Surgical Technique: Muscle Transfer Restores Extensor Function After Failed Patella-Patellar Tendon Allograft

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Abstract

Background Extensor mechanism allograft provides an effective remedy for severe quadriceps deficiency caused by loss of the patella, patellar tendon, and quadriceps tendon in TKA. Late failure is common, however, and major quadriceps deficiency occurs after removal of the allograft material.

Description of Technique Six human cadaver specimens were dissected to evaluate the feasibility of transferring the vastus medialis, vastus lateralis, and medial head of the gastrocnemius muscle to fill the defect caused by loss of the patella and extensor tendon mechanism after failure and removal of allograft material. Transfer of the medial and lateral vastus muscles with their distal attachments into the tibia achieved closure of the defect but did not provide

robust tendon material to fill the defect in the anterior knee. The medial gastrocnemius muscle reached easily to the muscular portion of the vastus medialis and lateralis flaps and provided secure closure of the anterior knee and strong attachment of viable muscle and tendon.

Methods Five knees (five patients) with failed patella-patellar tendon allograft between August 2008 and April 2010 were repaired using this technique.

Results Mean extensor lag was 47° (range, 35°–62°) before surgery and improved to 12° (range, 5°–15°) 1 year after surgery.

Conclusions These preliminary results suggest that the described muscle transfer technique may provide an approach to salvage the failed extensor mechanism allograft after TKA.

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

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The author certifies that his 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 can be a debilitating condition after TKA. Extensor mechanism allograft provides an effective remedy for severe quadriceps deficiency caused by loss of the patella, patellar tendon, and quadriceps tendon [1, 4, 5, 9, 12, 15, 18], but late failure is common with these salvage techniques [9, 14] and major quadriceps deficiency is common after removal of the failed allograft material (Fig. 1). Although quadriceps and patellar tendon allograft is a commonly used approach for irreparable deficiency of the quadriceps mechanism involving the knee, techniques to manage the frequent complications have not been described. In cases of multiple

Fig. 1 The defect left when a failed patellar tendon allograft is removed includes the quadriceps tendon and muscle, the patella, the patellar tendon, and the tibial tubercle. Whereas the allograft tibial tubercle bone may be left in place in noninfected cases, it must be removed if infection is involved. Reprinted with permission [20].

revision TKA, deficiencies of the anterior capsule and skin are common [20], so repeat cadaver allograft is not a good solution. Likewise, Achilles tendon allograft [7] and substitution with polymer mesh has had some success in restoring patellar tendon deficiency [3], but these procedures are inadequate to fill the defect left by removal of the allograft material. Furthermore, deficiency of anterior skin precludes the use of nonviable substitutes for the missing patella and tendons. Whereas gastrocnemius flaps can close deep soft tissue defects and protect synthetic mesh substitutes for the patellar tendon, they are not sufficient to close the proximal portion of the defect left when a failed quadriceps tendon-patellar-patellar tendon allograft is removed [20]. In cases of major deficiency of the quadriceps and patellar mechanism, transfer of the vastus medialis and vastus lateralis has been effective both to close the soft tissue gap and also to restore quadriceps function [20]. Addition of the medial gastrocnemius muscle to achieve soft tissue closure of the distal portion of the knee also further improved quadriceps function [20]. Even in cases with major anterior tibial bone loss, soft tissue closure can be augmented with transfer of the medial soleus muscle [20]. This combination of medial and lateral vastus and gastrocnemius muscles (sometimes augmented

with the soleus muscle) also can be done in the presence of anterior skin deficit [20].

This article is an extension of previous work [20] describing quadriceps and gastrocnemius muscle transfers, in which the vastus medialis and vastus lateralis are transferred to fill the proximal gap and the gastrocnemius and soleus muscle flaps are transferred to fill the distal gap in defects created by removing the allograft quadriceps tendon, patella, patellar tendon, and tibial tubercle. A cadaver study was done to evaluate the feasibility of this technique. Additionally, retrospective results of using this combination of muscle flap transfers in five patients (five knees) with TKA and failed patella-patellar tendon allograft are reported.

