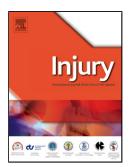# Accepted Manuscript

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Medial Gastrocnemius Flap for Reconstruction of the Extensor Mechanism of the Knee Following High-Energy Trauma. A minimum 5 year follow-up

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Level of evidence:
IV, case series

Running title:
medial gastroc flap

Abstract

Introduction:

The purpose of this study was to assess the medium-term results of reconstruction of the extensor mechanism using the medial gastrocnemius while also providing soft tissue coverage.

Materials and Methods:

This retrospective review consisted of a consecutive series of four patients (age 28-40 years) with complex high energy traumatic injuries to lower extremity including both soft tissue loss and disruption of the knee extensor mechanism. The medial gastrocnemius rotational flap was used to reconstruct the patellar tendon and restore soft tissue coverage simultaneously. Range of motion and extensor lag; functional recovery was judged by return to work and sports activity. Validated measures included the Oxford Knee Score, Knee Injury and Osteoarthritis Outcome Score, and the modified Cincinnati Score.

Results:

At the final follow up was 61.5 (57-66) months after reconstruction, the mean SF 12 physical component score ranged from 21.7 to 56.8 with a median of 55.3; the mental component from 42.8 to 60.7 with a median of 58.6. The KSS knee score ranged from 50 to 78 with a median of 68; the function score from 65 to 90 with a median of 85. The Oxford knee score ranged from 22 to 45 with a median of 33.5. The KOOS ranged from 28 to 82.7 with a median of 73.7 and the modified Cincinnati score from 38 to 82 with a median of 76.5. Knee range of motion ranged from 0 to 120 degrees. Of the four patients three returned to working fulltime in their profession and returned to sports, including mountain biking and fitness training.

Conclusions: For severe traumatic knee injuries with the combination of soft tissue defects and disruption of the extensor mechanism, the medial gastrocnemius flap provides an

excellent reconstructive option to address both problems simultaneously. The results of this

small case series support the use of this limb salvage technique.

Introduction

Extensive traumatic injuries at the knee with involvement of the extensor apparatus are a challenging problem [16,17]. The soft tissues overlying the knee are relatively thin and high-energy trauma in this region often leads to open fractures or dislocations, with a significant risk of developing infection [7,17]. When the extent of soft tissue loss is severe enough to destroy the extensor mechanism, the potential problems involved in limb salvage and reconstruction are compounded [17,23]. These injuries are often associated with contamination of the wound, and internal fixation and definitive surgery is routinely delayed [7]. The combination of a soft tissue deficit and an absent patellar tendon can result in arthrodesis or amputation if these efforts are unsuccessful [30].

Management of open injuries with aggressive débridement and early coverage is a basic principle of modern treatment, often involving muscle flaps to restore the soft tissue envelope [8]. Reconstruction of the extensor mechanism using the medial gastrocnemius muscle has been previously described for combined tissue loss during revision knee arthroplasty or tumour surgery [5,15,20,26,27], but few prior reports describe its use as a post-traumatic reconstructive option [3,7,16,23].

The management objectives are therefore complex, but generally include preliminary stabilization with external fixation, aggressive débridement, and restoration of the soft tissue envelope as early as possible [10]. Soft tissue coverage with viable muscle delivers nutrients and antibiotics to augment control of bacterial contamination, limiting the risk of further infection [8]. With this constellation of injuries it is important to restore the extensor mechanism while minimizing immobilisation, to reduce potential stiffness and maximise the power of knee extension [25].

The purpose of this retrospective review was to assess the medium-term results of reconstruction of the extensor mechanism using the medial gastrocnemius while also providing soft tissue coverage.

Material and Methods

This case series reviewed four male patients aged 28–40 years who sustained high-energy trauma and were treated with a medial gastrocnemius rotational myoplasty for simultaneous soft tissue coverage and reconstruction of the patellar tendon (Table 1). Prior approval to conduct this study was obtained from our Institutional Review Board. Two patients were admitted directly to our unit, and two transferred from another hospital after initial debridement and spanning external fixation. Disruption of the extensor mechanism occurred at the time of injury in three patients.

