Journal of Plastic, Reconstructive & Aesthetic Surgery 77 (2023) 298–308

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JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Muscle-only versus chimeric musculocutaneous gastrocnemius pedicled flap in complex orthoplastic reconstructions of the knee region: A retrospective study

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Received 20 May 2022; accepted 9 December 2022

KEYWORDS
Gastrocnemius muscle flap;
Pedicled chimeric musculocutaneous medial sural artery perforator flap;
GM-MSAP;
Knee defects;
Lower limb reconstruction

Summary *Background:* The knee region represents a challenging area of soft tissue reconstruction. Specifically, in the context of total knee arthroplasty (TKA) or following high-energy trauma with fractures and hardware fixation, soft tissue defects can expose critical structures such as joint, bone or tendon, besides the implant/plates themselves, with dramatic consequences in terms of postoperative infection and hardware contamination.
Methods: A retrospective study was conducted on a prospectively maintained database from January 2016 to February 2021. Inclusion criteria involved all patients who underwent an implant-associated infection of the knee and upper third of the leg coupled with a soft tissue reconstruction (STR) using the traditional gastrocnemius muscle (GM) pedicled flap or the chimeric GM-MSAP (medial sural artery perforator) flap.
Results: Thirty-eight patients were included (group A, GM flap, 22 patients; group B, chimeric GM-MSAP flap, 16 patients). No statistically significant differences were detected in terms of

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https://doi.org/10.1016/j.bjps.2022.12.006

age, comorbidities, defect size, follow-up, and flap complications. A statistically significant difference was seen among the groups in terms of successful flap re-raise (required because of a persistent infection of the implant or in a two-stage procedure setting, including the use of a cemented spacer) in favour of the GM-MSAP group.

Conclusion: The chimeric GM-MSAP, being safer to reraise if required, can be a significantly more powerful tool in those cases in which a two-stage procedure is planned or when there is a high probability for secondary intervention need, reducing the need to convert to either free flap coverage or amputation.

Introduction

The knee region represents a challenging area of soft tissue reconstruction. The coverage should be stable, while preserving mobility. Specifically, in the context of total knee arthroplasty (TKA) or following high-energy trauma with fractures and hardware fixation, soft tissue defects can expose critical structures (such as joint, bone or tendon) besides the implant/plates themselves, with dramatic consequences in terms of postoperative infection and hardware contamination.[1,2] Considering the increasing numbers of such procedures, the incidence of wound breakdown, infection, and major surgery complications is expected to raise accordingly.[2]

When possible, a local coverage should be preferred, leaving the free tissue transfer as a backup option.[2,3]

The gastrocnemius muscle is the workhorse flap to reconstruct soft tissue defects in the knee and upper leg area, particularly when hardware, bone, tendon, or joint capsule are exposed.[3] The ease of harvest and the minimal donor-site morbidity, together with its capacity to fill dead space, are the major advantages of this technique, which has proven to be effective also in post-traumatic injuries with exposed framework and TKA salvage.[4] However, gastrocnemius muscle is sometimes insufficient to reach supero-lateral and supra-patellar defects, being sometimes particularly narrow or tendinous in its distal part, making coverage less stable. Moreover, the need for skin grafting makes postoperative immobilization and healing longer.[4,5] Furthermore, another limit of muscle-only gastrocnemius flap resides in the fact that the muscle component may incur shrinkage and atrophy over time, making reraise difficult when hardware materials (including plates and screws, TKA, or temporary cemented spacer) need to be exchanged or removed.

Despite its description a long time ago,[3] the musculocutaneous gastrocnemius flap has had limited success, probably because of its bulkiness and inset difficulties when harvesting the whole skin over the calf area. Lately, chimeric principles and perforator/propeller flaps have recently opened new tailoring possibilities in complex knee reconstructions.[6] Indeed, chimeric flaps can incorporate multiple tissue types (e.g. muscle and skin), which are potentially connected only by branching or perforating vessels.[7] A chimeric gastrocnemius-MSAP flap can therefore serve for the double aim of filling a deep defect, while at the same time addressing skin shortage with the fasciocutaneous component.[8] Such a property may be critical when secondary procedures are needed, demanding further flap reraise because of framework exchange or resistant infection.

This work compares the chimeric GM-MSAP flaps and the traditional GM pedicled flaps in specifically complex orthoplastic scenarios, where TKA explant following infection or multiple-stage surgeries because of chronic osteomyelitis were necessary, with limited skin availability and complex infectious conditions. Surgical technique and orthoplastic planning have been described. Outcomes and complications have been critically analysed.

