Surgical Technique

Vastus Medialis and Vastus Lateralis as Flap Transfer for Knee Extensor Mechanism Deficiency

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Abstract

Background Loss of the quadriceps tendon, patella, and patellar tendon leaves a major anterior defect that is difficult to close and compromises knee extension strength. Gastrocnemius muscle transfer does not sufficiently cover such major defects. This paper describes a new surgical technique that addresses these defects and the results of eight cases of revision TKA managed with this new technique.

Description of Technique The new procedure transfers the vastus medialis or the vastus lateralis and their tibial attachments or both muscles and their distal expansions combined with gastrocnemius and soleus flaps to cover major deficiencies in the anterior knee. Nine cadaver knee specimens were dissected to determine the effect of the transfer on nerve and blood supply of the muscles.

Methods Eight patients underwent the new procedure between 2005 and 2009. Four knees had vastus medialis

transfer, two vastus medialis and vastus lateralis transfer, two vastus medialis and medial gastrocnemius transfer, and two medial gastrocnemius and medial ½ of the soleus muscle transfer. Minimum followup was 15 months (mean, 43 months; range, 15–74 months). Patients were evaluated for anterior knee pain, quality of knee closure, ROM, extensor lag, walking ability, use of assistive devices, and ability to climb stairs with the operated extremity.

Results All patients achieved closure of the knee without synovial leaks by 10 days postoperatively. Mean flexion contracture at last followup was 3° (range, 0°–7°). Mean extension lag was 22° (range, 5°–65°). Extension lag was less in those knees that included gastrocnemius or soleus muscle transfer. None of the flaps developed necrosis.

Conclusions The vastus medialis and vastus lateralis muscles provide adequate coverage for anterior soft tissue deficits of the knee.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Loss of the extensor mechanism in the knee causes poor knee function after TKA, and loss of the patella, patellar tendon, or quadriceps tendon can cause deficiency that makes closure of the capsule impossible without soft tissue transfer flaps (Fig. 1). The skin often is deficient and cannot be closed primarily, so deep closure is required in these cases. While gastrocnemius flaps can close deep soft tissue defects and even restore some function of the quadriceps mechanism [1, 20, 21], they may be insufficient to close defects of the lower portion of the capsule of the knee and never are adequate for defects involving the

Fig. 1 Deficiency of the quadriceps muscles and knee capsule often extends proximally, and the knee cannot be closed with the usual gastrocnemius flaps used to close distal defects in the capsule and patellar tendon.

quadriceps tendon and rectus femoris muscle [1, 20, 21]. Quadriceps deficiency caused by patellar tendon or quadriceps tendon disruption has effectively been treated by allograft substitute of the patellar tendon, patella, and quadriceps tendon [2–5, 8, 9, 16, 17, 19, 22]. However, this technique cannot be used in the presence of major deficiencies of the capsule and skin in the anterior portion of the knee.

Reconstruction of defects about the knee has been achieved with a variety of muscle transfer procedures that could be used for proximal capsular and extensor mechanism defects. The latissimus dorsi free flap [12], reversed gracilis pedicle flap [24], distally based vastus lateralis flap [1], rectus abdominus free flap [6], perforator flaps [11, 18], and neurofasciocutaneous flaps [25] all have the potential to close large anterior defects, but all are technically demanding procedures and involve a dedicated plastic surgery limb salvage team in most institutions.

In many cases of quadriceps deficiency and destruction of the extensor mechanism, the vastus medialis and vastus lateralis muscles are still intact, and they maintain their attachment to the tibia through the quadriceps expansion, capsule, and synovial membrane of the knee. These muscles, along with their capsular attachments to the tibia and underlying synovial membrane, can be elevated and

transferred into the anterior defect to achieve closure of both proximal and distal capsular and extensor mechanism defects. In knees that require closure of defects that include the distal portion of the knee joint capsule, a medial gastrocnemius and soleus flap can be added, and large, complex spaces can be closed with adequate overlap of structures and without excessive tension to form a watertight closure of the joint. This is especially important in cases in which the skin and subcutaneous tissues are missing, and the surgical wound must be dressed open.

