



The Role of Split Anterolateral Thigh Free Flaps in Reconstructive Surgery: a Systematic Review and Case Report

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Abstract

Radical tumor ablation or severe trauma can result in challenging tissue defects. The split anterolateral thigh free flap has been promoted as an ideal option for complex defects. We aimed to evaluate whether this flap could be performed without major morbidity. A systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines was conducted to assess this hypothesis. An illustrative case about pharyngeal reconstruction is discussed, and the role of free split anterolateral thigh free flaps in modern reconstructive surgery is evaluated. The systematic search of literature yielded 221 studies with 7 articles about free anterolateral thigh flaps fully split in two separate flaps based on one pedicle. Favorable outcomes in a total of 31 patients were described. Tissue defects were mainly located at extremities, chest wall, lip, and cheek. A low complication incidence was reported in all studies, in terms of flap loss, donor site morbidity, and general wound healing problems. The flap was utilized for pharyngeal reconstruction and simultaneous neck resurfacing, which allowed a more convenient way of flap monitoring in the present case. Being technically a rather demanding flap variant, splitting the anterolateral thigh free flap has still become an accepted technique among microsurgeons. Currently, literature suggests that it can be performed without major complications for reconstructing extremities and the head and neck area. Rearrangement of the flap units in pharyngeal reconstruction increases the flap's versatility as it allows neck resurfacing and external monitoring of buried inaccessible flaps.

Keywords Anterolateral thigh flap · Microsurgery · Split flap · Flap monitoring

Introduction

Reconstruction of large soft-tissue defects after radical tumor ablation and major trauma disrespecting anatomical borders and shapes continues to be challenging due to three-dimensional irregularity and complex geometry of resulting defects. Microsurgeons can choose from a variety of well-established free flaps to close various types of challenging defects. The anterolateral thigh flap (ALT) has become a work horse in reconstructive plastic surgery. Some popular advantages of the flap are its long pedicle, the extension and reliability of the skin paddle, a relatively constant anatomy, and a low and predictable donor site morbidity compared to other fasciocutaneous flaps. When harvested as a sole fasciocutaneous flap, donor-site morbidity is low. Since its

first description by Song in 1984, who initially characterized it as a soft tissue flap based on septo-cutaneous vessels between rectus femoris and vastus lateralis muscle, the anatomical variability of the flap perforators has been repeatedly assessed [1–4]. The flap more often relies on musculocutaneous perforators through the vastus lateralis. Designing and harvesting the ALT flap has been traditionally recognized as being technically demanding due to a wide range of possible perforator anatomy [3, 4]. Using the handheld Doppler has been suggested as a good method to localize perforators but can be misleading, as its accuracy depends on the expertise of the surgeon and the amount of subcutaneous fat [3, 4]. Authors have described a simplified technique for the ALT flap design and dissection without the use of preoperative imaging or vascular studies utilizing the ABC-system to locate typically three perforators [4]. Usually, a large elliptical flap may be harvested. However, if one wishes to achieve primary closure of the donor site, the width of the harvested ellipse must be limited to a maximum of 9 cm in most cases [5]. To expand the flaps versatility, it can be harvested as

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a split flap based on one vascular pedicle allowing a more efficient design [5, 6]. The split anterolateral thigh flap (sALT) has been described as an effective strategy for covering irregular, non-elliptical and unconventionally shaped defects mainly in the extremities, but also became popular in head and neck surgery, where unconventionally shaped defects are common especially after radical ablative procedures after radiation therapy leaving fragile tissues behind [7, 8]. It is however unclear whether the utilization of the sALT poses a risk for a complicative course. We therefore aimed to evaluate whether these complex procedures could be performed without major complications and conducted a systematic review of the literature to assess this hypothesis. We further provide an illustrative case for its use in pharyngeal reconstruction.

Patients and Methods

We performed a systematic review in accordance with the PRISMA guidelines. In addition, the systematic review has been registered on PROSPERO (CRD42020211073). An electronic literature search was conducted on March 17, 2020, using the following databases: Medline, Embase, Cochrane, Scopus, and Web of science. Language was restricted to English, German, French, and Spanish. There was no time restriction. Main search terms were as follows: sALT OR split ALT OR s-ALT OR split anterolateral thigh OR double skin paddle anterolateral thigh OR puzzle ALT (Supplementary Information 1 Search Strategy Embase).