Materials and methods

A retrospective analysis based on a prospectively maintained database, involving all lower-limb reconstructions with pedicled flaps from January 2016 to February 2021, was performed. Inclusion criteria involved all patients who underwent an implant-associated infection of the knee and upper third of the leg coupled with a soft tissue reconstruction (STR). Implant-associated infections were either seen in infected total knee joint arthroplasties (TKAs) or in fractures where osteosynthesis materials were present and became contaminated. Among such reconstructions, this study focused only on patients who underwent STR with a pedicled gastrocnemius muscular flap, or a chimeric gastrocnemius muscular flap, including a skin paddle based on the medial or lateral sural artery perforator (MSAP/LSAP).

Moreover, all patients without complete follow-up (at least 6 months since last procedures) were excluded from analysis. Patients' demographic data and comorbidities were gathered from medical and anaesthetic charts. Operative notes were screened for technique details. Hospital letters and outpatient reports were used to evaluate the operative time, the hospital stay, as well as flap complications, and the number of surgeries each patient underwent.

Orthoplastic approach

The duration of the infection and its cause dictated the treatment concept of the orthopaedic team (one-stage revision vs. two-stage procedure).[9,10] In one-stage revision procedures, the STR was performed directly after the debridement, antibiotics, and either implant retention, implant exchange, or implant removal procedures. One-stage revision procedures were routinely performed in the acute setting

of implant infection (<6 weeks from the onset of symptoms/diagnosis). In patients who underwent a two-stage procedure, the flap was used at the first time point after implant removal and spacer implantation (as coverage over the spacer) or at the second time point, after spacer removal, implant placement, and final coverage. The timing of the flap was dictated by patient needs and time of presentation to our hospital. (The same patients have already done one stage of the surgery in other centres.)

Surgical technique

GM and GM-MSAP flaps were harvested according to the previous literature.[3,8]

When performing a GM-MSAP particularly, acoustic Doppler ultrasound was used as a starting point for preoperatively localizing reasonable perforators overlying the head of the gastrocnemius muscle. A line was drawn from the midpoint of the popliteal crease along the medial leg to the apex of the medial malleolus. A major perforator was usually found within a semicircle with a 2–3 cm radius, centered distal to a point along this line 8 cm from the popliteal crease. The axis of the flap was oriented in a longitudinal direction, parallel to the long bones of the leg, to capture adjacent perforasomes.

The incision started at midcalf, 2 cm behind the posterior border of the tibia on the medial aspect of the leg and curved proximally in the direction of the popliteal fossa. A subfascial dissection allowed fast visualization of perforators on the skin paddle. Intramuscular dissection of the chosen perforator was performed if needed to reduce the risk of perforator kinking or torsion after flap transposition.

Once the flap was harvested and rotated into the defect, the skin paddle could be further propelled up to 90° to extend proximally and distally the flap coverage surface. Donor site was closed directly or skin-grafted, depending on skin paddle size.

Flap reraise for second-stage procedures was generally performed 6–8 weeks after debridement and cement spacer placement. When the skin paddle was present, no undermining between the skin and the muscle was performed. Outpatient follow-up was performed at one, three, or six weeks after STR, followed by monthly assessments for at least 6 months.

Outcome analysis

The STR is considered successful when no further flap procedures are necessary to ensure bone or hardware coverage.

The complications were listed as major and minor. Major complications were considered full or partial flap necrosis (at least 1/3 of the flap, implying new plastic surgery procedures), while minor complications were considered partial flap necrosis (less than 1/3 of the flap, maintaining vascularization and allowing STSG). Early complications were defined as complications occurring within 6 weeks after flap surgery (first or second stage). Late complications were defined as complications arising between 6 weeks and up to 4 years.

The study was conducted according to the guiding principles outlined in the Declaration of Helsinki of 1975. Informed consent was obtained from all patients, including approval for scientific publication and photographic\video documentation.

The manuscript was written in accordance with the STROBE checklist.[11]

Statistical analysis

All investigated parameters were statistically analysed (average, range, and standard error of the mean). Patients' groups were compared using independent two-sided t tests for means, Mann–Whitney U tests for medians, and two-sided Chi-square or Fisher's exact test as appropriate to analyse categorical variables. The assumption of normality was verified using the Shapiro–Wilk test. Statistical significance was set at a p value <0.05. Statistical analysis was performed using GraphPad Prism (version 8.0, GraphPad Software, La Jolla, CA).

Results

More than 180 soft tissue reconstructive procedures using pedicled flap on the leg were screened. After application of the inclusion criteria, 39 patients were included. Patients were divided into two groups depending on the presence of the MSAP skin paddle (group A, GM flap; group B, chimeric GM-MSAP flap). Refer to Tables 1–2 for the patient's data and characteristics.

