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ALT flap with vascularized fascia lata for one-stage functional patellar tendon reconstruction

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Summary *Introduction:* Composite anterolateral thigh (ALT) flap with vascularized fascia lata can reconstitute patellar tendon integrity and knee soft tissue coverage in one stage. However, long-term evidence of outcomes is lacking. This work analyzes long-term functional results, compares subtotal and total reconstruction of patellar tendon, and assesses the respective function of the extensor apparatus.
Patients and methods: Outcomes of reconstruction using 10 ALT flaps in 9 patients (age range 21–87 years) were analyzed (mean follow-up 30 ± 6 months). Knee Society Scores, isometric knee extensor strength (M1-M5), and sensory recovery were evaluated, together with active range of motion and extensor lag of the reconstructed limb, compared to contralateral.
Results: Ten flaps were used for tendon replacement in 9 patients. Eight (80%) free flaps and 2 (20%) propeller distally based flaps were used. Complications requiring the harvest of a second flap were seen in 2 patients. All patients could return to their daily activities without the use of walking supports. Mean active ROM was 94.4° with an extensor lag of 9.4°, without a significant difference between partial and total patellar tendon reconstruction. The mean knee and functional scores of the Knee Society were 81/100 and 77/100, respectively.

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Conclusion: Composite ALT flap with fascia lata can satisfy the twofold needs of functional restoration and soft tissue coverage, thus ensuring stable results in total and subtotal knee extensor mechanism reconstruction. Distally based flaps should be carefully considered, as they lead to higher complication rates.

Introduction

Reconstruction of composite defects of the knee joint is often challenging, not simply as these defects involve filling the three-dimensional defect that changes with knee flexion and extension but may also involve reconstitution of the extensor mechanism of the knee. This is particularly true when trauma, oncologic resection, or debridement following total knee prosthesis (TKP) infection and replacement leads to complex loss of knee substance extending beyond the soft tissues. When the extensor mechanism of the knee is lost, not only must the joint coverage be guaranteed but the functional and anatomical reconstruction of tendons and ligaments must also be guaranteed.

Different local and free flaps have been reported in literature to re-establish knee extension dynamics, combined with tendon autograft[1] or cadaveric patella tendon allograft,[2] in single- or two-stage procedures. Local flaps are often inadequate in size to address large defects coverage and their own vascular supply may have been jeopardized following debridement.[3] Free flaps associated with nonvascularized tendon or artificial ligaments represent a valuable option at the price of potentially increased infections rate and worse long-lasting outcomes.[4] Other options such as latissimus dorsi with lumbar fascia have significant donor site morbidity.

This study assesses the use of the anterolateral thigh (ALT) flap with fascia lata (FL), as a one-stage functional reconstruction of composite defects around the knee. The ALT flap has valuable anatomic versatility that allows the combined use of skin, fat, muscular tissue, and FL, thereby mimicking the key components of articular regions, with minimal donor site morbidity. It is particularly useful in knee reconstruction, and it can be harvested as a musculocutaneous flap (including vastus lateralis) when highly vascularized tissue is needed[5] and associated with a vascularized sheet of FL, folded as a tendon-like structure for the reconstruction of articular ligaments.[6] Moreover, the large caliber and the length of the pedicle of the ALT flap allow the surgeon to adapt the flap components in the desired joint location, potentially splitting muscle, skin, and vascularized FL when required.

There are, however, few reports on the outcomes of functional joint reconstruction using an ALT chimeric or composite flap with vascularized FL, with outcome data limited to case reports.[7,8] A comprehensive study with long-term functional outcomes using validated outcome measures is therefore lacking. This study evaluated one-stage functional reconstructions of composite defects around the knee, including soft tissue and extensor apparatus, using the ALT flap with vascularized FL to provide quantitative data and information about potential challenges, risks, and outcomes in such complex procedures. Functional outcomes were assessed with validated outcome scores (Knee Society Score) together with standard functional outcome measures such as range of motion (ROM), extensor lag and MRC grade strength, and nonfunctional outcomes including esthetics.

Materials and methods

This study retrospectively analyzed consecutive knee reconstructions involving the patellar tendon, performed between October 2011 and July 2016 at the University Hospital of Lausanne (CHUV). Inclusion criteria included single-stage functional reconstructions, knee defects involving both soft tissues and tendon extensor mechanism, and coverage by ALT flaps with vascularized FL. Details of all patients were added to a prospectively maintained database, with prospective collection of medical records including operation details, physiotherapy reports, clinical follow-up, and anesthesiology charts. Postoperative complications were recorded and graded as minor or major.[9] Minor complications were considered superficial flap necrosis requiring split-thickness skin graft (STSG) or flap advancement only. Major complications were considered full-thickness partial or total flap necrosis requiring a second flap procedure for defect coverage. Long-term follow-up (minimum 12 months) was recorded for each patient, with a final examination performed by a plastic surgery resident blinded to the study between March and July 2017.