Articles were selected based on inclusion and exclusion criteria (Supplementary Information 2 Study Selection). All retrospective and prospective studies, case reports, and case series analyzing outcomes of a fully split ALT with separated skin paddles each based on different perforators and based on one pedicle to cover trauma or oncologic defects were included into further analysis. Conference abstracts and articles without available full-texts, comments, and letters as well as reviews and experimental research or anatomical studies without additional case reports were excluded. Studies analyzing pedicled flaps, chimeric flaps, flaps with more than one pedicle, and flaps with two skin paddles after de-epithelization of bridging skin only were also excluded. Titles and abstracts were identified and screened for inclusion by 2 independent coders in Endnote version X7 (Clarivate Analytics, Philadelphia, United States) with a structured manual in respect to inclusion and exclusion criteria. For training purposes and intercoder agreement evaluation, a random sample of 5% of all references was independently rated by both coders. The percentage of agreement for the reasons of exclusion was larger than 75%, and all raters identified the same studies for a full-text screening. During the screening, coders were able to mark references as unclear. In

such cases, a definite decision was taken by consensus with a senior researcher.

Selected studies were included for detailed descriptive analysis. Study design, level of evidence, and demographic data were thoroughly assessed for all studies. Relevant data related to complications and outcomes was determined prior to reading the selected articles, and a narrative synthesis was included with a focus on indications and outcomes. We abstained from conducting a meta-analysis due to heterogeneity and low number of cases.

Results

A total of 312 articles were identified in the original database search. After deleting duplicates, 221 unique articles remained for review. After screening the titles and abstracts, 207 articles were considered irrelevant and were excluded. 14 studies were fully assessed and evaluated for reporting of clinical response data, of which seven did not meet the inclusion criteria and were excluded. Based on our predefined selection criteria, seven studies were finally deemed eligible and selected for data analysis [6–12]. The overall level of evidence in the seven selected studies was low and ranged between III and IV: Three retrospective cohort studies, two case series, and two case reports were included. A total of 31 patients, of which 21 were female and 10 were male, received free ALT flaps split into two flaps based on a single pedicle. Mean age of the patients was 44.2 years. The biggest retrospective study reports about 13 cases with crush injuries, diabetic gangrene, and postburn contractures in extremity reconstruction [7]. Defect mechanism was traumatic in four and oncologic in three articles. Study characteristics and demographic data are summarized in Table 1. Main tissue defect locations were the upper and lower extremities, chest wall, lip, and cheek. Follow-up ranged from 2 to 24 months in the selected articles. All 62 flaps survived without emergency revision. In one case, a limited margin necrosis occurred [7]. The average range and dimensions of the split paddles were not reported in most of the studies. No other major wound healing problems were reported in the selected studies. The overall outcome was favorable in all 31 cases, but standardized outcome measurements were not reported. Only five patients that received oral cavity reconstruction with sALT were identified: Lin, P. Y., et al. report on four patients who received sALT for lip and/or buccal reconstruction and found that the speech was near normal in three and intelligible in 1 of the cases after a mean follow-up period of 12 month [8]. Sun et al. reconstructed the lip and part of the cheek, and good oral competence was obtained at 2 months postoperatively [12]. All but two donor sites

Table 1 Study characteristics and demographics

Author (year)	Country	Study type (level of evidence)	N patients	Sex M/F	Age (years)	Defect mechanisms
Chang et al. (2011) [7]	Taiwan	Retrospective cohort study, (III)	13 (15)	7 / 6	40.6 (mean)	Crush injury, BI DG, PBC
Lin, P. Y., et al. (2012) [8]	Taiwan	Retrospective cohort study, (III)	4 (13)	4 / 0	45–52 (range)	Cancer resection
Sun et al. (2013) [12]	China	Retrospective cohort study, (III)	1 (11)	0 / 1	62	Cancer resection
Marsh and Chana (2010) [6]	UK	Case series, (IV)	6	5 / 1	24–35 (range)	Crush injury, salvage BR, PWB
Peng et al. (2013) [9]	China	Case series, (IV)	5	4 / 1	36.6 (mean)	Crush injury
Vigneswaran et al. (2011) [13]	Singapore	Case report, (IV)	1	0 / 1	17	Degloving injury
Scaglioni et al. (2019) [10]	Switzerland	Case report, (IV)	1	1 / 0	75	Cancer resection
Total			31	21/10	44.2 (mean)	