GM group

The mean age of patients in GM the group was 60 ± 13 years old (average ± standard error of the mean, SEM).

Of 22 patients (41%), 9 required a GM flap coverage following knee trauma and internal fixation. Among these, 7 benefited from a one-stage procedure, including surgical debridement, hardware ablation, and soft tissue coverage, while in 2 patients the bone debridement required the use of a cemented spacer in a two-stage procedure (Masquelet procedure).

Thirteen patients (59%) presented an infection following a TKA. Among these, a one-stage procedure was attempted in 9 out of 13 patients (the TKA was either completely replaced or only the mobile parts were changed, according to an orthopaedic decision), while in 4 patients a two-stage procedure was performed, including the temporary use of a cemented spacer.

A skin graft was used to cover the transposed muscle in all cases. The donor site was primarily closed in all patients.

Among flap complications, distal flap necrosis occurred in 5 patients. In 3 patients, simple debridement and skin graft were sufficient to ensure complete implant coverage (minor complications), while in 2 patients, the hardware exposure required further flaps procedure to ensure effective coverage (major complications).

A persistent infection of the implant vs. chronic osteomyelitis with the appearance of a cutaneous fistula was

Table 1 Gastrocnemius group: patients' characteristics and surgery-related data.

Pt n°	Age/Sex	BMI	Smoke	Diabetes	ASA score	Aetiology	Localization	Flap	Defect size (cm^2)	OP time	FU	Ortho Strategy	Flap Compli-cations	Need for reraise	Successful reraise	Further Plastic surgery
1	72/F	22	N	N	2	Infected TKA	Knee	M-GM	60	256	60	I stage	None	N	-	-
2	73/M	28	N	Y	3	Infected TKA	Knee	M-GM	150	190	64	I stage	None	Y	Failure	Amputation
3	52/M	36	N	N	2	Infected TKA	Tibia	M-GM	15	210	54	I stage	None	Y	Failure	Free Flap
4	78/F	24	N	Y	2	Infected TKA	Knee	M-GM	120	120	55	II stage	Superficial necrosis	Y	Y	-
5	39/M	30	Y	N	2	Infected OM	Knee	M-GM	50	195	52	I stage	Superficial necrosis	Y	Y	-
6	60/M	48	N	Y	3	Infected TKA	Knee	M-GM	50	232	40	I stage	None	Y	Failure	Amputation
7	51/M	18	Y	N	2	Infected OM	Tibia	M+L-GM	120	275	41	I stage	Partial necrosis	Y	Failure	Fasciocutaneous flap
8	76/F	39	N	Y	3	Infected TKA	Knee	M-GM	70	258	37	II stage	Wound dehiscence	Y	Y	-
9	47/F	28	Y	N	2	Infected TKA	Knee	M-GM	60	189	25	II stage	None	Y	Y	-
10	47/M	30	N	N	2	Infected OM	Tibia	M-GM	20	261	24	II stage	None	Y	Y	-
11	74/F	22	N	N	1	Infected TKA	Tibia	M+L-GM	25	180	20	I stage	None	N	-	-

(*continued on next page*)

Table 1 (*continued*)

Pt n°	Age/Sex	BMI	Smoke	Diabetes	ASA score	Aetiology	Localization	Flap	Defect size (cm^2)	OP time	FU	Ortho Strategy	Flap Complications	Need for reraise	Successful reraise	Further Plastic surgery
12	47/M	29	Y	Y	2	Infected TKA	Knee	L-GM	16	100	18	II stage	None	N	-	-
13	54/M	24	N	N	2	Infected OM	Tibia	M+L-GM	140	260	12	II stage	None	Y	Y	-
14	61/M	26	N	N	2	Infected TKA	Knee	M-GM	40	120	10	I stage	None	N	-	-
15	45/M	25	Y	N	2	Infected OM	Tibia	M-GM	75	95	10	I stage	None	N	-	-
16	62/M	30	N	Y	3	Infected OM	Tibia	M-GM	64	139	9	I stage	None	Y	Failure	Free Flap
17	77/F	19	Y	N	3	Infected TKA	Knee	M-GM	9	255	8	II stage	None	N	-	-
18	51/M	22	N	Y	3	Infected OM	Tibia	M-GM	30	353	7	I stage	None	N	-	-
19	47/M	29	Y	Y	2	Infected TKA	Knee	L-GM	8	100	19	I stage	None	N	-	-
20	82/F	16	N	N	3	Infected OM	Tibia	M+L-GM	4	205	19	I stage	Partial necrosis	Y	Failure	Free Flap
21	63/M	24	Y	N	3	Infected OM	Tibia	M-GM	48	132	19	I stage	None	Y	Failure	Free Flap
22	65/M	25	Y	N	2	Infected TKA	Knee	M-GM	15	200	41	I stage	None	Y	Failure	Free Flap

ABB: TKA, total knee arthroplasty; OM, osteosynthesis material; M-GM, medial gastrocnemius; L-GM, lateral gastrocnemius.