Particular attention was spent on the assessment of the difference in long-term outcomes between subtotal and total patellar tendon reconstruction. A subtotal reconstruction was defined as a residual tendon of less than 50% despite maintained longitudinal integrity. The following functional data were analyzed: knee and functional scores of the Knee Society,[10] active extensor ROM (degrees) of the operated limb eventually compared to contralateral, extensor lag (degrees), isometric knee extensor strength (M1-M5), and sensory recovery (2-point discrimination test, Semmes-Weinstein monofilament test).

Esthetic outcomes were assessed using the Likert scale,[11] in which general appearance, shape, color, and texture are evaluated on a combined numerical scale (4–20). This evaluation was performed by both the patient and a plastic surgery resident blinded to the research. The combined numerical score of the Likert scale (min, 4; max, 20) was classified as follows: 4–6, poor; 7–9, bad; 10–13, regular; 14–16, good; and 17–20, very good.

Surgical technique

With the patient in the supine position, a line was drawn from the superior anterior iliac spine to the medial upper

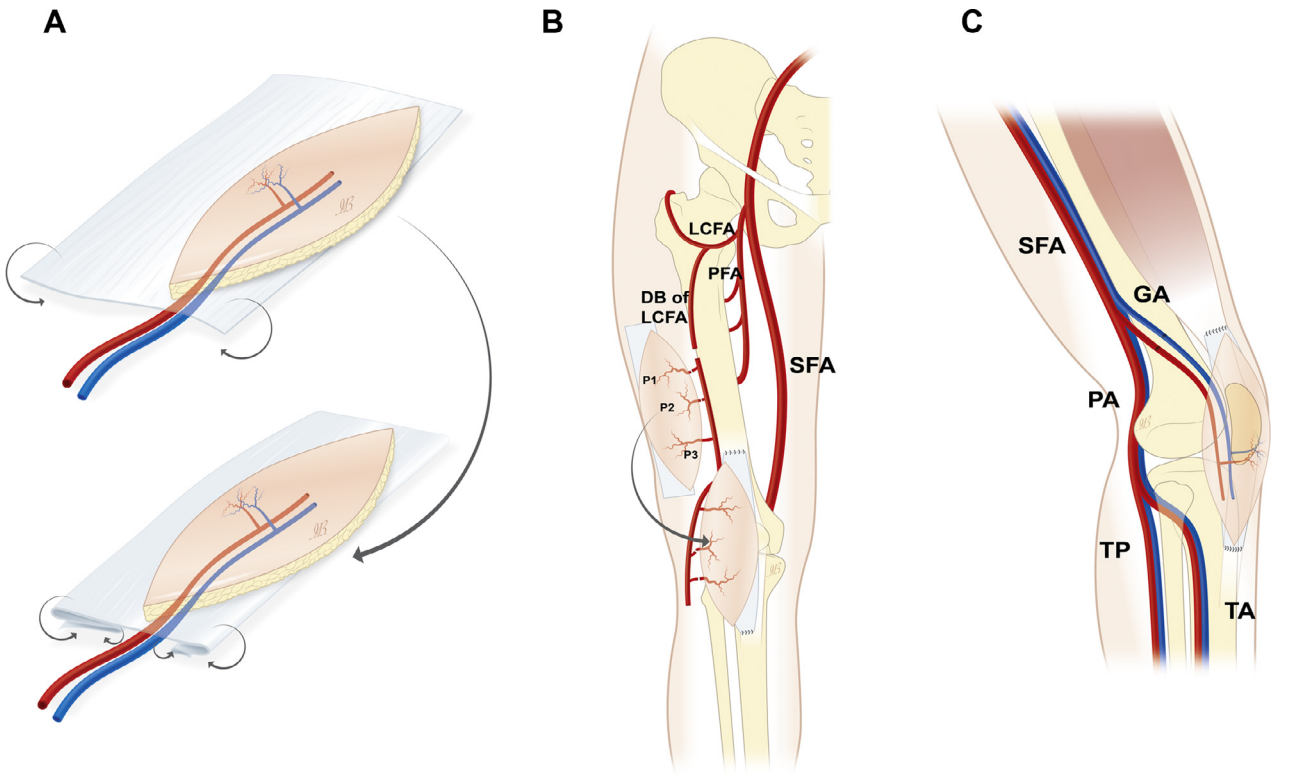

Figure 1 Schematic illustrations showing. (A) ALT flap with vascularized fascia lata folded as a tendon-like structure. (B) Propeller distally based ALT flap harvesting and insetting. SFA: superficial femoral artery; PFA: profunda femoral artery; LCFA: lateral circumflex femoral artery; DB: descending branch; P: perforator. (C) ALT free flap insetting in a ¾ knee view. SFA: superficial femoral artery; GA: genicular artery; PA: popliteal artery; TP: posterior tibial artery; anterior tibial artery.

