic. Spastic quadriceps femoris occurs after the muscles fuse together due to intramuscular injections into the anterolateral aspect of the thigh during infancy and childhood [2]. The first obvious signs appear at the age of 2 years. Affected children are often born prematurely and require multiple hospitalizations in the first 6 months of life, during which time they receive intramuscular antibiotics (usually penicillin or aminoglycosides). Quadriceps femoris is a clinical entity found in infants and young children characterized by changes in the normal extensor mechanism of the knee joint due to replacement of the quadriceps muscle by fibrofatty tissue. It was previously thought to occur as an idiopathic or congenital condition [3], but has since been considered a sequela of multiple injections [4]. Injection myopathy has also been reported in other muscles.

Lameness, stiff-knee gait, and limited knee flexion after multiple antibiotic injections into the quadriceps muscle in infants and young children have been reported over the past 50 years, primarily in Asian and African countries [1,5-7].

Assessing and treating loss of knee extension range of motion is an important part of rehabilitation after any knee surgery. Loss of knee extension range of motion can be one of the biggest contributors to knee osteoarthritis, and considering some methods of assessing and treating loss of knee extension range of motion can help maximize outcomes after knee surgery or injury while minimizing long-term complications.

Tendon transfer surgery may also be necessary when a muscle becomes fibrotic or torn and fails to heal. Common muscle or tendon injuries treated with tendon transfer surgery include tendon ruptures due to rheumatoid arthritis or surgery. Additionally, tendon tears that do not heal after injury can be treated with tendon transfer surgery.

There are many ways to treat loss of knee range of motion, however, proper assessment of range of motion is even more important. Some degree of hyperextension is normal, with studies showing an average of 5 degrees of hyperextension in men and 6 degrees in women. Simply restoring knee range of motion to 0 degrees is not beneficial. We performed ITB to strengthen the knee.

The most important factor in assessing loss of knee extension range of motion is to look at the unaffected knee. It sounds simple, but it cannot be overlooked because you need to establish a baseline of what is considered "normal" for each patient or client.

We performed a retrospective long-term follow-up after iliotibial band transfer to restore extension function.

Purpose of the Study

The purpose of this study was to evaluate the long-term results of the iliotibial band transfer technique to restore knee extension function.

Materials and Methods

A retrospective study was conducted to evaluate the outcomes of surgical techniques performed between January 2000 and August 2018 in 146 patients (185 knees) with stiff knees. Eight patients (10 knees) were lost to follow-up. The remaining 146 patients (185 knees) formed the basis for this study.

The surgeries were performed by a single surgeon (Author) and the evaluation was performed by three independent orthopaedic surgeons who were not members of the faculty.

Informed consent was obtained from all participants. The study was approved by the Ethics Review Committee of our Institute and was conducted in accordance with the principles of the Declaration of Helsinki.

We performed Surgery in two Groups (G): From January 2000 to November 2009, in G 1, including 70 patients (89 knees); and from December 2009 to December 2018, in G 2, including 76 patients (96 knees).

Before surgery, information was collected on the type and amount of injection, history of trauma, age at onset of symptoms, duration of symptoms, associated contractures, local skin changes, pain, cosmetic problems, and changes in functional activities. Parents often reported that their children had difficulty squatting, kneeling, sitting cross-legged, running, or climbing stairs.

Normal knee motion is described as 0 degrees of extension to 130 degrees of flexion [8]. Knee stiffness is when the patient has limited knee flexion. Knee range of motion (ROM) was measured at each visit by the surgeon performing the surgery (SBH) using a goniometer with a 30 cm movable arm and a scale marked in 1˚ increments. Knee range of motion was measured first with the hip flexed and then with the hip extended. The fixed 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 epicondyle, and the movable arm was placed parallel to the long axis of the fibula, midway between the head of the fibula and the lateral malleolus.

To measure Extension Latency (EL), the examiner placed a clenched fist under the patient's heel so that the foot did not touch the table. The patient was then asked to contract the quadriceps by pushing the knee down toward the table. Using the other hand, the examiner palpated the quadriceps tendon at the superior pole of the patella to ensure that the muscle was exerting force [8].