Table 2 Gastrocnemius-MSAP group: patients' characteristics and surgery-related data.

Pt n°	Age/Sex	BMI	Smoke	Diabetes	ASA score	Aetiology	Localization	Flap	Defect size (cm^2)	OP time	FU	Ortho Strategy	Flap Complications	Need for reraise	Successful reraise	Further Plastic Surgery
1	72/M	25	N	Y	3	Infected TKA	Knee	GM-MSAP	80	135	30	I stage	None	N	-	-
2	64/M	28	N	N	3	Infection OM	Tibia	GM-MSAP	50	141	26	I stage	None	Y	Y	-
3	49/F	23	Y	Y	2	Infected TKA	Knee	GM-MSAP	45	200	25	I stage	None	Y	Y	-
4	63/M	20	N	N	1	Infection OM	Tibia	GM-MSAP	60	120	20	II stage	None	N	-	-
5	48/F	23	N	N	1	Infection OM	Tibia	GM-MSAP	48	180	19	I stage	None	N	-	-
6	62/M	29	N	Y	3	Infected TKA	Knee	GM-MSAP	35	330	7	II stage	None	Y	Y	-
7	55/M	27	Y	N	2	Infected TKA	Knee	GM-MSAP	48	150	7	I stage	Wound dehiscence	Y	Y	-
8	88/F	25	N	N	2	Infected TKA	Tibia	GM-LSAP	15	160	15	II stage	None	Y	Y	-
9	85/F	35	N	N	3	Infected TKA	Tibia	GM-MSAP	36	145	20	II stage	None	Y	Y	-
10	80/M	31	N	N	2	Infected TKA	Tibia	GM-MSAP	100	210	25	II stage	None	Y	Y	-
11	76/F	28	N	N	3	Infected TKA	Tibia	GM-MSAP	70	240	18	I stage	None	Y	Y	-
12	76/M	21	N	N	3	Infected TKA	Knee	GM-MSAP	15	211	12	II stage	None	Y	Y	-
13	50/F	31	N	N	3	Infected TKA	Knee	GM-MSAP	30	200	27	I stage	None	Y	Y	-
14	61/M	31	N	N	3	Infected TKA	Knee	GM-MSAP	54	279	30	I stage	None	N	-	-
15	27/F	34	N	N	3	Infection OM	Tibia	GM-MSAP	140	235	15	I stage	Superficial skin necrosis	N	-	-
16	78/F	31	N	N	3	Infected TKA	Knee	GM-MSAP	9	245	7	II stage	None	Y	y	-

ABB: TKA, total knee arthroplasty; OM, osteosynthesis material; GM-MSAP, chimeric medial gastrocnemius + medial sural artery perforator flap; GM-LSAP, chimeric lateral gastrocnemius + lateral sural artery perforator flap.