border of the patella. With a handheld Doppler, perforator vessels were found around the midpoint of this line. The skin incision was deep to the FL, which was included in the composite flap according to reconstruction requirements. The fascia was inspected for bleeding from the subcutaneous plexus during harvesting and was kept in contact with the flap skin paddle to assure better stability for reconstruction. Flap dissection was continued in a subfascial plane from medial to lateral as previously described.[12]

When a free flap transfer was planned, a second operative team identified the recipient vessel at the recipient site. The descending branch of the lateral circumflex femoral artery (LCFA) was anastomosed to the recipient vessels in an end-to-end or end-to-side manner depending on vessel match, quality of recipient vessels, and appropriate outflow. For patients with supero-lateral knee defects, a distally based pedicled ALT flap from the ipsilateral limb was harvested. The pivot point was identified at the anastomotic connection between the superior genicular lateral artery and the pedicle. In one case, a skin bridge was left in place after FL fixation, thereby allowing for supplementary venous drainage (see Figure 1).

To reconstruct the patellar tendon, the FL was folded twice or thrice, thereby increasing its linear strength. The neo-tendon was sutured with nonresorbable sutures (Ethibond 1-0, Ethicon) to the remnants of the patellar tendon or directly to tendon insertion by Mitek anchors. The donor site was closed primarily in all patients (see Figure 2). When the tendon was still in continuity but more than 50% of the width was missing, the reconstruction was classified as subtotal, with increasing size and width of the remnant tendon.

Physical therapy, mobilization, and weight bearing

Postoperatively, patients followed a protocol of 5 days in bed without cast immobilization. Orthostatic position was progressively achieved from days 5–10, with joint mobilization from day 7 onward. Weight bearing was progressively introduced from week 2. Progressive mobilization of reconstructed joints was done under physiotherapy supervision, with values recorded at 3, 6, and 12 months. Particularly, active extension of the knee joint was allowed after 4 weeks in partial tendon reconstruction and after 6–8 weeks in total tendon reconstructions.

Statistical analysis

All breast parameters were statistically analyzed (average, range, standard error of the mean), and graphs were constructed with GraphPad Prism 6.00 (GraphPad Software, La Jolla, California, USA). When comparing total and subtotal tendon reconstructions, considering the relatively low number of patients involved, statistical significance was determined as $^{*}\ p < 0.05$.