Three patients with open injuries sustained direct trauma to the patellar tendon or the tibial tubercle. In one of these patients direct repair of the patellar tendon was attempted at another institution, but was complicated by deep infection leading to subsequent débridement of the patellar tendon and overlying soft tissues. The degree of soft tissue loss in the others precluded primary repair. In all four patients, debridement was repeated until healthy tissue margins were attained; an average of 3.5 procedures (2–5) were required before wound final coverage was performed. Definitive reconstruction and soft tissue coverage with the medial gastrocnemius flap was achieved an average of 32 days after the initial injury (13–44 days). The final follow up was 61.5 (57-66) months after reconstruction.

Surgical technique:

The surgical technique followed the principle described by Babu et al. [3]. Through a posterior midline or posteromedial incision the gastrocnemius muscle was isolated and then raised with its deep fascia from the underlying soleus. The medial muscle belly was released distally to the musculotendinous junction, the medial portion of which was harvested together with the muscle. The medial gastrocnemius was denervated after identifying the neurovascular bundle proximally, taking care to preserve the sural arterial pedicle. Most of the deep fascia was scored or removed to increase muscle compliance and maximize the potential area covered by the flap. However the distal fascia was maintained and used for the reconstruction of the patellar tendon.

The muscle was rotated on its pedicle, passed through a subcutaneous tunnel beneath the medial skin bridge proximally, to cover the anterior soft tissue defect. When aligned over the site of the disrupted patellar tendon, the muscle fibres lay approximately 20 degrees to the horizontal. The inferior border of the muscle was sutured to the deep fascia of the anterior compartment and the periosteum of the subcutaneous tibia, and the superior border was sutured to the remnant of the patella tendon. The position of the flap was initially set with the knee in extension, and any slack was taken out of the tendon. Flexing the knee to 90 degrees, the patellar tendon tension and length was set with the inferior pole of the patella at the level of the apex of the inter-condylar notch.

Postoperative protocol:

The involved limb was splinted at 10 degrees flexion for two weeks to allow healing of the skin graft. From week 2-6 the knee was passively mobilised from 0 – 45 degrees, and full weight bearing was allowed within a rigid extension splint. From week 6-12 weight bearing

was allowed in a brace set 0-30 degrees and active physiotherapy with maximal knee flexion was encouraged. From week 12 full weight bearing was allowed without brace support.

Outcome Variables

Four validated knee scoring systems, the SF 12 short form quality of life health survey were used. Range of motion of the involved knee was measured and all surgical complications were recorded by an independent research associate.

Short Form SF 12

The short form 12 (SF12) is a generic measure and consists of twelve SF-36 items Physical component score (PCS) and mental component Score (MSC) were calculated as described by Ware et al [33]. These scores range on a scale from 0 to 100, where a zero score indicates the lowest level of health measured by the scales and 100 indicates the highest level of health. One of the major benefits of the additional use of a generic questionnaire is the patient's psychological status can be assessed [12] and correlates with a decreased knee score in a condition specific questionnaire [14]

Knee Society Clinical Rating System (KSS)

The Knee Society Clinical Rating System is divided into the knee score and the function score. The Knee score is comprised of pain (50 points), range of motion (25 points with a maximum of 125 degrees) and stability, measuring antero-posterior and mediolateral stability separately (25 points). Deductions are made for flexion contracture, extension lag, and alignment. The Function score is comprised of walking distance (50 points), and stair climbing (50 points) with deductions for using a walking aid.

Oxford Knee Score

The Oxford Knee Score consists of twelve items, each with a score of one to five (from worst to best): pain; difficulty washing and drying self; difficulty getting in and out the car/public transport; walking duration; pain on standing; limp; ability to kneel; night pain; interference with work; giving way; ability to do shopping and ability to descend stairs [9].