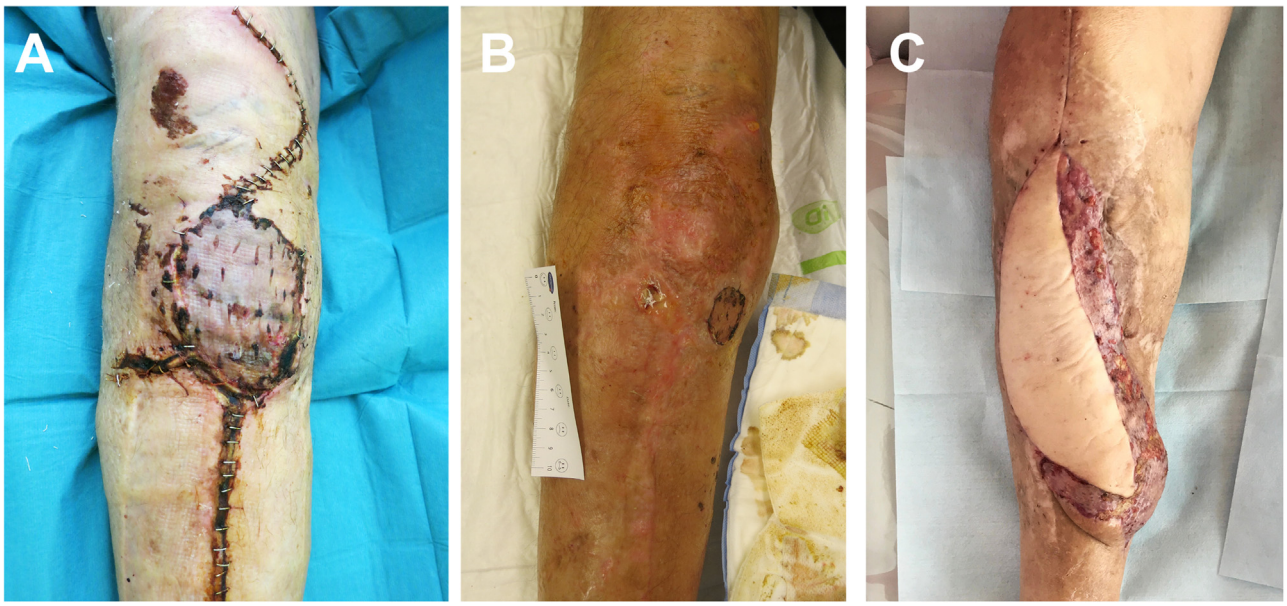

Figure 1 Patient no. 21 sustained a high-energy trauma with a Gustilo IIIb fracture of the tibial bone. The fracture was initially stabilized with an external fixator because of a loss of substance of 48 cm^2 with bone exposition. Three days after the injury, the patient returned to theatre for internal fixation and skin coverage using a GM flap and skin graft (A). Six months later, the patient presented a chronic osteomyelitis with infection of the osteosynthesis material requiring exchange and debridement. The GM flap re-harvesting failed (B) requiring a new extensive debridement and eventually a free flap coverage using a latissimus dorsi flap (C).

seen in 12 patients (54%) (in 11 cases after a single-stage orthopaedic procedure). Taking into account planned (e.g. in a two-stage procedure) or unplanned (e.g. need for further implant exchange because of persistent infection) orthopaedic secondary procedures, a GM flap reraise was necessary in 14 patients (63%). The average number of surgeries per patient was 4.7.

Considering muscle flap shrinkage and fibrosis because of the scar process, plus the need for further soft tissue debridement in cases of persistent infection, a simple flap reraise and closure were not possible in 8 out of 14 patients (57%). Among these, 5 patients underwent free flap reconstruction (Figure 1) and in one patient the limb was salvaged with a double fascio-cutaneous local flap. For the remaining 2 patients, the local status of the infection and patient's comorbidity did not allow for complex flap procedure and, together with the orthopaedic team, a Gritti amputation above the knee was performed.

Refer to Table 1 for the results of patients in the GM group.

GM-MSAP group

The mean age of patients in the GM-MSAP group was 64 ± 16 years old (average ± SEM).

Of 16 patients (25%), 4 required a GM-MSAP flap coverage following knee trauma and internal fixation. Among these, 3 benefited from a one-stage procedure, while in 1 patient a two-stage procedure (Masquelet procedure) was attempted.

Twelve patients (75%) presented an infection following a TKA. Among these, a one-stage procedure was attempted in 5 out of 12 patients, while in 7 patients a two-stage procedure was performed.

In the case of two-stage procedures, flap coverage was performed concomitantly with the first stage in 7 out of 8 patients (88%).

Among flap complications, we recorded 1 case of flap wound dehiscence and 1 case of distal flap necrosis, both managed successfully without the need for further major surgical procedures. One case of donor-site infection was recorded following skin graft and was addressed with a superficial debridement and a new STSG. The donor site was closed primarily in 7 patients (44%), while in the remaining 9 a skin graft was necessary.

We recorded 5 cases of persistent infection following the flap coverage procedure (in 3 cases following a one-stage implant exchange), and flap re-raise was necessary in 11/16 patients (68%). The average number of surgeries per patient was 3.5.

Nevertheless, the flap reraise, eventually associated with a further implant exchange or an extensive debridement/washout when implant infection was persistent, was successful in all cases, and no further flap procedures were necessary (Figure 2).

Refer to Table 2 for GM-MSAP group single patient details.