The vascular supply and innervation of the quadriceps muscle make each of its constituents suitable for forming muscle flap transfers. The femoral nerve divides into separate branches in the proximal thigh, and the nerves and blood vessels run separately in these muscles along their entire length [10]. The muscles are long and flexible, so their neurovascular supply is not compromised by the modest changes in position that are necessary to cover deficiencies in the extensor mechanism and capsule of the knee.

This paper describes the technique of local transfer of the vastus medialis and lateralis muscles and further describes their use in conjunction with gastrocnemius and soleus flaps to close the knee in the presence of extensive deficiencies in the quadriceps mechanism, joint capsule, and upper tibial bone stock of the knee. This retrospective analysis determined whether soft tissue closure and restoration of quadriceps function can be achieved with this approach.

Surgical Technique

Nine cadaveric specimens were dissected to determine the extent of dissection necessary to release the vastus medialis and lateralis muscles from their attachments and to identify the landmarks for soft tissue release without affecting knee stability.

The vastus medialis flap dissection included the synovial membrane, capsule, and quadriceps expansion anterior to the medial collateral ligament (MCL). The distal fibrous portion of the vastus medialis flap was separated from the anterior edge of the MCL. The distal capsular and synovial portion of the flap was thin but was easily pulled distally to cover the tibial tubercle. The muscle tissue could easily be pulled distally to reach the midportion of the patellar groove of the femur but could not be pulled to the tibial edge. Proximal dissection of the muscle did not endanger the femoral artery or any major arterial branches. In all specimens, a fibrous septum separated the vastus medialis from the femoral artery and vein, and the femoral nerve entered proximally in the vastus medialis and ran along the posterior surface of the muscle to its distal end. Dissection

of the muscle from its bone and soft tissue attachments was performed without damaging this neural structure. Vascular branches from the femoral artery entered the vastus medialis directly in its upper $\frac{1}{3}$. The distal $\frac{2}{3}$ of the muscle was released from the femur and soft tissue attachments without endangering its nerve or blood supply.

The vastus lateralis muscle was separated sharply from the vastus intermedius and rectus femoris muscles, and the distal attachment of the lateral quadriceps expansion, the synovial membrane, and the anterior $\frac{1}{2}$ of the iliotibial (IT) band including $\frac{2}{3}$ of the portion attached to Gerdy's tubercle were elevated as a composite flap. The flap was dissected proximally, dividing the IT band and leaving the anterior $\frac{1}{2}$ adherent to the vastus lateralis muscle. The portion of the vastus lateralis under the posterior $\frac{1}{2}$ of the IT band was dissected from the femur and the undersurface of the posterior portion of the IT band. The perforating branches from the profunda femoris artery and vein were noted as this dissection was performed. This could be done while leaving the popliteus tendon and lateral collateral ligament (LCL) undisturbed. The distal fibrous position of the quadriceps expansion of the vastus lateralis was thin, but the IT band was robust in all specimens so that the two layers made a substantial structure for attachment to the tibia.

One or two perforating arterial branches from the profunda femoris artery were encountered in all specimens. Branches of the femoral artery were encountered antero-medially only in the upper $\frac{1}{3}$ of the vastus lateralis. The vastus lateralis muscle could be transferred easily to the anterior surface of the knee. The synovial membrane, capsular expansion of the vastus lateralis, and IT band could be stretched easily to cover the tibial tubercle in all specimens. The lateral quadriceps expansion and underlying synovial membrane did not have enough substance to resist even moderate tensile loads, but including the anterior portion of the IT band provided substantial thickness and tensile strength. Because the vastus lateralis takes origin partly from the undersurface of the fascia lata, including the IT band in the transfer did not decrease the flexibility of the transferred unit.