The quadriceps continued to atrophy and felt tight and fibrous. The patella is small and high. In some patients, there is an injection scar, consisting of a depression in the skin in the mid-thigh, which becomes more visible when the knee is flexed. This is due to the muscle being tightly attached to the skin and is an indication of the site of abscess formation after intramuscular injection.

Surgical technique

We perform surgery to separate the two groups.

The patient was placed supine on a standard operating table, under general anesthesia, with a sandbag behind the knee to hold the knee at a 5° to 10° angle; the anterolateral portion of the thigh was exposed. We used an anterolateral approach extending from the middle third of the thigh to the tibial tuberosity and the slightly curved lateral border of the patella. The subcutaneous tissue was weakened enough to create a skin flap that allowed us to expose the quadriceps, the iliotibial line. The incision continued proximally, lateral to the rectus femoris tendon, thereby completely releasing the vastus lateralis and vastus medialis. Any abnormal attachments of the iliotibial line to the patella and the lateral capsule were incised longitudinally. It was always necessary to dissect the vastus lateralis attachment from the patella, separate it from the rectus femoris medially and the iliotibial line laterally, and then move it proximally (cf. figure 2). The vastus medialis muscle is released 2 - 8 cm distal to attempt to straighten the line.

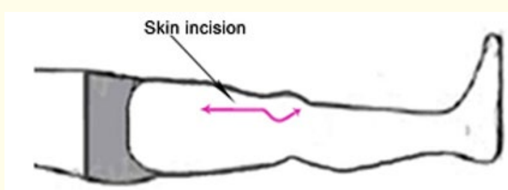

Figure 2: *Skin incision.*

Group 1-(89 knees): According to Payr's technique

We separated the adhesion between the vastus intermedius tendon and the rectus femoris tendon. Next, the vastus intermedius tendon was separated at the musculotendinous junction, 5 cm distal to the patella. If knee flexion > 90° was not achieved, the rectus femoris tendon was separated 2 cm distal to the patella. The proximal vastus intermedius tendon and the distal rectus femoris tendon were then overlapped and sutured together with the knee at 60° flexion [9].

Lengthening the rectus femoris and vastus medialis. We separated the adhesion between the vastus intermedius tendon and the rectus femoris tendon. Next, we separated the vastus intermedius tendon at the musculotendinous junction, 5 cm distal to the patella. We performed knee flexion; If the knee is not flexed >90°, the rectus femoris muscle is separated 2 cm above the superior border of the patella, the two tendons, the vastus medialis and rectus femoris, are sutured together with a No. 2 Ethibond suture while the knee is flexed at 60° (cf. figure 3) (Group 1). Finally, the remaining vastus medialis is sutured to the rectus femoris.

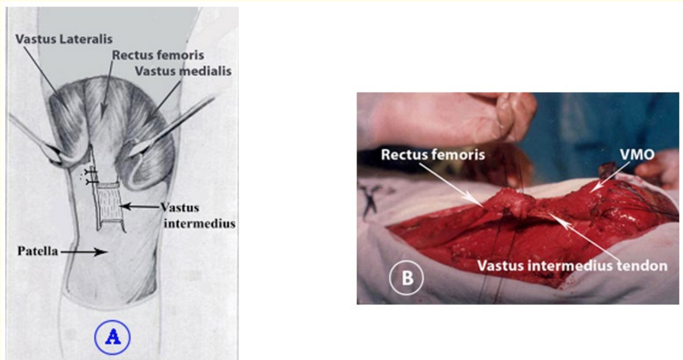

Figure 3A and 3B: *The vastus intermedius and the rectus femoris, being sewn together with the knee in 60° of flexion by No. 2 Ethibond [9] in Group 1.*

Group 2-(96 knees): Transfer the iliotibial band

Transfer the iliotibial band to the proximal vastus medialis tendon and the distal rectus femoris muscle, overlapping and suturing to the knee at a 20° angle.