Surgical Technique

Six lower extremity cadaver specimens were dissected to evaluate the feasibility of transferring the vastus medialis, vastus lateralis, and medial head of the gastrocnemius muscle to fill the defect caused by loss of the quadriceps tendon, patella, patellar tendon, and tibial tubercle after removal of the allograft material. The specimens were prepared by removing entirely the quadriceps tendon, patella, patellar tendon, and tibial tubercle. The bone removal included a segment 10 cm long, 3 cm wide, and 2 cm thick. The vastus medialis flap was detached from the tibial attachment of the medial quadriceps expansion and capsule and dissected posteriorly to the anterior edge of the medial collateral ligament (MCL) (Fig. 2). The flap was dissected proximally, separating the vastus medialis from the sartorius muscle, tendon of the adductor magnus, and the adductor septum (Fig. 3). 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 one-third. The distal two-thirds of the muscle was released from the femur and soft tissue attachments without endangering its nerve or blood supply. This dissection was much more extensive than was necessary to cover the defect created by removing the patella and extensor mechanism. The distal portion of the flap included the synovial membrane, capsule, and quadriceps expansion anterior to the MCL. The distal capsular and synovial portion of the flap was thin but was easily pulled distally to cover the tibial tubercle. The inferior edge of the muscle

Fig. 2 Elevation of the vastus medialis flap began with releasing the medial retinaculum, capsule, and synovial tissue from their tibial attachments as far posteriorly as the anterior edge of the MCL. Reprinted with permission [20].

Fig. 3 Sharp dissection is used to separate the vastus medialis flap from the anterior edge of the MCL, the sartorius muscle, and the adductor tendon and aponeurosis. Reprinted with permission [20].

itself 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 (Fig. 4).

The vastus lateralis muscle was separated sharply from the vastus intermedius and rectus femoris muscles, and the

Fig. 4 The distal end of the vastus medialis flap could be pulled distally to partially cover the tibial defect. In the surgical procedure, the distal end of the flap was attached to the tibia with a double running-lock suture and sutured to the vastus lateralis over the front of the knee. Reprinted with permission [20].

distal attachment of the lateral quadriceps expansion, the synovial membrane, and the anterior half of the iliotibial band (ITB) including half of the portion attached to Gerdy's tubercle were elevated as a composite flap (Fig. 5). The flap was dissected proximally, splitting the ITB longitudinally and leaving the anterior half adherent to the vastus lateralis muscle. The portion of the vastus lateralis under the posterior half of the ITB was dissected from the femur and the undersurface of the posterior portion of the ITB. The perforating branches from the profunda femoris artery and vein were noted as this dissection was performed (Fig. 6). This could be done while leaving the popliteus tendon and lateral collateral ligament undisturbed. The distal fibrous portion of the quadriceps expansion of the vastus lateralis was thin but the ITB 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, and the distal-most perforating artery consistently was found approximately 5 cm (one handbreadth) above the superior pole of the patella. Branches of the femoral artery to the vastus lateralis muscle itself were encountered

Fig. 5 The vastus lateralis flap was fashioned distally by separating the vastus lateralis expansion, lateral capsule, and synovial membrane from the tibia as far posteriorly as the middle of Gerdy's tubercle. Sharp dissection was carried proximally just anterior to the fibular collateral ligament, splitting the ITB in line with its fibers. Reprinted with permission [20].

anteromedially only in the upper one-third 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 ITB could be stretched easily to the tibial tubercle in all specimens but did not cover the defect in the bone created by excision of the tibial tubercle (Fig. 7). The lateral quadriceps expansion and underlying synovial membrane did not have enough substance to resist even moderate tensile loads. Grasping the distal end of the transferred flap with a Kocher clamp and pulling distally resulted in visible stretching of the fibrous quadriceps expansion and synovial membrane. However, including the anterior portion of the ITB provided substantial thickness and tensile strength. This tissue could not be stretched with manual tensile load. Because the vastus lateralis takes origin partly from the undersurface of the fascia lata, including the ITB in the transfer did not decrease the flexibility of the transferred unit.