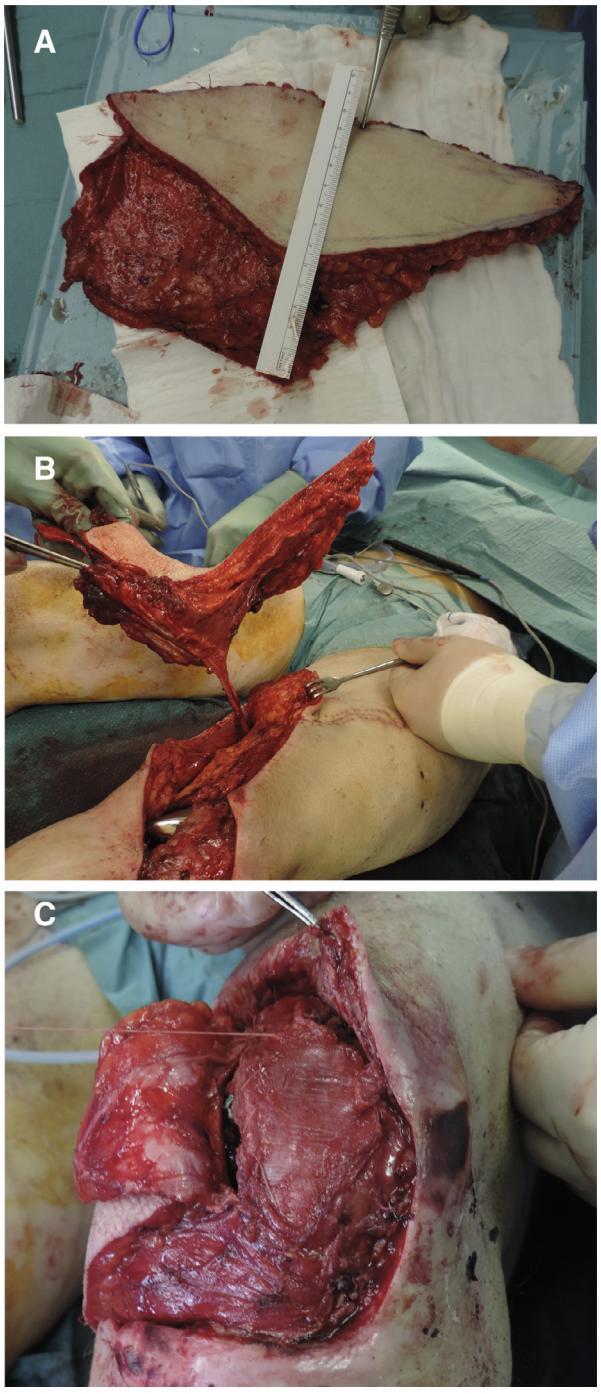

Figure 2 (A) ALT free flap with vascularized fascia lata. (B) Anastomosis to the superficial femoral artery in an end-to-side manner. (C) Insetting of the fascia lata to re-establish the patellar tendon continuity.

Results

Ten ALT flaps with vascularized FL were performed in 9 patients (5 males and 4 females). Age ranged from 21 to 87 (62 ± 5.7; average ± SEM). Smoke and hypertension were the most frequent comorbidities (see Table 1). Etiologies leading to the defects were oncologic resections (6 out of 9 cases) or debridements after TKP exposure (2 cases) and infected bursitis/septic arthritis (1 case). Two patients had postoperative radiotherapy (patient nr. 1 and 7). Patellar tendon reconstruction was total in 5 patients and subtotal in 4 patients. Defect size was 154.5 cm^2 ± 23.7 (range 36-242 cm^2). The operative time including the resection or debridement was 330 min ± 35 (range 120-480 min). The mean hospital stay was 19 ± 2.3 days. Mean follow-up was 30 ± 6 months, ranging from 12 to 76 months (see Table 2).

Flap outcomes and complications

Among flaps, 8 were harvested as free flaps (80%) and 2 as pedicled propeller flaps (20%).[13] Eight ALT flaps were raised as musculocutaneous flaps including a component of vastus lateralis muscles, while 2 fasciocutaneous ALT flaps were used in the remaining cases. For free flaps, end-to-end anastomosis was performed to the posterior tibial (2 cases), anterior tibial (2 cases), medial genicular (2 cases), and end-to-side to the superficial femoral artery (2 cases). Pedicle length ranged from 7 to 14 cm (average 9.7 cm).

No total flap necrosis occurred in this series. One flap (10%) had pedicle compression resulting in venous congestion and full-thickness distal necrosis, requiring a medial gastrocnemius flap + STSG to cover the lower part of a TKP (patient nr. 6). Patient nr. 3 presented with superficial distal necrosis, treated by simple debridement and flap advancement. One flap, raised in reverse flow on the LCFA (patient nr. 5, heavy smoker with more than 5 previous knee procedures for TKP infections), presented with distal dehiscence, and wound discharge was associated with implant infection. This led to an extensive debridement and prosthesis change from the orthopedic team, and a contralateral free ALT flap + VL and FL were raised to reconstruct the whole knee joint and the patellar tendon (see Figure 3). No complications were noted at the donor site (see Table 2).

Functional results

All patients regained sufficient extensor mechanism function to return to original work and independent ambulation without the need for crutches.

The mean active ROM was 94.4° ± 3.7 with a mean loss of approximately 17%, when compared to the contralateral knee, and an average extensor lag of 9.4° ± 2 (range, 0-20°) (see Figure 4). When analyzing statistical differences among the two groups, extensor lag was 13° ± 3 (range 5-20°) in total extensor apparatus reconstructions, while in subtotal reconstructions, extensor lag accounted for 5° ± 2 (range 0-10°). Despite a strong positive trend (p value of 0.076), this difference did not reach statistical significance. ROM between groups showed only a slight trend toward the subtotal reconstruction group but, similarly, did not achieve statistical significance (93° ± 3 in total reconstructions vs. 101 ° ± 7 in subtotal reconstructions; $p = 0.3$) (Figure 5).