Same as G 1 and transfer the iliotibial band. Extend the incision in G 1 to just below the greater trochanter 4 cm. The skin edges are then reflected on each side by blunt dissection, completely exposing the vastus intermedius fascia from the mid-thigh to the lower edge of the lateral surface. It is important that the reflected skin be wide enough to expose the gluteus maximus attachment to the vastus lateralis fascia. A strip approximately half an inch wide is freely dissected, until the iliotibial band is clearly identified. Starting approximately two inches distal to the knee joint, the vastus lateralis fascia covering the iliotibial band is gradually extended toward the upper third of the thigh. Next, the tip of the iliotibial band is transferred to the vastus intermedius muscle and the distal portion of the rectus femoris tendon is overlapped and sutured to the knee at 20° flexion using a No. 2 Ethibond suture (cf. figure 4A-4C) in Group 2**.**

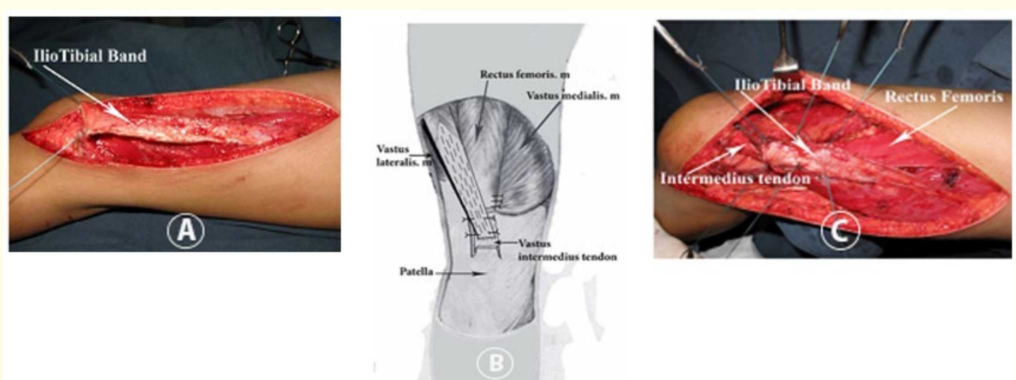

Figure 4A-4C: *A: Expose Iliotibial Band; B-C: Transfer end of the iliotibial band to site the vastus intermedius and the distal portion of the rectus femoris tendon are overlapped and sutured together with the knee in 20° of flexion in Group 2.*

After operation

Postoperatively, the knee is placed in a double bag cast with the knee flexed at 60°. This is a long leg cast (cf. figure 5). The cast can be easily removed for physical therapy to mobilize the knee and then replaced later. The knee is then fully extended at night and exercised during the day with a counterweight. The patient is allowed to get out of bed 1 day after surgery. Static quadriceps exercises and gentle knee movements (passive range of motion not exceeding 60°, knee flexion at 60° is allowed, but no forceful or wide movements are allowed in the first week to minimize effusion or bleeding. During the first 2 weeks, passive range of motion up to 60° and below 90° is practiced with a physical therapist. After 2 weeks, range of motion is increased to 90° (note: range of motion and weight bearing limits are only counted during exercise time and the cast must be worn outside of exercise time). After 3 weeks, range of motion is increased to normal. The cast is removed after about 6 weeks, but no weight bearing is allowed. After that, the patient is allowed to bear 25% of body weight in the first 2 weeks and 50% of body weight in the next 2 weeks. Full weight bearing is allowed from the fourth week by the sixth week after cast removal.

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

Critical results

Final outcome was assessed according to the Judet criteria [10] for the knee: excellent, if flexion was greater than 100°; good, between 81° and 100°; fair, between 50° and 80°; and poor, if flexion was less than 50° and extension lag added to a constant extension lag of 15° did not interfere with activities of daily living or work [11]. Patients with poor outcomes always had significant extension lag. Any patient with full flexion but poor quadriceps strength (graded below 2) was included in the poor outcome group [12] (Table 1).

Function	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 [10], and addition of extension lag with persistent extension lag.*

Patients with poor outcomes always had a significant delay in extension. Any patient with full flexion but poor quadriceps strength (graded below 2) was included in the poor outcome group [13]. Several authors had significant results (Table 2).

Classify	Judet [10]	Gbenou [42]	Petrea [40]	Mukherjee [8]	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 2: *Some Author's critical results.*

EL: Extension Lag.

Follow-up

All patients were examined and evaluated by three other physicians after 3, 6 weeks, 3, 6 months, 1 year, and then annually. At the final follow-up, after a mean of 22 years, 4 months (range, 19 years, 6 months to 31 years, 8 months).