Knee and Osteoarthritis Outcome Score (KOOS)

The KOOS is a knee specific instrument, which assesses patients' views on their knee and associated quality of life [28]. It contains 42 items in 5 separately scored subscales: pain, other knee symptoms, function in daily living (ADL), function in Sport and Recreation (Sport/Rec), and knee related quality of life. A Likert scale is used to score the KOOS and all items have five possible answers scored from zero (no problems) to four (extreme problems). Each of the five scores is calculated as the sum of the items included and scores are then transformed to zero to one hundred (0-100) scale with zero (0) representing extreme knee problems and one hundred (100) representing no knee problems. An aggregate score is not calculated as the KOOS is designed for analysis of each subscale separately.

Modified Cincinnati Score

The Cinncinati Knee Rating System consists of 13 scales including a series of hopping tests and clinical and radiological assessment. This rating system was modified to a questionnaire version that patients can complete without outside input. For this research the version used by Agel & LaPrade was utilized [1].

Range of motion

Range of motion (ROM) was evaluated using a standard goniometer using the method described by Brosseau et al. [4]. Patients were placed supine on the hospital bed and the bony landmarks, the greater trochanter and lateral malleolus, were marked. The goniometer was aligned along these landmarks in maximal knee flexion and extension. As suggested by Brosseau et al. all measures were taken by the same independent research associate [4]. The authors have demonstrated high intra-tester reliability of 0.99 in flexion and 0.97 in extension.

Results

Table 2 summarizes the clinical results including scoring systems, range of motion and extend of extensor lag.

Outcome scores

The mean SF 12 physical component score ranged from 21.7 to 56.8 with a median of 55.3; the mental component from 42.8 to 60.7 with a median of 58.6. The KSS knee score ranged from 50 to 78 with a median of 68; the function score from 65 to 90 with a median of 85. The Oxford knee score ranged from 22 to 45 with a median of 33.5. The KOOS ranged from 28 to 82.7 with a median of 73.7 and the modified Cincinnati score from 38 to 82 with a median of 76.5. Patient no. 3 consistently displayed the lowest scores.

Range of motion

Knee range of motion ranged from 0 to 120 degrees. Of the four patients three returned to working fulltime in their profession and returned to sports, including mountain biking and fitness training. Similar to the outcome scores patient no. 3 was unable to return to work or any meaningful physical activity. This is most likely caused by the severity of his injury.

Complications

Complications were common, indicative of the severity of the initial injuries. All four developed wound infections or bacterial colonization, three of which involved the original open wounds. Only Patient no. 1 developed infection as a complication of treatment, following limited open fixation of his Schatzker 6 plateau fracture and stabilization with an Ilizarov external fixator. This infection was managed in stages, with débridement and bead sterilization beneath his flap; the infection resolved completely, but he progressed to malunion. Gradual distraction with a Taylor Spatial Frame corrected the malalignment, and he has achieved the best clinical outcome in this group of patients. Patient 2 required several further operations, which included débridement of his bone graft donor site, an MUA for stiffness, fixation and bone grafting for a tibial non-union, three other operations for removal of metalwork, a scar revision and four weeks of parenteral antibiotics. Patient no. 2 had also sustained ipsilateral tibial and femoral fractures, a fracture of the ipsilateral femoral neck, and a contralateral tibial fracture. Despite this, he progressed to a very good clinical result.

Patient no. 3 sustained the most devastating constellation of injuries, and his clinical course and outcome reflect the severity of his initial injuries. He had a Grade 3b open segmental fracture extending the entire length of his tibia, with 8 cm of bone loss including his tibial tubercle, complete disruption of the proximal tibio-fibular joint, and an open Schatzker 6 plateau fracture with extrusion of the lateral plateau articular surface. After initial débridement, acute shortening, and external fixation, he was later converted to an Ilizarov fixator for bone transport. He required a peroneal nerve release, adjustment of his Ilizarov frame to correct alignment on several occasions, closed osteoclasis after premature consolidation, and delayed reconstruction of the proximal tib-fib joint. He subsequently

underwent further operations for infection of the proximal tibiofibular joint including procedures to address degenerative sequelae of other injuries sustained in the same accident, including arthrodesis of the ipsilateral subtalar joint. The post-operative course for Patient no. 4 did involve one further operation, a Judet quadricepsplasty for knee stiffness.