To assess the use of the medial gastrocnemius muscle to fill gaps in the extensor mechanism and anterior tibial bone structures, the incision was extended in the midline to a point just proximal to the ankle. Subfascial dissection was

Fig. 6 The vastus lateralis was left attached to the anterior half of the ITB, and the muscle was dissected from under the posterior portion of the ITB to expose the perforating vessels from the profunda femoris artery. Reprinted with permission [20].

done to expose the soleus muscle and continued to the medial edge of the gastrocnemius muscle. This dissection was continued with manual blunt dissection to expose the posterior surface of the gastrocnemius muscle, and the medial half of the gastrocnemius and soleus muscles were released from their attachments into the calcaneal tendon and sharply separated from the lateral half of the muscles up to their neurovascular pedicles (Fig. 8). These muscle flaps were folded proximally to cover the anterior knee (Fig. 9), 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. Closure of the medial and lateral capsular defects caused by elevating these flaps could be done by suturing the edges of the flaps to the undersurface of the deep fascia (Fig. 10).

Medial gastrocnemius and soleus muscle flaps all could overlap the joint line by 3 cm (range, 3–4 cm), and both could reach the distal muscular margin of the vastus medialis and vastus lateralis flaps in all specimens. Bone defects that enclosed the entire tibial tubercle and tibial crest 4 cm distally could be covered with a combination of gastrocnemius and soleus flaps.

Actual surgical exposure and elevation of the muscle flaps is considerably more difficult and complex than cadaver dissection. Special care must be used to identify the anterior edge of the MCL to avoid elevating it along

Fig. 7 With modest tension the vastus lateralis flap could be pulled distally far enough to partially cover the tibial tubercle defect. In the surgical procedure, this distal fibrous end of the flap was sutured to the edges of the bone defect with a double running-lock suture. The edges were sutured to the vastus medialis, and proximal lateral closure was done under minimal tension. Reprinted with permission [20].

with the medial vastus flap. Dense fibrosis often is encountered in both the medial and lateral vastus extensions to the tibia, but in some cases, the tissue is thin and tenuous. Once the posterior muscle fibers are encountered, the dissection becomes easier, and much of it can be done bluntly with finger pressure.

In the surgical procedure, the patient was supine for both the vastus medial and lateralis flap elevation as well as the medial gastrocnemius flap. The vastus medialis flap was developed by detaching the medial capsule and synovial membrane as a single layer from the tibia as far posteriorly as the MCL. 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 as much as was necessary to achieve substantial anterior closure with modest lateral traction on the vastus medialis. None of the clinical knees required an extensive dissection as was done on the cadaver specimens, and the adductor aponeurosis was only partially exposed for a distance of 3 cm above the adductor

Fig. 8 Exposure of the medial gastrocnemius muscle was achieved by extending the incision distally to a point just above the ankle. Dissection is carried medially beneath the deep fascia to expose the soleus and gastrocnemius muscles. The medial gastrocnemius is detached from the calcaneal tendon and dissected sharply proximally to the neurovascular bundle. Reprinted with permission [20].

tubercle. This dissection was performed gently to avoid damage to the femoral artery and vein. With the adductor tendon and aponeurosis clearly in view, the vastus medialis muscle was held under tension perpendicular to the underlying fibrous septum and tendon. Sharp dissection with the knife blade directed away from the deep tissues was done to avoid cutting the femoral vessels that are deep to the adductor aponeurosis at this position in the thigh. The surgeon must be prepared to transect the adductor aponeurosis and expose the femoral artery and vein in the posterior portion of the thigh if the vessels are injured.

Transfer of the lateral vastus flap was begun by incising sharply between the vastus lateralis and conjoint rectus femoris and vastus intermedius muscles at the top of the

Fig. 9 Closure of the distal defects was done with the medial gastrocnemius flap sutured to the distal fibrous portions of the transferred vastus flaps. Reprinted with permission [20].

defect formed by removing the failed allograft. Then the distal attachment of the lateral capsule, synovial membrane, and ITB were released with a knife from the tibia as far posteriorly as the middle of Gerdy's tubercle. The ITB was found to be a substantial structure. The distal end of the flap was pulled anteriorly as the ITB was split in line with its fibers from distally to proximally, leaving the posterior half of the ITB attached to the tibia. As the ITB 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 ITB and intermuscular septum down to the femur. Perforating vessels that were encountered were suture-ligated and transected. These vessels are clearly visible if the dissection is done under direct vision and with a dry field. The surgeon should be prepared to separate the intermuscular septum from the femur and expose the perforating vessel in the posterior thigh if it retracts after being transected. This

Fig. 10 Deep closure of the medial and lateral capsular defects was accomplished by suturing the edges of the muscle flaps to the undersurface of the deep fascia with interrupted absorbable sutures. Reprinted with permission [20].

dissection was much less extensive than was done in the cadaver specimens, and suture ligation of perforating vessels was necessary in two clinical cases.