No differences were detected among the two groups in either mean knee score (KS) or functional score (FS) of The Knee Society. Global values for KS and FS were 81.4 ± 1.8 and 77.7 ± 2.1, respectively, on a possible total score of 100

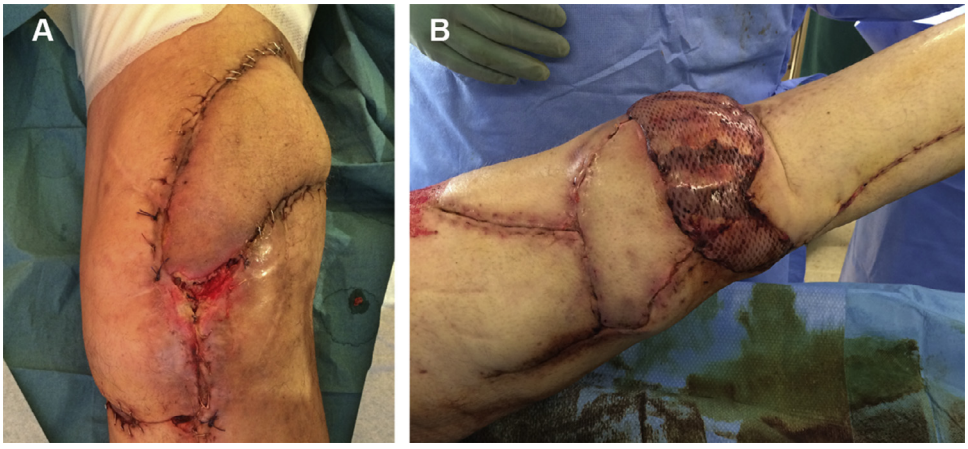

Figure 3 Complications requiring surgical reinterventions. (A) Pedicled reverse-flow ALT-FL flap presenting distal dehiscence and wound breakdown finally requiring a contralateral free ALT due to the exposed prosthesis (patient nr. 5). (B) Free ALT-FL flap which required a gastrocnemius flap + STSG after distal full thickness necrosis (patient nr. 6).

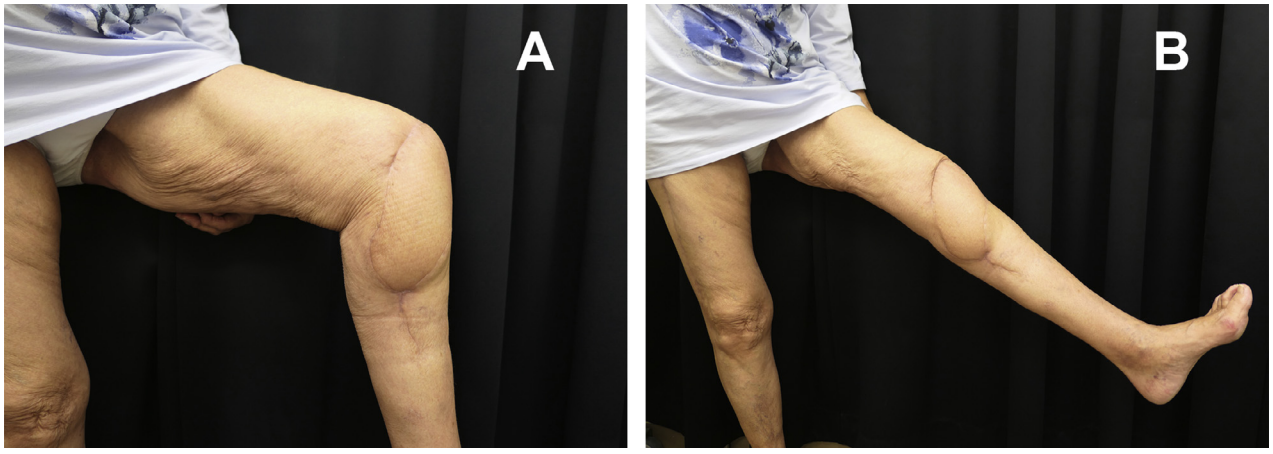

Figure 4 Functional recovery. (A) Active range of motion 100° in flexion. (B) Extensor lag 10°.