Discussion

The medium term results of this small case series with a follow-up of five years demonstrate that the medial gastrocnemius flap for reconstruction of the extensor mechanism of the knee is a suitable surgical technique in these difficult cases. It reliably restores range of motion with a minimal extensor lag without the need for complicated free flaps or vascular flaps and results in a high satisfaction rate with good functional outcomes. The medial gastrocnemius flap has been described by multiple authors as a salvage technique to provide soft tissue cover for failed or infected knee arthroplasty with soft tissue loss and as a suitable graft option in tumour surgery [5,15,20,21,26,27,32]. In the orthopaedic literature only 13 trauma cases have been reported so far [3,16,17,23]. These case series are limited by the short follow-up and the focus on range of motion and extensor lag as the only outcome measures. The current study has included various validated outcome measures and has the longest follow-up of all published series.

With most patellar tendon ruptures there is no tissue loss, and direct repair is normally successful [29]. However, following high-energy open injuries the conditions are considerably more hostile, limiting management options. Instead of reconstructing the patellar tendon, limb salvage by knee arthrodesis provides a durable alternative solution [2]. Intra-medullary nailing following open knee injuries, however, may present an unacceptably high risk of deep infection, and external fixation has been frequently used. Salem et al.

reported on 12 patients with infection after knee trauma that underwent knee fusion using an Ilizarov frame [30]. The time spent in the frame averaged 22 weeks, with a 50% complication rate. Garberina, et al. reported on 19 patients also undergoing knee arthrodesis using the Ilizarov technique [11]. Fusion was successful in 68% of cases with patients in frames for an average 19 weeks, but the complication rate was again high, 84% of cases.

Loss of the patellar tendon is occasionally encountered during complicated revision total knee arthroplasty, and extensor mechanism excision is often associated with proximal tibial tumour resection [5,15,20,21,26,27]. Tendon autograft [6], composite allograft [18,21,31] and synthetic grafts [22] have all been utilised during revision total knee replacement or following tumour excision. In those settings the adjacent soft tissue envelope is usually intact and healthy, the skeleton stable, and the host physiology often normal. However, extensor mechanism reconstruction after loss resulting from trauma is uncommon as mentioned earlier [3,16,17,23].

If knee joint salvage is attempted a vascularised graft has advantages, and various donor sites have been described. Hallock used a re-innervated latissimus dorsi flap to successfully repair an isolated quadriceps femoris gunshot defect [13]. Wechselberger et al. described the use of a free rectus femoris flap in two patients with similar post-traumatic quadriceps defects [34]. Kuo et al. reported a single case of composite soft tissue and patellar tendon deficiency managed with a composite antero-lateral thigh flap [17]. The fascia lata was tubulized and substituted for the tendon, the vastus lateralis component was used to power the knee, and the skin defect was reconstructed with a skin paddle. This patient reportedly had a residual extensor lag, but satisfactory function with ROM from 20-120 degrees at 5 years.