To assess the utility of the medial gastrocnemius muscle to fill gaps in the extensor mechanism and anterior tibial bone structures, the incision was extended to the ankle, and the medial $\frac{1}{2}$ of the gastrocnemius and soleus muscles were released from their attachments into the calcaneal tendon and sharply separated from the lateral $\frac{1}{2}$ of the muscles up to their neurovascular pedicles. These muscle flaps were folded proximally to cover the anterior knee, and the amount of overlap of muscle tissue of the gastrocnemius and soleus muscles and the vastus medialis and lateralis muscles was measured with a ruler in each specimen.

Medial gastrocnemius and soleus muscle flaps all could overlap the joint line by 3 cm (range, 3–4.5 cm), and both

could reach the distal muscular margin of the vastus medialis and vastus lateralis flaps in all specimens. Bone defects that included the entire tibial tubercle could be covered with a combination of gastrocnemius and soleus flaps.

In the surgical procedure, the vastus medialis flap was developed by detaching the medial capsule and synovial membrane as a single layer from the tibia posteriorly as far as the MCL (Fig. 2). This layer of tendon, capsule, and synovial membrane was dissected sharply from the MCL up to the medial femoral epicondyle; then the dissection was carried proximally, separating the vastus medialis from the adductor tendon and aponeurosis. Sharp dissection was directed toward the muscle and away from the femoral vessels that lie just under the adductor aponeurosis (Fig. 3). This dissection was performed carefully under direct vision to avoid damage to the femoral artery and vein. This flap was placed medially to evaluate its ability to cover the anterior deficiency. If the medial edge of this flap easily reached the lateral edge of the capsular opening in the knee and the distal fibrous portion of the flap was viable, robust tissue that reached to a reliable tibial bone surface or capsular attachment to the tibia, the flap was deemed sufficient to fill the anterior defect. With the knee fully extended, the transferred flap was pulled to moderate tension and the distal edge of the flap was sutured into the prepared bone bed in the region of the tibial tubercle or

Fig. 2 The distal attachment of the vastus medialis muscle is dissected over the surface of the MCL, leaving the synovial membrane intact if possible. This sharp release of the attachment of the vastus medialis is continued posteriorly to the edge of the sartorius muscle.

Fig. 3 Sharp and blunt dissection is continued proximally, separating the vastus medialis from the sartorius and adductor magnus muscles. The adductor fascia is carefully preserved over the femoral artery and vein.

capsular attachment of the knee using heavy nonabsorbable sutures (Number 5 TiCron™; Covidien, Mansfield, MA, USA) (Fig. 4A). Drill holes through the tibial bone surface allowed a heavy nonabsorbable suture to be passed through the distal end of the flap in a running-locked fashion as described by Krackow [15] (Fig. 4B). Two running-locked sutures passed through bone were used to secure the distal end of the flap (Fig. 4C). Next, the lateral edge of the medial flap was sutured with heavy absorbable interrupted sutures (Number 3 Vicryl®; Ethicon, Somerville, NJ, USA) to the medial edge of the lateral capsular tissue and vastus lateralis muscle. These sutures were angled so that they held the transferred flap distally (Fig. 5). The proximal edge of the flap was carried over the patella if it was still present, sutured to the patellar surface, and sutured into the vastus lateralis. If the patella was absent but the conjoint quadriceps tendon was present, the vastus medialis flap was placed over the conjoint tendon and sutured with heavy absorbable sutures (Number 3 Vicryl®). Passive knee flexion to about 20° was possible when the flap was secured in position. Next, the medial edge of the vastus medialis flap was secured by suturing it under the deep fascia using medium absorbable sutures (Number 2 Vicryl®) (Fig. 6) to close the joint space.