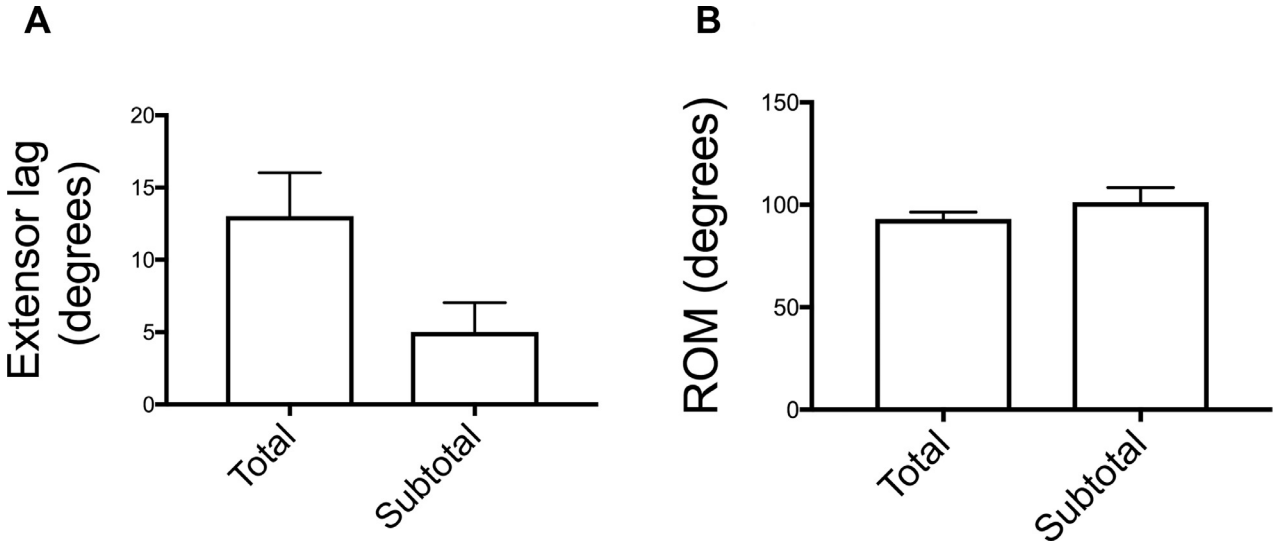

Figure 5 Graphics comparing the extensor lag (A) and ROM (B) after reconstruction in a patient with total and subtotal injury of the extensor mechanism. Despite a positive trend, in total reconstruction, the extensor lag was not significantly increased and did not affect functional scores.

Table 1 Data of patients.

Nr	Sex\age	Diagnosis	Injured structures	Tendon injured	Type of tendon injury	Defect size, cm^2	Comorbidities/risk factors
1	M\47	Sarcoma resection	Bone, muscle, tendon, skin	Patellar tendon	Total	105	Smoke
2	F\21	Sarcoma resection	Bone, muscle, tendon, skin	Patellar tendon	Subtotal	210	/
3	F\87	Infected knee bursitis	Muscle, tendon, skin	Patellar tendon	Subtotal	40	Smoke, hypotension, renal failure
4	F\62	Exposure of TKP following infection	Muscle, tendon, skin	Patellar tendon	Subtotal	242	Smoke, chronic TKP, infection
5	M\66	Exposure of TKP following infection and coverage by a gastrocnemius flap	Muscle, tendon, skin	Patellar tendon	Total	36	Smoke, obesity, cardiopathy, hypertension, COPD
		Exposure of TKP following pedicled ALT flap	Muscle, tendon, skin	Patellar tendon	Total	36	
6	M\65	Sarcoma resection + TKP	Bone, muscle, tendon, skin	Patellar tendon	Total	220	Hypertension
7	F\77	Sarcoma resection	Tendon, skin, bone, ligament	Patellar tendon, lateral and medial retinaculum	Total	207	Hypercholesterolemy
8	M\72	Sarcoma resection + TKP	Tendon, skin, bone, ligament	Patellar tendon	Subtotal	198	Hypertension
9	M\63	Sarcoma resection + TKP	Tendon, skin, bone, ligament	Patellar tendon	Total	133	/

Abbreviations: M, male; F, female; ALT, anterolateral thigh; TKP, total knee prosthesis; COPD, chronic obstructive pulmonary disease.

points each. Isometric knee extensor strength beyond M4/5 was clinically recorded in all patients.

As no sensate flaps were harvested, only poor sensory recovery was expected. Average 2-point discrimination test and Semmes-Weinstein test values were 4.2 cm and 52.9 g/mm^2, respectively, compared to 1.7 cm and 21 g/mm^2 at the contralateral side. No patients complained of impairments in daily living activities due to this issue. No functional impairments were noticed by the patients at the donor site (see Table 3).

Esthetic outcomes

According to patients' and surgeons' judgments, a mean Likert score of 16.6/20 ("good") was assigned (range 11/20-19/20). Globally, the best-rated features were color and texture; the worst-rated feature was overall appearance. No patients complained of esthetic appearance, and no secondary procedure such as flap defatting or flap revision was needed (see Figure 6).