The medial gastrocnemius flap is a standard technique for soft tissue coverage around the knee, and is reportedly safe and reliable with low donor site morbidity. Malawer et al. first described medial gastrocnemius reconstruction of the extensor mechanism in four tumour patients with knee endoprostheses [20]. Several authors [5,6,15,26,32] have reported very good results using this flap after patellar tendon loss during complicated knee arthroplasty. There are also reports of its successful use after both infection of the native knee and chronic osteomyelitis of the tibial tuberosity [5,24]. In this case series loss of the extensor mechanism involved complete detachment of the patellar ligament insertion, with destruction of portions of the ligament in all cases and complete or partial loss of the tibial tubercle in two cases. With complete loss of the extensor apparatus, including both patellar and quadriceps tendons, it could be argued that the medial gastrocnemius flap may be not be able to reconstruct the entire extensor mechanism and further augmentation with auto- or allograft tendon may be desirable. In a case report Raschke, et al. described the use of autologous ipsilateral gracilis and semitendinosus tendons, looping them through the quadriceps remnants [25]. However, other authors reported modifications by utilizing either a portion of the Achilles tendon or the thick aponeurosis from the deeper aspect of the gastrocnemius to reconstruct the entire extensor mechanism [3,16,23,27]. The strength of this technique is due to the fact that the same tissue is being used in the reconstruction to fill two roles. It is simultaneously providing vital soft tissue cover while also restoring the continuity of the extensor mechanism, facilitating re-attachment of the patellar ligament remnants back to the tibial tubercle [3,5,7,15,20,24,26,27].

Individual case reports and small series describe variations of this flap to reconstruct the extensor mechanism after trauma, and suggest good results may also be obtained in this clinical situation [19,23]. Park et al. reported using simultaneous medial gastrocnemius and

saphenous neuro-cutaneous flaps to address extensor mechanism loss and skin defects secondary to post traumatic infection and subsequent debridement [23]. At one year the authors reported full extension, 135 degrees flexion, and grade 4 power. Leung et al. also employed the medial gastrocnemius muscle in four trauma patients, but extended the graft to include the calcaneal tuberosity, which was fixed to the tibial tuberosity [19]. The proximal end of the Achilles' tendon was sutured to the quadriceps muscle, allowing mobilisation at one week. No other authors have reported problems with incorporation of the soft tissue flap, and it is uncertain if transferring the calcaneal tuberosity provides any advantage.

Few prior publications specifically describe using the medial gastrocnemius flap for extensor mechanism reconstruction following trauma. Babu et al. described this technique in two patients, but did not record the associated bone injuries or the clinical outcomes [3]. Rhomberg et al. used a variation of this technique in five cases (only one traumatic) using the medial gastrocnemius to augment partial thickness patella tendon loss, and adding partial harvest of the Achilles tendon fascia to address full thickness patella tendon defects [27]. One patient subsequently required further coverage with the lateral gastrocnemius, and another required amputation to control infection. Despite this, good results were reported in all five cases when reviewed at 3.5 years following reconstruction. We employed the same technique as described by Babu, and the deep fascia was used to provide strength for the reconstructed extensor mechanism, but oriented obliquely to that of the native tendon [3]. Rhomberg, however, described folding the deep fascia 3-fold for strength while orienting the fibres vertically [27].

Jepegnanam et al. reported their series of eight cases reconstructed using either the medial or both gastrocnemii following complete traumatic extensor mechanism loss [16]. In contrast

to other previously reported studies, these injuries were associated with significant fractures of the distal femur, patella or proximal tibia. Most similar in character to our series, this may obviously have an impact on the clinical outcome. Tendon loss was due to direct trauma in seven cases, and infection in the other. Seven of these eight patients had positive wound cultures at débridement, but all infections resolved by the 10th post-operative day. At two years follow up they recorded the Hospital for Special Surgery Score (HSS) and basic clinical data. Jepegnanam et al. reported no complications or donor site morbidity [16]. By contrast our study recorded a greater complication rate with all patients experiencing at least one complication. In our opinion, this complication rate accurately reflects the many problems and issues that would likely need to be addressed when managing patients with these devastating injuries. None of the complications in our series were directly related to the extensor mechanism reconstruction, but were instead complications associated with the initial trauma. We also noted a complete absence of donor site morbidity, consistent with prior reports using this flap.