There were 146 patients, the mean age of the patients at the time of surgery was 37 months (range, 12 to 81 months). The mean follow-up time was 22 years, 4 months (range, 19 years, 6 months to 31 years, 8 months). We used only our own criteria to evaluate the postoperative results and did not use the criteria of other authors (Table 1 and 2).

Statistical analysis

A paired-sample t-test was used to compare the range of motion of the knee before and after surgery. Univariate regression analysis was performed to determine whether there was a significant association between each surgical and preoperative variable and the final increase in knee flexion. All analyses were performed using SPSS, version 12.0 (SPSS Inc., Chicago, Illinois), and p values <0.05 were considered significant.

Result

There were 146 patients in this study, the mean age of patients at the time of the study was 42 months (range: 22 to 162 months). The mean age at the last follow-up was 21 years, 2 months (range: 16 years, 7 months to 24 years, 6 months). The mean follow-up age was 18.4 years (range: 6.2 years - 21.8 years).

The 4-6 year age group (58.3%) was most affected. Muscle stiffness began 6 months after injection (range: 3 - 15 months). Evidence of thigh muscle stiffness was found in all cases of joint immobilization. In unilateral knee stiffness, the mean difference between thigh circumferences was 3.61 cm (range: 2.2 - 5.6 cm).

Forty patients were injected, including a skin wound in the mid-thigh muscle, which became more evident when wearing a knee. This was to create a mechanical tightening mechanism and determine the application site for the carrier after intramuscular injection. Algorithm for postoperative knee carrier insertion (Table 3).

Post-operation time	Group 1 (89 knees)	Group 2 (96 knees)	Total
6 Months	76° (65° - 135°)	71° (60° - 130°)	73° (60° - 135°)
1 year	93° (78°-140°)	90° (82°-140°)	92° (78°-140°)
2 years	104° (85°-140°)	115° (90°-140°)	109° (85°-140°)
3 years	113° (94°-140°)	118° (98°-140°)	115° (94°-140°)
Latest follow-up	120° (120°-140°)	128° (125°-140°)	125° (120°-140°)

Table 3: *Knee flexion (Average range).*

Knee flexion improved from a mean of 73˚ (60˚ - 135˚) 6 months after surgery to 125˚ (120˚ - 140˚) at the most recent follow-up.

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

Post-Operation	Group 1		Group 2	
	Number (%)	Average (Range)	Number (%)	Average (Range)
6 Months	22 (40.7)	38° (25°-46°)	21 (35.6)	36° (27°-41°)
1 year	18 (33.3)	28° (21°-37°)	17 (20.8)	26° (20°-32°)
2 years	14 (25.9)	23° (16°-35°)	6 (10.2)	15° (12°-18°)
3 years	9 (16.7)	21° (14°-35°)	3 (5.1)	10° (12°-15°)
Latest follow-up	4 (7.8)	19 (14°-34°)	2 (3.4)	9° (8°-10°)

Table 4: *Extension lag (Average range).*

Extension lag improved from 38° to 19° in Group 1 and from 36° to 9° in Group 2. At final follow-up, the mean extension lag was 19°, with 2 knees having an extension lag > 30° in Variant 1; and the mean extension lag was 9° in Variant 2.

Preoperative flexion range ranged from 5° to 31° with a mean range of 23.5°. Postoperative range ranged from 78° to 140°. Improvement in flexion ranged from 5° to 140° with a mean increase of 98°. At final follow-up, the mean active flexion was 123.5° (78° to 140°). The mean final range of motion was 96.8° (25 to 135) (Table 3). The mean preoperative ROM was 36.8° (0° to 33°). The mean ROM achieved at surgery was 114.9° (76° to 140°). The mean postoperative flexion ROM was 76.8°. The mean flexion ROM increased from 75.2° to 108.5° after postoperative rehabilitation, or an average increase of 30.7° (Table 4).

	Group 1 (89 Knees)	Group 2 (96 Knees)	Total (185 Knees)
Excellent	46 (51.7%)	71 (73,9%)	117 (63,4%)
Good	29 (32.6%)	25 (26.1%)	54 (29.2%)
Fair	12 (13.5%)	0	12 (6.5%)
Poor	2 (2.2%)	0	2 (1.1%)

Table 5: *Lates results.*

Acceptable results were 76 (85.4%) in G 1; 96 (100%) in G 2; 171 (92.4%) in all patients. Acceptable results in G1 were similar to G2 (P value: 0.105455); and G2 was superior to G1 (P value: 0.019132) (Table 5).