Abbreviations: N number, M male, F female, BI burn injury, DG diabetic gangrene, PBC postburn contracture, BR breast reconstruction, PWB postoperative wound breakdown

were closed primarily [7, 9]. In one case, “shoe lacing” and skin grafting were deemed necessary although the harvested flap had a maximum width of 9 cm, and in the other case, split skin grafting was necessary to close donor site without further explanation [6]. Defect characteristics and related outcomes are shown in Table 2.

Surprisingly, we did not encounter an article using the sALT for simultaneous mesopharyngeal reconstruction and neck resurfacing.

Table 2 Free split anterolateral thigh flaps in patients and related complications

Study (year)	Defect location	Defect dimensions (cm)	N split flaps	FU month (mean)	Flap loss	Donor site closure	Overall outcome
Chang, N. J., et al. (2011) [7]	Hand, foot, ankle, lower leg	NR	26	NR	None (margin necrosis in 1 case)	Primary (12), shoelace and skin graft (1)	Good results
Lin et al. (2012) [8]	Lip, buccal	12×5–6×4	8	12	None	Primary	Speech: near normal in 3, intelligible in 1
Sun et al. (2013) [12]	Lip, part of cheek	8×7	2	2	None	NR	Good oral competence
Marsh and Chana (2010) [6]	Chest wall, foot, forearm, lower limb	30×18–11×12	12	NR	None	Primary	Good results
Peng et al. (2013) [9]	Hand, forearm	4.5×1.5–20×10	10	18	None	Primary in 4, skin graft in 1	Satisfied with appearance in 3/5, with functional recovery 5/5
Vigneswaran et al. (2011)	Heel, sole of foot	17–7	2	24	None	Primary	Full weight bearing at 2 mo, satisfied with appearance
Scaglioni et al. (2019) [10]	Posterior upper thigh	14×16	2	11	None	Primary	Satisfactory aesthetic outcome, no functional deficit
Total			62				

Abbreviations: NR not reported, mo months

Illustrative Case

A 64-year-old male patient with an oropharyngeal squamous cell carcinoma underwent resection after primary locoregional radiotherapy resulting in scarred and fragile neck tissue. Ear-nose-throat surgeons were in primary charge of the tumor resection, and defect coverage was planned by our reconstructive surgery team. The need for neck resurfacing was anticipated. An anterior lateral thigh flap was marked on the patient's left thigh. Potential perforators had been located prior to surgery with a handheld Doppler. If dissection had yielded a difficult anatomy preventing the splitting of the flap, the inclusion of muscle and split skin would have been the alternative option. Mandible split was performed for better exposure of and access to the oropharynx. Tumor resection revealed a large meso-pharyngeal defect (Fig. 1a). An anterolateral thigh flap was designed, and two perforators for a proximal and a distal territory were dissected as illustrated (Fig. 1b). The flap was divided accordingly (Fig. 1c). One flap was rectangular shaped 6 × 8 cm, and the other one triangular shaped 6 × 7 cm in dimension. Before definite sectioning of the pedicle with the flaps fully raised, both perforators were clamped sequentially and adequate perfusion to both

flap parts was ascertained clinically. The main vascular pedicle was then anastomosed to the facial artery in an end-to-end manner, while the outflow was reconstructed by an end to side anastomosis between the flap vein and the internal jugular vein. The division into two flaps made a convenient rearrangement of tissue possible: One flap was used to reconstruct the mesopharynx, and the second flap was used to resurface the neck area which revealed poor quality due to neo-adjuvant radiotherapy (Fig. 1d, e). The latter enabled easy access for routine vitality checks. Patients' hospital stay was 12 days. In regularly scheduled outpatient visits, optimal healing of both donor site and reconstruction site was documented.