In cases with massive anterior deficit and also deficiency of the quadriceps muscle, both medial and lateral vastus flaps were used. Transfer of the lateral vastus flap was

Fig. 4A–C (A) The distal end of the vastus medialis flap is sutured to the tibial bone surface in the region of the tibial tubercle. The flap is pulled down firmly with the knee fully extended. (B) Two running-locked sutures as described by Krackow [15] are used to anchor the end of the flap to the bone. A 1/8-inch drill bit is used to make a transverse hole through the tibial bone stock in the region of the tibial tubercle. (C) A Number 5 nonabsorbable suture is passed through the drill hole and advanced in a running-locked fashion proximally along the edge of the flap, then through the flap, then distally again in a running-locked fashion, and finally tied firmly in place. Two separate drill holes are made for the two Krackow sutures.

begun by incising sharply between the vastus lateralis and conjoint rectus femoris and vastus intermedius muscles; then, the distal attachment of the lateral capsule, synovial membrane, and IT band were released with a knife from the tibia as far as the posterior 1/3 of Gerdy's tubercle (Fig. 7). The distal end of the flap was pulled anteriorly as the IT band was split in line with its fibers from distally to proximally, leaving the posterior 1/2 of the IT band attached to the tibia. As the IT band was split proximally, the anterior portion was left adherent to the vastus lateralis. The flap then was pulled distally with moderate tension and dissected proximally, separating it from the undersurface of the posterior portion of the IT band and intermuscular septum down to the femur (Fig. 8). Additional dissection was then performed proximally to expose any perforating

Fig. 5 Anterior closure is begun as the vastus medialis transfer flap is sutured to the lateral capsule and vastus lateralis muscle. This is performed in full extension under moderate tension, and the interrupted heavy absorbable sutures are angled to pull the flap distally.

arteries. The vessels were suture-ligated and transected as necessary. When the flap could be easily approximated to the medial edge of the anterior defect, dissection was deemed sufficient. Distal attachment was performed first, placing the flap under moderate tension and securing the distal end as described for the medial flap transfer (Fig. 9). The distal fibrous portions of the flaps were placed one on top of the other and sutured to bone using the double running-lock technique. Anterior closure was completed by suturing the lateral edge of the transferred vastus lateralis to the lateral synovial edge and under the surface of the deep fascia and fascia lata (Fig. 10).

In cases with major proximal tibial bone deficiency, as well as inadequate capsular and skin closure of the distal wound, a medial gastrocnemius flap was used to provide attachment for the vastus medialis and lateralis flaps and to fill the distal soft tissue defect. Exposure of the medial gastrocnemius muscle was achieved by extending the incision distally to the distal 1/3 of the tibia. The medial skin flap was developed subfascially, dissecting under the saphenous nerve and vein. The soleus muscle was exposed, and the gastrocnemius muscle was separated from the soleus, exposing the plantaris tendon. Distal dissection of the interval exposed the attachment of the gastrocnemius

Fig. 6 The deep fascia and medial synovial membrane under the medial skin flap are sutured with heavy absorbable sutures to the medial edge of the flap to finish anterior closure.

muscle into the Achilles tendon. The tendinous attachment was released sharply, and the medial 1/2 of the gastrocnemius muscle was separated sharply from the lateral 1/2, continuing the dissection proximally with sharp and blunt dissection to a point near the neurovascular bundle that enters the muscle in its deep surface (Fig. 11). This muscle flap then was folded proximally and sutured to the ends of the vastus muscle transfers or over the top of the bone attachments of the vastus transfers into the tibia (Fig. 12). In cases with deficient gastrocnemius muscle, the medial 1/2 of the soleus was elevated and transferred in a similar manner.

The extremity was splinted in extension with a soft knee immobilizer, and gentle quadriceps contraction was started the next day, supervised by the operating surgeon. Gentle passive flexion was started on Postoperative Day 7 if the surgical incision was sealed and no joint fluid escaped with motion. Flexion was limited to 15° for 6 weeks, and then gradual increasing flexion was performed under the supervision of the surgeon and experienced physical therapist. The splint was discontinued at 8 weeks if the patient had adequate strength in the arms and opposite lower extremity to protect the operative limb. More vigorous quadriceps strengthening, including straight-leg raises, was started after the eighth week under the supervision of the operating surgeon and physical therapist.