All patients had a quadriceps test score of at least 3/5.

Movement

At final follow-up, the mean maximum flexion was 115° (range 84° to 140°), representing a mean increase in flexion of 85° (range 43° to 129°).

In our series, the mean maximum flexion was 113.5° (58° to 150°) and the mean range of motion was 110.4° (58° to 149°), with a mean increase of 74.3° (5° to 115°) in the mean flexion at a mean follow-up of 20.1 years.

Complications

There were no postoperative skin necrosis or suture abnormalities. Five (2.7%) intertrochanteric femoral fractures occurred during rehabilitation when the procedure was discontinued and fixation was performed with a flexion cast. In terms of outcomes, all patients had a quadriceps strength assessment >3/5 at the end of rehabilitation. There were 36 (19.5%) poor postoperative scars; there was 1 (0.9%) hematoma, and there were no femoral nerve or quadriceps tendon ruptures. Loss of active extension of all 3 knees with an angle >30° in Group 1.

Discussion

Extension lag (EL) occurs in the knee after injury or surgery, and the treatment goal in a physical therapy program is to eliminate EL. EL is defined as a condition in which the active range of knee extension is less than the passive range of knee extension. The term Extension lag is used instead of quadriceps lag because it is thought that other factors may be involved in this condition besides normal quadriceps function.

Although there were no significant correlations between EL and the measured variables that would allow prediction of EL from another variable, the results of this study indicate some factors that may be most associated with EL. These results, obtained by comparing groups, suggest that certain characteristics are present in the groups of patients with knee disability and affected knees that also exhibit EL.

Based on these comparisons between groups, it seems reasonable to conclude that, in the patient groups with EL, one might also find general weakness, stiffness, and laxity in the quadriceps. This study was unable to identify any direct factors causing EL due to the lack of significant correlations between EL and other variables. However, it is thought that the relatively small degree of EL found in most patients is because any factors causing EL may have been largely modified by the nature and/or treatment before the measurements were taken. There was a suggestion of a relationship between some variables and EL when measurements from patients with larger ELs (greater than 3°) appeared on the scatterplot. However, this suggestion of a relationship completely disappeared when measurements from patients with smaller ELs appeared on the scatterplot. It is therefore recommended that in any further studies, an attempt should be made to include patients with larger ELs.

Physioanatomy iliotibial band

The iliotibial band (ITB) is a thick band of fascia formed near the hip by the fascia of the gluteus maximus, gluteus medius, and vastus lateralis. Its primary function is to stabilize the pelvis and control posture. The iliotibial band runs along the outer thigh and serves as an important structure involved in lower limb movement. There are many clinical conditions that can manifest secondary to various iliotibial band dysfunctions, such as hip pop syndrome, ITB syndrome.

Since the iliotibial band attaches to Gerdy's tubercle, it has no true bony attachment along the femur. Therefore, it tends to move anteriorly/posteriorly (from front to back) when your knee is flexed and extended. The iliotibial band (ITB) is a thick band of fascia formed near the hip by the fascia of the gluteus maximus, gluteus medius, and vastus lateralis. It passes superficially to the vastus lateralis muscle and attaches to Gerdy's tubercle of the lateral tibial plateau and partially to the supracondylar crest of the lateral femur. There is also an anterior extension called the iliotibial band that connects the lateral patella and prevents the patella from moving medially. There is a small recess between the lateral femoral condyle and the ITB, which contains the synovial extension of the knee capsule (lateral synovial recess). The ITB shares innervation with the TFL and gluteus maximus via the superior gluteal nerve and the inferior gluteal nerve. Composition: The iliotibial band is mainly composed of collagen fibers. Collagen is the strongest protein found in nature.