Discussion

Under certain circumstances the reconstruction of deep functional structures, external skin resurfacing with complementary vascularized tissues can become inevitable, e.g., in head and neck reconstruction. When neck resurfacing is necessary, splitting the ALT flap rather than harvesting it with a certain amount of muscle and skin grafting decreases the donor site morbidity. The possibility of two independent flaps on the lateral circumflex femoral artery has been

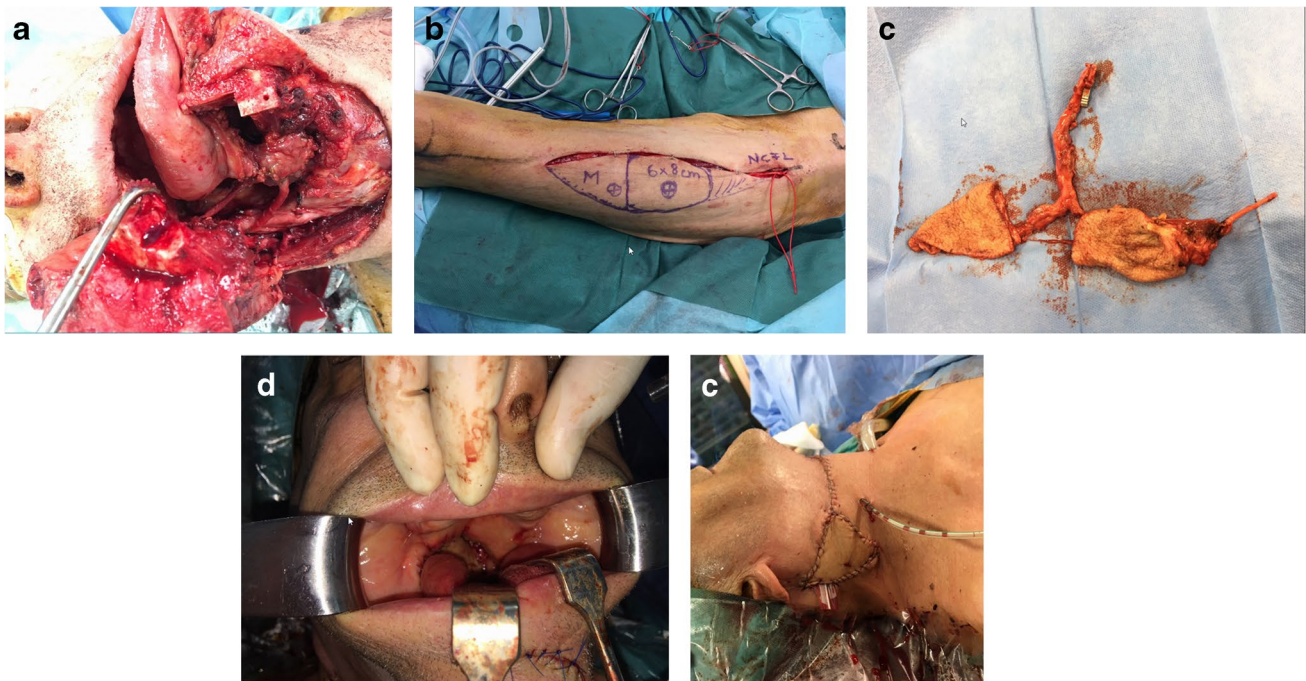


Fig. 1 **A** Mandible split for adequate exposure of the tumorous oropharyngeal mass leaving a large defect after resection. **B** An anterior lateral thigh flap was marked on the patient's left thigh. Potential perforators had been located prior to surgery with a handheld Doppler. **C** Two perforators for a proximal and a distal territory were prepared as illustrated. The flap was divided accordingly after serial clamping of

perforators and ICG guided clinical prove of viability. **D** The division into two flaps made a convenient rearrangement of tissue possible: One flap was used to reconstruct the mesopharynx, and the second flap was used to resurface the neck area which revealed poor quality skin due to prior radiotherapy. **E** The external flap provided an easy access for routine vitality checks