Groups comparison

No statistically significant differences were detected in terms of age, BMI, ASA score, diabetes, and follow-up. Similarly, the number of smokers was comparable in the two groups despite a positive trend seen in favour of the GM group (p 0.08), which, however, did not correlate with the

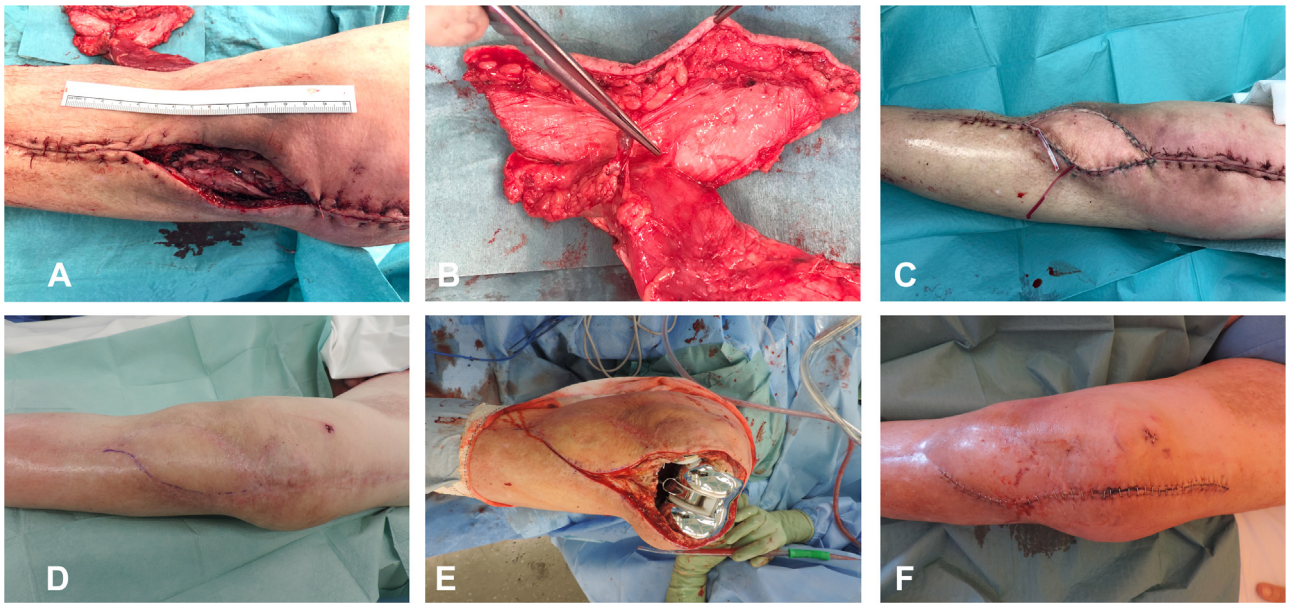

Figure 2 Patient no. 6 presented a chronic infection of a TKA. Following surgical debridement, a 35 cm^2 loss of substance with implant exposure was seen (A), a two-stage procedure strategy was chosen, the TKA was removed, and a spacer was placed. A GM-MSAP was used for skin coverage (B-C). After 2 months (D) the flap was re-raised to allow for spacer exchange (E). Thanks to the skin paddle, a tension-free skin closure was achieved (F).

Table 3 Group comparison and statistical analysis.

Outcomes	GM	GM-MSAP	*p* value
Age mean, (SD)	60 (13)	64 (16)	0.35
No. of Smokers	9	2	0.08
Defect size cm^2 median, (IQR)	49 (55)	48 (36)	0.9
Follow-up months median, (IQR)	22 (32)	19.5 (13)	0.2
No. of one-stage procedures	16/22	8/16	0.1
No. of two-stage procedures	6/22	8/16	0.1
No. of flap complications	5/22	2/16	0.4
No. of persisting infection after STR	12/22	5/16	0.1
Number of surgeries, mean	4.7	3.5	0.2
Number of unplanned surgeries following STR, mean	1.3	0.9	0.3
Operative time (min)	186	196	0.7
No. of patients needing flap re-raise	14/22	11/16	0.9
No. of successful reraise	6/14	11/11	**0.001
No. of successful STR	14/22	16/16	*0.01
No. of successful limb salvage	20/22	16/16	0.5

Table 3: Group comparison.
ABB: SD, standard deviation; IQR, interquartile range; STR, soft tissue reconstruction; GM, gastrocnemius flap; GM-MSAP, chimeric gastrocnemius + medial sural artery perforator flap.

incidence of persistent material infection or flap complications (Table 3).

The defect size and the operative time were superimposable in the two groups (*p* value 0.9). No significant differences were seen in the distribution of one-stage vs. two-stage procedures among groups, despite a trend towards a greater number of staged procedures recorded in the GM-MSAP group (50% vs. 27% in the GM group).

In terms of flap complications, no significant differences were seen among the two groups as both flaps were reliable and provided efficient tissue coverage (*p* 0.4) (Figure 3).