When the two flaps could be easily approximated to one another, dissection was deemed sufficient and distal attachment of the flaps was done. With the knee in full extension, the distal fibrous portions of the graft were placed one on top of the other with the vastus lateralis portion placed under the vastus medialis. They were sutured into remaining bone stock with drill holes in the edges of the tibial defect and a running locked suture in the tendon as described by Krackow [13]. The flaps were pulled to moderate tension and two running locked sutures using heavy nonabsorbable sutures (number 5 TiCron; Covidien, Mansfield, MA, USA) were placed. This was reinforced with heavy absorbable sutures (number 2 Vicryl; Ethicon, Somerville, NJ, USA) to attach the flaps to the

available periosteum and capsular tissue on both sides of the bone defect.

A medial gastrocnemius and/or soleus muscle flap was used to provide distal attachment for the vastus medialis and vastus lateralis flaps and to fill the distal soft tissue and bone defect. This portion of the procedure was done with the patient lying supine. Exposure of the medial gastrocnemius and soleus muscle group was achieved by extending the midline incision distally to the distal one-third of the tibia and further to the ankle, if needed. The medial skin flap was developed under the deep fascia, dissecting under the saphenous nerve and vein. The lower extremity was externally rotated at the hip to bring the medial gastroc-soleus muscle group into view, and the knee was flexed approximately 20°. 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 muscle into the calcaneal tendon. The tendinous attachment was released sharply, and the medial half of the gastrocnemius muscle was separated sharply from the lateral half, continuing the dissection proximally with sharp and blunt dissection to a point near the neurovascular bundle that enters the muscle in its deep surface. This dissection was accommodated by retracting the released medial portion distally and medially to achieve exposure. This muscle then was folded proximally and sutured to the ends of the vastus muscle transfers over the top of the bone attachments into the tibia. In cases of deficient gastrocnemius muscle (one knee), the medial half of the soleus was elevated and transferred in a similar manner.

The proximal portions of the vastus muscle flaps then were closed with interrupted heavy absorbable sutures (number 2 Vicryl). The muscle edges were closed in two layers over the knee, and the medial and lateral edges of the transferred muscle mass were sutured to the deep fascia with interrupted heavy absorbable sutures to form watertight closure of the knee.

Subcutaneous tissue and skin were closed over the transferred muscles, taking care not to pull the edges tight. Surfaces that could not be covered by the skin closure were dressed open and covered with antiseptic gauze (Xeroform™; Cardinal Health, Dublin, OH, USA).

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 gradually 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.

Patients and Methods

Five patients (five knees; four women, one man) with failed patella-patellar tendon allograft were treated with the described technique between August 2008 and April 2010 and evaluated at a mean of 39 months after the muscle flap reconstruction (range, 20–51 months). Two of the failed allografts were associated with infection of the TKA, and three were caused by mechanical failure of the graft. The two knees with infection were treated with complete revision, thorough débridement, and antibiotic infusion as well as muscle transfer. The mean age of this group was 68 years (range, 63–78 years). Before surgery, the mean extensor lag was 47° (range, 35°–62°) and the mean flexion contracture was 2° (range, 0°–10°).

The patients were evaluated 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 1-month, 3-month, 6-month, and yearly postoperative clinical followup visits. They were evaluated at their latest visit for anterior knee pain, presence of draining sinuses, unhealed skin, 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 leaks, necrosis of the transferred muscle flap, donor site complications, and extensor lag.