Techniques for reconstructing the knee extensor mechanism

Techniques for reconstructing the knee extensor mechanism have been described since the late 19th century [14], with modern techniques originating from techniques originally developed in patients with polio [15,16]. The need for rehabilitation of knee extensor function 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 [16,17]. Several other muscle transfers have been described, but their functional outcomes have not been reported separately. These include the vastus lateralis transfer described by Ober in 1933 [18]. In 1925, Spitzy proposed iliotibial band transposition to the patella as a treatment for quadriceps paralysis following poliomyelitis [19,20]. His proposal was based on the fact that the muscle's path extends across two joints, lying anterior to the axis of motion of the hip and posterior to the axis of motion of the knee. When the hip is extended, its extension path lengthens and stabilizes the knee. He also pointed out, like Erlacher [21], that the strained fascia often escapes paralysis when the flexors of the upper limb are affected. In 1933, Ober pointed out the risk of relapse after hamstring transposition and proposed the use of fascia and fascial replacement [18]. In 1926, Yount proposed iliotibial transposition [22] and in 1938, presented his series of 16 cases in which good results were obtained [23]. In half of these cases, the biceps femoris was used in conjunction with the iliotibial transposition. Apart from isolated case reports [24,25], no other series with iliotibial transposition as the sole treatment for quadriceps palsy have been published.

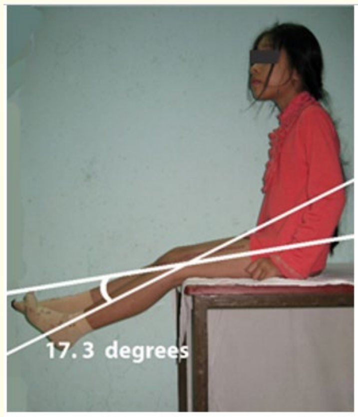

Figure 6: *Extension lag 17.3° in Group 1.*

Figure 7: *Extension lag 8.6° in Group 2.*

In 1940, Debrunner [26] showed that the muscle strength required to transmit the stabilizing force of the knee joint to the ligaments is small. We performed iliotibial displacement in 76 patients (96 knees) in Group 2. Comparison of extension lag showed that extension lag improved from 38° to 19° in Group 1 in 70 patients (89 knees) and from 36° to 9° in Group 2. At the end of the follow-up period, the average extension lag was 19°, 2 knees had lag > 30° in Group 1 (cf. figure 6); and the average extension lag was 9° in Group 2 (cf figure 7); Results of quadriceps reconstruction surgery (Table 4).

Quadriceps reconstruction affects knee function

The adductor is often asymptomatic and any symptoms are due to the possibility of nerve compression [27,28] or local compartment syndrome during exercise [18]. In some cases, it can mimic a soft tissue tumor [29-31]. We believe that the progressive limitation of knee flexion in our patient was due to the inelasticity of the adductor muscle, which becomes a tether as the femur grows. The muscle belly is short compared to its long tendon [32].

Quadriceps reconstruction is a major surgery; the ability to successfully achieve a range of knee flexion depends on both the surgeon and the patient. To achieve a successful outcome, preparation begins in the preoperative period with patient education on knee exercises; continue in the perioperative period using sharp dissection and meticulous hemostasis, followed by strict adherence to postoperative physical therapy combined with the patient's strong will and ability to prevent quadriceps inhibition and allow for toning and strengthening of the quadriceps and hamstrings. Patients must be warned of the slight delay in extension that they may experience during follow-up.

Among the various techniques for quadriceps reconstruction, Thompson and Judet are the most popular. The most obvious difference between the two techniques is the location of the release of the quadriceps mechanism: release at the insertion site in the Thompson technique.

Therefore, Judet quadriceps reconstruction requires a much more extensive dissection and cannot use a ligature. On the other hand, the Thompson technique has inherent weaknesses, such as delayed wound healing, infection, and prolonged lag because the rectus femoris muscle is separated from the rest of the quadriceps muscle through an anterior midline incision [33,34] which are the main reasons for seeking a change in technique, and early proximal release and late distal release are the recommended treatments [35] (Table 2). Thompson quadriceps reconstruction surgery [36] and its modifications [37] include complete separation of the rectus femoris muscle from the vastus lateralis, release of the vastus medialis 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 [37,38]. Prolonged lag after quadriceps surgery has been widely reported with rates ranging from 8° to 61.1° in the literature [37-40]. Lengthening of the rectus femoris has been identified as a causative factor.