The number of persistent infections of the implant following the STR showed a discrete trend towards a decrease in infection in the GM-MSAP group (*p* value 0.1) but did not reach statistical significance. The need for flap reraise was highly comparable in the two groups despite a higher need in the GM group (p value > 0.99), matching the higher number of persisting infection in such a group. The number of total surgeries and unplanned surgeries per patient among groups did not show significant differences.

Importantly, a statistically significant difference was seen among the groups in terms of successful flap reraise ($p < 0.05$) in favour of the GM-MSAP group. Final limb sal-

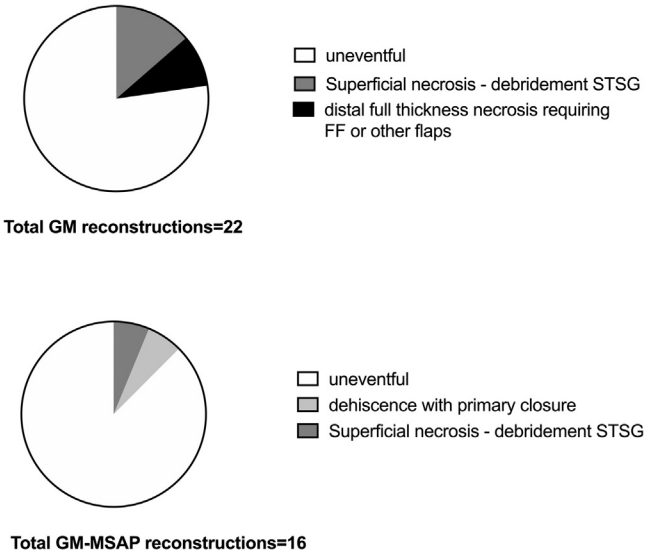

Figure 3 The graph shows the complication rate among the two groups.

vage, even including supplementary procedures such as free tissue transfer, was 100% in the GM-MSAP group and 90% in the GM group (Figure 4).

Discussion

TKA is a recognized procedure for the management of disabling knee arthritis with successful outcomes resulting in marked pain relief and improved patient functionality. Studies have cited survivorship of TKA of >90%, 80%, and 70% at 10, 15, and 20 years, respectively.[10] With an increasing elderly population, the number of primary TKAs is projected to increase by 673% by 2030, and revision total arthroplasty will likely mirror this trend, particularly as patients continue to live longer. In this contest, the incidence of wound-healing complications and supplementary major surgery in the long term is increasing as well.[12,8]

In addition, the risk of IAOM (implant-associated osteomyelitis) after fracture fixation depends on the type and site of injury, and particularly on the soft tissue damage.[13] It is particularly high in patients with open fractures of the tibia, multiple injuries, high-energy trauma, vascular injury, and late admission to trauma treatment centres. While in the thigh and in the upper limb it is often possible to close the skin directly and muscles provide a healthy cover, in the leg, high-energy fractures can disrupt the limited soft tissues, producing major compromise.[14] Over the tibia, even when skin closure can be achieved, surrounding tissues are often insufficient to guarantee sufficient vascularity and coverage, with the risk of bacterial adherence and biofilm formation on the framework.[15]

Adequate coverage of the knee and the upper third of the leg can be extremely challenging in case of foreign material infection (following TKA or internal fixation) or bone infection with osteomyelitis.[1,14] Extensive aggressive debridement is of paramount importance for infection eradication; however, vascularized soft tissues around the implant critically impact on the reconstruction as they provide blood flow to the area, allowing delivering systemic antimicrobial agents, immune cells, and antibodies.[16]

As an evolution of the originally described myocutaneous GM flap,[3] Hallock described the potential use of the pedicled chimeric GM MSAP flap in 2008.[6] These concepts were further developed by other groups, exploiting flap chimerism[17] and as a useful tool for knee reconstruction where the defect is too large or too complex for a single medial gastrocnemius muscle flap. Indeed, the perforator nourishing the skin paddle could serve for tailored reconstructions according to the propeller flap principles.[8] However, despite case reports and small series, no article specifically focused on knee complex prosthetic surgery and revision surgery in the case of implant contamination. Moreover, no study in the literature quantified or compared outcomes between simple gastrocnemius muscle flap and its chimeric modification, including the skin paddle.

This paper analyses two patient cohorts in terms of age, patients' comorbidities, orthopaedic surgical indication for knee prosthetic revision, and soft tissue defect size.

Flap surgery was ideally performed in the first surgical step to maximize the time for the soft tissue to heal and integrate. Moreover, an early flap placement over a spacer could assure well-vascularized tissue to act synergistically with the antibiotic-loaded cement to deliver antimicrobial agents to the site of infection. However, this was not always possible as patients were often referred after an initial surgical attempt where an exchanged TKA was already placed (and contaminated after a wound dehiscence) or a spacer had already been placed but soft tissues were precluding a safe definitive implantation.