Results

Active extension was restored in these patients. The mean extension lag in this group was 12° (range, 5°–15°) 1 year after surgery, and the mean knee flexion contracture was 2° (range, 0°–6°). These numbers were unchanged at latest followup. Also at the latest followup visit, walking distance was greater than five blocks in all patients, and their walking distance was not limited by the affected knee. Three of the five patients could ascend one flight of stairs with the affected extremity and aid of the handrail. All patients could actively plantar flex the ankle, and all could do a standing toe raise on the affected extremity. Two patients reported slight anterior knee pain, and the other three reported no significant pain in the reconstructed quadriceps.

Complete skin closure was not possible in two of the knees because of skin loss, and the knees were dressed open with XeroformTM gauze. Split-thickness skin grafting was not a good option in these patients because of the thin and atrophic condition of their skin. These two knees achieved final closure with secondary skin growth by 3 months postoperatively. All knees achieved deep closure of the joint without synovial fluid leaks by 7 days after surgery. None had clinically apparent necrosis of the transferred muscle flaps, and none had evidence of donor site complications.

Discussion

Quadriceps deficiency in TKA has been treated effectively with patellar-tendon allograft, and 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 [1]. Results with this technique have been reported by several investigators, and it has been effective in restoring quadriceps function if the muscles are tensioned correctly in extension [2, 4, 6, 8, 9, 13, 14, 16]. However, it has a high failure rate, and recurrence of quadriceps deficiency is common [9, 14]. The literature is virtually silent regarding surgical techniques to repair or reconstruct the quadriceps mechanism and bone deficit that remain after the failure of an extensor mechanism allograft. This article describes a new surgical procedure that transfers the vastus medialis and/or the vastus lateralis and their tibial attachments to the anterior tibial defect and transfers the medial gastrocnemius and/or soleus muscles to attach to the transferred quadriceps muscles, substitute for the missing patellar tendon, and cover the tibial bone deficit. The anatomic dissections suggested that the vastus medialis and vastus lateralis flaps are accessible with modest dissection and can fill the proximal soft tissue deficit effectively and that the medial gastrocnemius and soleus muscles are capable of covering the anterior tibial bone deficit and attaching to the transferred vastus muscles without excessive stretching.

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 with short followup, 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. The results of this study should be considered to be preliminary because followup is so short. It is possible that the quality of quadriceps function may

deteriorate as time passes and that longer followup might reveal increasing dysfunction of the quadriceps.

Whereas it may be feasible to revise failed patellar tendon allograft with another allograft, this would be difficult in the face of major proximal tibial deficiency and would not be appropriate if the capsular defect could not be filled and sealed with allograft or if skin closure could not be done completely. The superficial position of the allograft tissue and the poor condition of the skin over the anterior portion of the knee makes repeated revision surgery with repeat allograft unattractive. Likewise, if infection were part of the pathological process, repeat allograft might be contraindicated. Previous reports suggest that the vastus medialis and lateralis flaps can be effective for closure of major defects in the quadriceps tendon and proximal capsule of the knee [20]. 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 these 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 functions, and reeducation of the muscle is not necessary during rehabilitation. Despite good soft tissue coverage with vastus flaps, extensor function is not effectively restored with these transfers alone [20]. However, addition of a medial gastrocnemius flap seems to restore extensor function of the transferred muscles [20].

Transfer of local muscles to restore strength of movement has been encouraging in other areas. 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 enables capsular closure of the hip and improved abductor function [19, 21]. Using the gastrocnemius muscle to achieve soft tissue closure of the knee is also common and is generally successful, and the gastrocnemius also restores extensor function of the knee when transferred into the quadriceps [11, 17]. This current series of revision of failed patellar tendon allograft ultimately achieved anterior wound closure by using a combination of vastus medialis, vastus lateralis, gastrocnemius, and soleus muscles to seal the knee and to restore quadriceps power. The clinical results revealed that these techniques restored quadriceps function with minimal anterior knee pain, and the anatomical study confirmed that the technique is feasible with modest exposure and dissection that should be within the capabilities of a surgeon who is accomplished in TKA revision. Although the series is too small to provide reliable statistical comparison, these results suggest that

this combined muscle transfer technique can achieve soft tissue closure of the knee in the presence of major deficiencies in muscle, bone, and skin. 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. Before undertaking such a demanding and lengthy surgical procedure, conservative measures including bracing and a drop-lock hinge prosthesis should be considered and attempted on patients whose extremities are amenable.

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