Discussion

The key objectives in composite knee reconstruction should be not only coverage and limb/joint salvage but also, if possible, *restitution ad integrum*. Because of surgical and microsurgical advancements, functional reconstruction, by maintaining a mobile and useful joint, has become possible in a single-stage procedure. This can provide significant improvements in the potential capability of the patients to resume activities of daily living, with lesser social and health care costs. Furthermore, a single-stage procedure offers several advantages such as reducing hospitalization costs, rapid healing, early mobilization, and potentially lower incidence of infection.[14]

Several flaps have been described for this challenging reconstruction. The extended medial gastrocnemius muscle flap, including a tendinous portion of the Achilles tendon, was described by Babu et al.[15] Adhesions occurring after the surgery may lead to a stiff knee and extension lag of the joint, and the gastrocnemius flap may not provide sufficient overlay depending on the size of the defect, requiring simultaneous use of a second local flap for additional coverage.[16]

Allografts, despite initial ambivalent results in literature,[17,18] have shown effectiveness in reconstructions involving the total extensor mechanism (including patella and quadriceps), thereby allowing for ideal reproduction of previously lost anatomy.[2,19] However, these often require a two-stage procedure particularly in infected cases and have significant financial costs associated with the cadaveric patella tendon.[20] There have also been concerns about allograft-tendon interface weakening, thus leading to lag, particularly after radiotherapy.[21]

Table 2 Flap outcomes.

Nr.	Reconstructive procedure	Type of flap	Operating time (min)	Total Pedicle Length (cm)	Anastomosis	Fascia lata (cm^2)	Outcome	Time to Healing (days)	Hospital stay (days)	Follow-up (month)
1	ALT myocutaneous flap + VL + FL	Free flap	342	8	Tibial Anterior A E-E	220	Favorable	10	18	31
2	ALT myocutaneous flap + VL + FL	Free flap	390	7	Superficial Femoral A E-S	170	Favorable (mild distal congestion)	12	14	76
3	ALT fasciocutaneous flap + FL	Pedicled flap	120	10	N/A	72	Distal necrosis + debridement and flap readvancement	15	16	49
4	ALT myocutaneous flap + VL + FL	Free flap	360	7	Tibial Anterior A E-E	136	Favorable	21	28	24
5	ALT myocutaneous + VL + FL	Pedicled flap	120	10	N/A	77	Distal flap necrosis + dehiscence	22	24	24
	ALT myocutaneous flap + VL + FL	Free flap	480	14	Posterior Tibial A E-E	180	Favorable	15	17	21
6	ALT myocutaneous flap + VL + FL	Free flap	360	12	Superficial Femoral A E-S	120	Distal necrosis, debridement + coverage with gastrocnemius flap + STSG	30	35	25
7	ALT fasciocutaneous flap + FL	Free flap	345	11	Posterior Tibial A E-E	70	Favorable	12	18	18
8	ALT myocutaneous flap + VL + FL	Free flap	380	10	Medial genicular A E-E	90	Favorable	10	12	15
9	ALT myocutaneous flap + VL + FL	Free flap	410	8	Medial genicular A E-E	80	Favorable	12	10	12

Abbreviations: ALT, anterolateral thigh; VL, vastus lateralis muscle; FL, fascia lata; A, artery; E-E, end-to-end; E-S, end-to-side; N\A, not applicable; STSG, split-thickness skin graft.

Table 3 Functional outcomes.

Nr.	Extensor lag	ROM injured side	Loss of ROM % (compared with contralateral)	S-W filaments	2-point discrimination	Muscle strength recipient site	Knee society score knee functional score		Likert score
1	10°	85°	25%	61.7 (contralateral = 18.4)	4 cm (contralateral = 2 cm)	4 + \5	80	80	16\20
2	0	120°	0	52.6 (contralateral = 24.4)	5 cm (contralateral = 1.5 cm)	5\5	92	80	18\20
3	5°	100°	20%	61.7 (contralateral = 24.4)	3 cm (contralateral = 3 cm)	5\5	88	90	16\20
4	10°	100°	5%	40.3 (contralateral = 18.4)	4 cm (contralateral = 2 cm)	5\5	83	70	18\20
5	20°	80°	20%	40.3 (contralateral = 18.4)	5 cm (contralateral = 1.5 cm)	5\5	74	65	15\20
6	10°	95°	20%	61.7 (contralateral = 27.4)	4 cm (contralateral = 1 cm)	5\5	82	75	11\20
7	5°	100°	15%	52.6 (contralateral = 18.4)	4 cm (contralateral = 1.5 cm)	5\5	83	80	18\20
8	5°	85°	25%	52.6 (contralateral = 27.4)	5 cm (contralateral = 1.5 cm)	5\5	74	80	19\20
9	20°	85°	30%	52.6 (contralateral = 24.4)	4 cm (contralateral = 1 cm)	4 + \5	77	80	19\20

Abbreviations: ROM, range of motion; S-W, Semmes-Weinstein.