No significant differences were noticed regarding the flap complications between the two groups. Both flaps are safe and reliable. However, a slight trend towards a reduction in flap complications was seen in favour of the GM-MSAP flap group, and it is questionable whether this difference would have reached significance with a bigger patient population. Indeed, the well-vascularized skin paddle provided by the MSA perforator ensures a more solid soft tissue coverage compared with the muscle flap-only design, where the distal extremity (tendinous part) is less strongly vascularized.

In our series, the operative time was comparable between the two groups, despite the common belief that raising a chimeric flap should be more complex and time consuming. This could be explained by the fact that the dissection of the perforator in GM-MSAP flaps is minimal, and the learning curve is mainly directed towards perforator choice and appropriate skin paddle insetting.

According to the literature, the need for revision surgery after implant infection is high and often unpredictable, regardless of the orthopaedic strategy chosen (one-stage vs. two-stage).[9] Overall, a mean of 4 ± 1 surgeries was performed on each patient following the implant infection with a global rate of unplanned surgery of 1 ± 0.2, without significant differences between the two groups. This can be explained as the need for revision is not related to the STR procedure itself but instead is depending on the recurrence of implant or bone infection.

In this context, the need for a flap reraise procedure should always be considered when dealing with implant infection. Therefore, the possibility to have a stable skin pad-

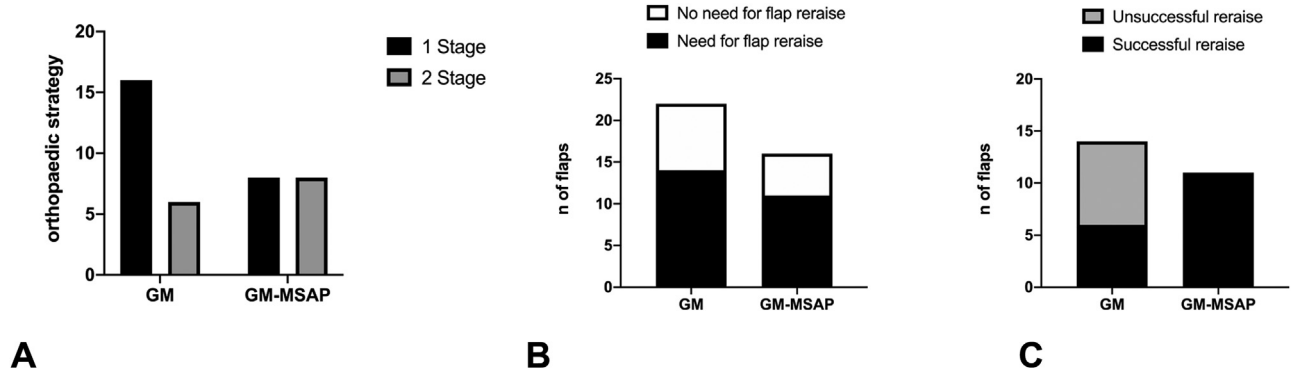

Figure 4 Graphic content showing the comparison among groups and particularly the orthopaedic procedure (A), the need for flap reraise (B), and the number of reraise failure (C).

dle over the implant represents a powerful tool for a safer flap reraise/readvancement. This goes in line with our results in which the GM-MSAP flap reraise was possible in all cases, while the GM flap was insufficient in 8 patients out of 22, requiring more complex reconstructive procedures.

Despite the promising results, some limitations need to be acknowledged. In particular, because of the small numbers of patients enrolled in the study, the statistical significance of our findings is underpowered, and, therefore, larger studies are required in the future to validate our results.

Conclusion

Implant-associated infections of the knee and upper third of the leg often require multiple reinterventions and represent a real limb-threatening complication.

This study compares the outcomes of gastrocnemius muscular flap and chimeric musculocutaneous MSAP in soft tissue reconstruction of the knee.

Both techniques provided efficient coverage in this complex scenario. According to our results and clinical experience, the chimeric musculocutaneous MSAP flap can be a significantly more powerful tool in those cases in which a two-stage procedure is planned or when there is a high probability for secondary intervention need, as the skin paddle of the flap guarantees a more reliable scarring process (skin–skin vs. skin-grafted muscle), does not incur shrinkage (while improving over time in terms of elasticity), and allows for easier flap-reraise. All properties being of critical importance in knee implant revision surgery, this flap modification could significantly decrease complications, reducing the need to convert to either free flap coverage or amputation.

Conflict of Interest

None.

Ethical approval

Not required.

Funding

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2022.12.006.

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