To restore maximum knee movement, the reconstruction must be robust enough for early rehabilitation. We allowed passive knee mobilisation at two weeks, whereas Jepegnanam immobilised his patients in extension for six weeks [16]. Despite this, knee motion at final follow up was similar. It is possible that our series had more complications as a result of early motion, although the high complication rate was most likely related to the severity of the soft tissue injuries, incomplete initial débridement, and delays in treatment associated with transfer to our unit.

Patient 3 had progressive lateral tibial plateau resorption, and later developed instability secondary to valgus mal-alignment. Upon referral to our unit at post-injury day four his

lateral plateau was almost completely extruded, displaced several centimetres, and rotated 140 degrees. This bone was nearly avascular, but was retained in an attempt to preserve the knee joint. Patient 4 had a dislocated knee and ruptured PCL at the time of injury, but was clinically stable after reconstruction of his patellar tendon, and he has not required further ligament surgery. The multiple other injuries sustained by three of our patients may have affected their outcome scores [27], and makes it difficult to independently assess the results specifically regarding traumatic disruption and subsequent reconstruction of the patellar tendon.

Conclusion

For severe traumatic knee injuries with the combination of soft tissue defects and disruption of the extensor mechanism, the medial gastrocnemius flap provides an excellent reconstructive option to address both problems simultaneously. The results of this small case series support the use of this limb salvage technique.

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Table

Table 1: Clinical Summaries

	Patient 1	Patient 2	Patient 3	Patient 4
Mechanism	Motorcycle	Motorcycle	Motorcycle	Boating accident, Propeller injury
Injury	Schatzker VI tibial plateau #	3B open proximal tib/fib #, ipsilateral femoral condyle #	Segmental 3b tib/fib #, Schatzker VI component, 8 cm bone loss including tibial tubercle	Open knee dislocation
Initial Treatment	Admitted direct	Admitted direct	Referred day 4	Referred day 25
Other injuries	N/A	Ipsilateral ankle open # dislocation, displaced NOF, contralateral distal tib'fib #	Ipsilateral Pilon #	Pelvic #, peroneal nerve palsy
Skeletal Management	ORIF, Ilizarov	ORIF femur Ilizarov tibia	ORIF, Ilizarov	Patella tendon primary repair
Cause of patella tendon loss	Infection post ORIF	Primary loss	Primary loss	Infection following direct repair of severely injured tendon
Sequence of operations	ORIF Reconstruction	Extensor reconstruction, ORIF	Extensor reconstruction, ORIF	Tendon repair, ORIF
Débridement before reconstruction	4	2	3	5
Injury-reconstruction interval (in days)	44	25	13	44
Organism	Enterobacter cloacae Staph warneii	MRSA Enterobacter cloacae	MRSA Pseudomonas aeruginosa	Mycobacterium fortuitum
Complications	Late malalignment, prominent metal	Infection bone graft donor site, non-union, stiffness prominent metal, prominent scar	Infection, malalignment, nerve entrapment, knee OA	Knee stiffness
Further operations	Late re-alignment, removal of metal	MUA knee ORIF LFC, Debridement (x1)	Frame adjustment (x3), debridement (x6), re-alignment frame	Judet Quadricepsplasty
Return to work	Yes: IT	Yes: Lecturer	No	Yes
Return to sport	YES: Cycling	Yes: Bushwalking, hiking	No	Yes: Gym, fitness

Table 2: Clinical Results and Outcome Scores

Outcome Score		Patient 1	Patient 2	Patient 3	Patient 4	Median
SF12	Physical	56.8	54.1	21.7	56.6	**55.3**
	Mental	57.9	59.3	42.8	60.7	**58.6**
Knee Society Score	KSS	73	78	50	63	**68**
	Function	90	80	65	90	**85**
Oxford Knee Score		44	45	22	23	**33.5**
KOOS		82.7	80.4	28	67.1	**73.7**
Modified Cincinnati		81	82	38	72	**76.5**
ROM*		5-120	10-120	0-80	5-70	**5-95**
Extensor Lag*		0	0	5	0	**<5**

*In degrees