Fig. 7 Transfer of the vastus lateralis muscle begins by detaching with a knife the distal attachment of the lateral quadriceps expansion and capsule from its tibial attachment. The IT attachment into Gerdy's tubercle is left intact in most cases, but the IT band may be transferred as part of the flap if needed.

Fig. 8 Sharp and blunt dissection is used to develop the vastus lateralis flap proximally, dissecting under the fascia lata and IT band.

Patients and Methods

All cases of revision TKA performed in a single-surgeon arthroplasty specialty practice from January 2005 through December 2009 were reviewed for this study, yielding 81 knees (76 patients). Eight knees (eight patients) had transfer of the quadriceps to manage extensor mechanism deficits, closure problems, or both. One patient fell in physical therapy 8 days postoperatively, avulsed the wound, and required emergency repair. She had cardiovascular complications and died 3 weeks later. All patients except the one who died in the early postoperative period were available for followup examination. Mean age of this group of patients was 75 years (range, 56–85 years). Minimum followup was 15 months (mean, 43 months; range, 15–74 months).

Four patients had vastus medialis transfer to fill gaps in the extensor mechanism caused by infection and necrosis of the patella, patellar tendon, and quadriceps tendon. Two had transfer of both the vastus medialis and vastus lateralis to achieve adequate closure of the defect and to provide extensor power of the knee. Two patients underwent transfer of the vastus medialis and medial gastrocnemius muscle and two had transfer of both the medial

gastrocnemius and medial $\frac{1}{2}$ of the soleus muscle to close the knee and to secure distal attachment of the vastus transfer. In four knees, primary skin closure was impossible, and they were dressed open with Xeroform™ antiseptic gauze (Cardinal Health, Dublin, OH, USA) coverage to allow granulation and secondary closure. Split-thickness skin grafts were not used, but subfascial flaps were used in three knees (three patients) to cover exposed tendons and hardware. Two of these subfascial flaps required partial débridement because of edge necrosis.

The patients were evaluated in the clinical office at 1- or 2-week intervals after discharge from the hospital. Those patients whose surgical site had been left to close by granulation and secondary skin growth were followed weekly until the wound no longer required expert care. The patients were evaluated for wound closure, knee stability, ability to do straight-leg raises, and ability to flex the knee at the 1-month, 3-month, 6-month, and yearly postoperative clinical followup visits. They were evaluated at their latest visit for anterior knee pain, quality of knee closure, ROM, extensor lag, walking ability, use of assistive devices, and ability to climb stairs with the operated extremity. The potential complications included delayed healing and synovial leak, necrosis of the transferred muscle flap, donor site complications, and extensor lag.

Fig. 9 Distal attachment is performed first, placing the flap under moderate tension and securing the distal end as described for the medial flap transfer. Medial and lateral vastus flaps may be placed side to side or one on top of the other. In this illustration, the lateral flap is sutured to the lateral edge of the vastus medialis muscle, which has not been transferred. Heavy absorbable sutures are used, and they are angled to pull the flap distally.

Results

All knees achieved deep closure of the knee without synovial fluid leaks by 10 days after surgery. All four patients in whom primary skin closure was impossible finally had durable skin coverage at latest followup achieved by secondary skin healing over the granulating bed. Two patients required return to the operating room during the first week for minimal débridement of transferred flaps and repair of the suture line to treat synovial leaks. None had necrosis of the transferred muscle flap and none had donor site complications.

At latest followup, walking distance was unlimited in all patients, but only one patient could ascend stairs with the affected extremity. Four patients reported slight anterior knee pain, and the other three patients had no anterior knee pain. Mean knee flexion contracture was 3° (range, 0° – 7°). Mean extensor lag was 22° (range, 5° – 65°). The four patients who had reconstruction using the gastrocnemius and soleus muscles had extension lag varying from 5° to 15° . The four patients who had direct attachment of the

Fig. 10 Anterior closure is completed by suturing the lateral edge of the transferred vastus lateralis to the lateral synovial edge and under the surface of the deep fascia and fascia lata.