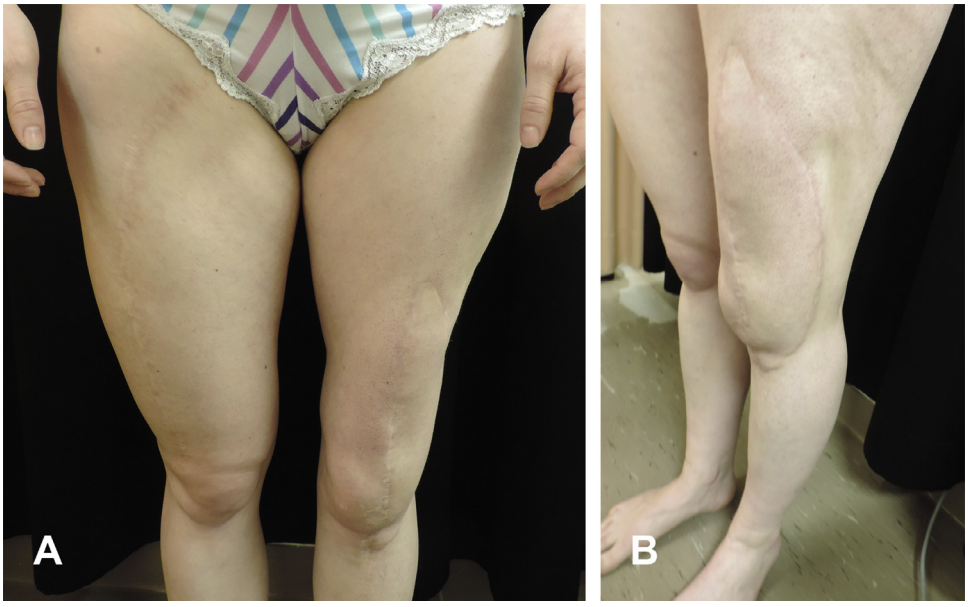

Figure 6 (A,B) Likert score in patient nr. 2; color match 5/5, general appearance 4/5, shape 5/5, and texture 4/5.

Vascularized fascia and tendons have significant advantages compared to nonvascularized grafts in complex knee defects, as they are less prone to infection and necrosis and may be more radiotherapy resistant.[22] Vascularized peritendon has also been shown to decrease adhesion formation and reduce tenocyte apoptosis, thereby improving tendon repair strength and guaranteeing better gliding properties.[23] In our series, vascularized FL was particularly effective to reconstruct the patellar tendon, with a minor extension lag in both total and subtotal tendon reconstructions (extensor lag of 13° and 5°, respectively) that compares favorably with other forms of knee extensor reconstruction.[12]

Comparing extensor lag in total and subtotal tendon reconstructions, there was no significant difference noted, although given the limited numbers in this study; this would be prone to a false-negative/Type II error ($p = 0.07$), and there was a trend toward increased extensor lag in total tendon reconstructions. Both ROM and functional scores did not show significant difference, thus supporting the fact

that this technique can give satisfactory outcomes even when the extensor tendon is absent.

Despite the long-term satisfactory functional outcomes, significant postoperative complications should be noted. This was particularly true when reconstruction involved the presence of a prosthetic material for total knee replacement and with the use of reverse-flow ALT flaps. The reverse-flow ALT flap may compromise the design and inset of the flap around the knee and are known to have an impaired venous circulation that may result in a lower oxygen tension around the wound. In our experience, partial harvest of the vastus lateralis muscle with the ALT flap allowed it to conform better to cavities around the exposed bone/prosthesis, and coverage with a highly vascular tissue may increase resistance to infections.[5]

Validated functional outcome evaluation showed a "good" to "excellent" grade on long-term outcomes using the Knee Society Scores (KS 81.4 ± 1.8 and FS 77.7 ± 2.1).[24,25]

Donor site morbidity was minimal. The vastus lateralis represents the largest compartment of the quadriceps femoris muscle, and sacrificing a part of it may result in deficiency in contraction force ranging from 10% to 15%, as this does not significantly influence extension or functional outcomes.[12]

This study represents one of the largest series of one-stage functional knee reconstruction using the ALT flap with FL, although the limited sample size leads to limitations in the interpretation of statistical analysis. Nonetheless, this study provides valuable data on validated functional outcomes, expected ROM and extensor lag, and complications associated with this procedure.

Conclusion

Functional reconstruction remains a challenge when the knee injury involves both the soft tissue and the extensor mechanism. In our experience, the ALT composite flap with vascularized FL has proven to be a long-term viable choice when used for single-stage functional reconstruction of knee joint tendons (for both total and subtotal restoration) and soft tissues, thus enabling a "good" to "excellent" functional outcome on validated Knee Society Scores, with minimal extensor lag.

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