All patients with extension lag gradually improved strength and decreased lag with quadriceps strengthening and stretching exercises. Extension lag resolved within three months to ten years after surgery [34,39]. In this study, two cases were 21 years after surgery (Table 4). Despite some complications, most of our patients had significant improvement in knee flexion after quadriceps surgery at two or more years of follow-up.

We recommend that surgeons consider lengthening of the rectus femoris if satisfactory knee flexion cannot be achieved with gentle passive manipulation after periarticular fusion to avoid disruption of the extensor mechanism. If full extension and flexion cannot be maintained, full extension should be the first goal [41].

We agree with Hesketh that the Thompson technique should be used initially in surgery [17]. It is important not to use a ligature, as many large blood vessels are cut during the cut, especially in the peripatellar region, and these must be seen and fixed.

Diathermy is most useful for dividing the vastus muscle and treating multiple small bleeding points, especially in areas with extensive scarring. In the first two cases, blood transfusion was required, but with careful hemostasis, this is no longer necessary. The hematoma can significantly slow its progression.

We agree with Gbenou [42] that when lengthening the quadriceps, the proximal vastus intermedius tendon 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 90° flexion during surgery, V-Y reconstruction of the rectus femoris should not be performed [7]. According to Wang., *et al*. [43], stretching the suture at 90° knee flexion can lead to significant extensor weakness and extension lag.

Their parents often had difficulty squatting, kneeling, sitting cross-legged, running, or climbing stairs. In each case, a depression was observed in the affected thigh, which deepened with forceful knee flexion [44].

Gbenou., *et al*. [42] and Shivaprasad., *et al.* [45] used increased knee flexion and gait quality as measures of treatment outcome. Outcomes were rated as ‘good’ if the flexion increased above 90˚, allowing normal walking and squatting, which are often required for toileting and farming in African and Asian countries. Outcomes were rated as ‘acceptable’ if the flexion increased from 45° to 90°, with normal gait and achieving a comfortable sitting position. Outcomes were rated as ‘poor’ if the flexion increased below 45°, associated with limping and discomfort when sitting.

Knee flexion below 45° interferes with the patient’s normal gait and causes gait problems and interferes with daily activities [7].

Authors in different countries should report different daily activities and knee flexion angles and important postoperative outcomes (Table 3 and 4).

Effective wound healing is the foundation of any surgery. When a wound fails to heal, the reason is usually obvious and often involves inadequate blood supply to the area. Hematoma, overstretching, foreign bodies, and radiation all lead to ischemic necrosis and wound breakdown. In the Thompson technique, an anterior midline incision is used and a long lateral incision is used to release the original site in the Judet technique [33]. Several authors have modified the incision and reported postoperative quadriceps necrosis rates ranging from 13.2% to 67% [39,41,46] (Table 6).

Author	Procedure	Excellent	Good	Fair	Poor
Hnѐvkovsky [1]	Bennett’s	0%	70%	30%	-
Bos & Chong.1976 [27]	Thompson’s/Bennett’s	55%	25%	20%	-
Mukherjee & Das. 1968 [8]	Thompson’s/Bennett’s	15%	60%	10%	0%
Jacson & Hutton. 1985 [51]	Thompson’s	45%	45%	10%	-
Hung - Group 1. 2024	Payr’s/Hung’s	57.4%	35.2%	3.7%	0%
Hung - Group 2. 2024	Payr’s/Hung’s and TITB	79.7%	20.3%	-	-

Table 6: *Compare results of surgical quadricep plasty and was transferred iliotibial band.*

TITB: Transferred Iliotibial Band.*

Our long-term postoperative results are similar to the Excellent and Good results of other authors. However, with ITB transfer, the results are very good (Excellent and Good are 100%).

Conclusion

There are various surgical options depending on the location of the spasticity, age, cause, and duration of the spasticity. Better results are achieved whenever surgery is performed early and also helps prevent secondary adaptive changes in soft tissue, cartilage, and bone. Physical therapy is the mainstay of postoperative management not only to achieve maximum flexion but also to regain active extension. Iliotibial ligament transfer to the quadriceps after quadriceps surgery with good postoperative results.

Limitations of the Study

This article is a retrospective study. Not all patients included were followed to skeletal maturity, which is important because clinical and radiographic findings tend to change over time.

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Volume 16 Issue 1 January 2025