Fig. 11 When anterior tibial bone stock is deficient and the vastus muscle flaps are inadequate to cover distal bone and capsular defects, the medial gastrocnemius muscle may be used to achieve soft tissue coverage and attachment for the other flaps. The skin incision is extended to just above the ankle, and subfascial dissection is performed to expose the soleus and medial gastrocnemius muscles. The medial portion of the gastrocnemius muscle is separated bluntly from the soleus and detached distally from the Achilles tendon. A combination of blunt and sharp dissection is used to separate the medial head of the gastrocnemius from the lateral up to the neurovascular pedicle.

Fig. 12 In the case illustrated here, the vastus medialis and vastus lateralis flaps have been sown together and the medial head of the gastrocnemius muscle has been used to provide distal anchorage of the quadriceps flaps and to add soft tissue coverage over bone deficiency in the tibia. The suture lines all are made with heavy absorbable sutures.

vastus medialis and/or lateralis to bone had an extension lag of between 35° and 65°. Mean flexion was 99° (range, 75°–110°).

Discussion

Loss of the quadriceps tendon, patella, and patellar tendon leaves a major anterior defect that is difficult to close and compromises knee extension strength. Quadriceps deficiency in TKA has been treated effectively with patella-patellar tendon allografts. This technique combined with proximal tibial block allograft has been successful in managing quadriceps deficiency combined with massive deficit in the proximal tibia caused by osteolysis [2]. This technique has been reported by several investigators, and it has been effective in restoring quadriceps function if the knee is tensioned correctly in extension [3–5, 8, 9, 16, 17, 19]. However, in cases that involve major deficiencies of the quadriceps tendon, anterior capsule, and skin, allograft

replacement would not be effective [22]. Gastrocnemius muscle transfer does not sufficiently cover such major defects [1, 18, 20, 21]). This paper describes a new surgical procedure that transfers the vastus medialis or the vastus lateralis and their tibial attachments or both muscles and their distal expansions to cover major deficiencies in the anterior knee, and reports the results of eight cases of revision TKA managed with this new technique.

This study has a number of limitations. First, the anatomic series is small and may not include anomalies of the femoral artery that could expose it or its branches to damage during dissection of the vastus medialis flap. Second, the clinical series is small and retrospective, and it reports the experience of a single surgeon who specializes in arthroplasty of the lower extremity and commonly performs limb salvage procedures, so the results may be different in a general orthopaedic practice (Table 1).

The vastus medialis and lateralis flaps have been especially effective for closure of major defects in the quadriceps tendon and proximal capsule of the knee. The anatomic characteristics of the quadriceps muscle group make its parts especially amenable for use as local muscle transfer flaps. The innervations of each of these muscles enter proximally and allow the muscles to be separated from each other distally without risking denervation. The vascular supply follows a similar pattern [10], so circulation remains brisk in transferred muscle flaps. Transferring the vastus medialis and vastus lateralis from their original positions to a new position in the front of the knee does not change their function, and reeducation of the muscle is not necessary during rehabilitation. Major proximal soft tissue defects are difficult to manage with gastrocnemius flap transfers [18, 20, 21]. Free flap transfers, such as the latissimus dorsi [12] or rectus abdominus [6], offer excellent coverage over major defects but require special expertise in vascular surgery and other plastic surgical techniques. These flaps also have substantial donor site morbidity [6, 12]. Perforator flaps can be successful for this purpose [11, 18]. Reversed gracilis pedicle flaps [14] and distally based vastus lateralis flaps [1] also offer effective coverage for the upper portion of the knee, but both require separate elongated incisions to free the proximal portions of the muscle and special techniques to manage the vascular pedicles [1]. The peroneal flap offers anterior soft tissue coverage for the lower portion of the knee but cannot be brought far enough proximally to fill the defects left by loss of the patella and quadriceps tendon [13]. The vastus lateralis muscle has been transferred proximally to cover major soft tissue defects in the hip [7, 23]. It also has been used as a distally based flap to cover soft tissue defects of the knee [7, 23]. This requires a long incision, often jeopardizes the blood supply of the transferred muscle, and fails

Table 1. Outcomes of various flap transfer options in revision TKA

Study	Type of flap	Number of knees	Mean followup (months)	Extensor lag (°)*	Required vascular pedicle dissection	Required microvascular anastomosis	Required separate donor incision	Frequency of donor site morbidity	Frequency of flap necrosis	Capable of coverage of major anterior defects
Jaureguito et al. [14]	Gastrocnemius	6	33	24 ± 18.8	No	No	No	Frequent	2 (33%)	No
Ries and Bozic [21]	Gastrocnemius	12	27	9 (0–40)	No	No	No	Frequent	3 (25%)	No
Cetrulo et al. [6]	Latissimus dorsi	5	NA	NA	No	Yes	Yes	Frequent	Frequent	Yes
Hierner et al. [12]	Latissimus dorsi	14	34.6 (12–59)	NA	Yes	Yes	Yes	Frequent	Frequent	Yes
Hallock [11]	Perforator	2	NA	NA	Yes	No	Yes	Rare	1 (50%)	Yes
Ikeda et al. [13]	Peroneal	3	20	NA	Yes	No	Yes	0	0	No
Cetrulo et al. [6]	Rectus abdominus	6	NA	NA	No	Yes	Yes	Frequent	Frequent	Yes
Tiengo et al. [24]	Reversed gracilis pedicle	3	24	NA	Yes	No	Yes	Rare	0	No
Auregan et al. [1]	Distally based vastus lateralis	4	18	3 (0–10)	Yes	No	Yes	Rare	2 (50%)	No
Current study	Vastus medialis and vastus lateralis	8	43	22 (5–65)	No	No	No	Rare	0	Yes

* Values are expressed as mean ± SD or mean with range in parentheses; NA = not available.

to preserve the extensor function of the transferred muscle flap [1].

Other reports of local muscle transfer procedures to restore strength of movement have been encouraging, as we have reported in this series. In cases with chronic avulsion of the greater trochanter, transfer of a portion of the posterior gluteus maximus muscle into the defect between the greater trochanter and lateral femoral cortex enabled capsular closure of the hip and improved abductor function [26, 27]. Using the gastrocnemius muscle to achieve soft tissue closure in the knee is also common and is generally successful, and the gastrocnemius also restores extensor function of the knee when transferred into the quadriceps [14, 20]. This current series of revision TKAs ultimately achieved anterior wound closure by using a combination of vastus medialis, vastus lateralis, gastrocnemius, and soleus muscles to achieve soft tissue closure and to restore quadriceps power in knees with major quadriceps and anterior soft tissue deficiencies. The clinical results revealed these techniques restored some quadriceps function with minimal anterior knee pain at the latest followup. The patients who had gastrocnemius or combined gastrocnemius and soleus flaps all had better knee extension strength than those with transfer of the vastus muscles directly to the tibia. While the series is too small to provide reliable statistical comparison, these results suggest the gastrocnemius and/or soleus transfer improves the extension power of the transferred quadriceps muscles. Major soft

tissue deficiency in the anterior part of the knee, even quadriceps deficiency, need not condemn reconstruction of the knee. Quadriceps muscle transfer, especially when combined with medial gastrocnemius and/or soleus muscle transfers, can facilitate closure of the joint and also restore much of the function of the quadriceps muscle. The surgeon must be aware of the proximity of the femoral artery and vein to the vastus medialis and the presence of perforator vessels from the profunda femoris artery in the vastus lateralis flap.

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