described in 2006 by other authors [14]. Since then, many surgeons well versed with the anatomical variations of the ALT pedicle have been using it quite frequently. Splitting the ALT requires tedious surgical dissection performed under loupe magnification, which could be associated with a longer operation time. However, operating time is subjective and those who are familiar with the vascular anatomy and variability can harvest the flap very easily. The flap can be dissected suprafascial or subfascial. The latter is often conducted to minimize the risk of injuring perforators. The perforators can either be septocutaneous (13%) or musculocutaneous (87%). Unroofing musculocutaneous perforators and tedious intramuscular dissection of perforators are the key points in dissecting this flap. Usual pitfalls are inadvertent perforator division at fascial plane, inadvertent perforator injury during intramuscular dissection, pedicle twisting during inset, and vessel size mismatch. There is a conflict about the skeletonization of perforators. Some groups claim that it is not necessary, and thus, the risk of damage to the perforating artery and its venae comitantes can be reduced. On the other hand, complete skeletonization of perforator is often proposed to be inevitable as soft tissue and fibrous bands around perforators may cause compression of perforating vessels. Issues regarding its use in facial reconstruction often refer to unfavorable aesthetic outcomes like sagging of flap, color mismatch, hair growth, and bulkiness. Authors have suggested that careful patient selection may improve aesthetic outcome of the anterolateral thigh flap in reconstruction of external skin defects in the head and neck region [15]. Unfavorable functional outcomes are speech problems, oral incontinence, swallowing issues, nasal obstruction, and flap contracture. Overall, there is a need for large-scale studies and standardized outcome measurements need to be utilized for assessment of functional outcomes.

Cadaveric and statistical analyses were performed on the distribution of cutaneous perforators that perfuse the scapular, radial forearm, and lateral arm cutaneous flaps [16, 17]. The authors found that the cutaneous territory within these flaps can be independently manipulated based on statistically distinct clusters of cutaneous perforators, which are not randomly distributed but have a consistent pattern in distribution [16]. As an example, the radial forearm flaps could be harvested as three well-perfused segments. Authors have found that in-transit and terminal perforators lateral to the source artery allow the placement of skin paddles that do not follow, e.g., the direction of the source artery as long as the primary fascial branches remain intact [16]. On the other hand, they have demonstrated that direct cutaneous perforators allow discarding fascia and much of the subcutaneous tissue lateral to the source artery [16]. Skin grafting of the donor is the main drawback of large RFF as it results in unacceptable contour deformity and an unsightly appearance. In a comparative study, the ALT and RFF showed

similar practicability and reliability for the reconstruction of soft-tissue defects, but ALT flaps had fewer impacts to donor site functionality than RFF [18].

Our results demonstrated that the free sALT is mainly used in reconstruction of extremities and of the oral cavity and is associated with a low number of flap-related complications, whilst providing stable outcomes. During our analysis, we found an interesting article that proposed sALT as an alternative to the free latissimus dorsi muscle flap in extended scalp reconstruction [19]. The article was in fact labeled as a communication, which is why — in accordance with our predefined eligibility criteria — it was not included for further assessment. The authors stated that they had achieved primary coverage of extensive scalp defect with a split ALT flap as well as tension-free direct closure of donor sites in eight patients [19]. In our opinion, scalp reconstruction with muscle flaps and skin grafting is more favorable in terms of an almost perfect color and texture match. ALT flaps for the scalp unexceptionally look patchy and not rarely bulky necessitating further flap thinning.

Sometimes due to the location of the flap monitoring can be difficult especially for inexperienced nurses and junior residents, so that the flap might be manipulated inadequately for monitoring purposes. The exteriorization of a segment of free flaps by harvesting free flaps with a secondary monitor skin paddle permits a direct visualization and allows monitoring the status of the paddle externally [17, 20]. It is advised to use the more distal perforator skin paddle for neck resurfacing, so that it remains “downstream” of the conduit blood supply [12]. This helps to avoid a false-negative scenario in which the external skin paddle is perfused, and the internal skin paddle is compromised. However, we do not promote the exteriorization of a skin paddle for purely monitoring purposes but have noticed its benefit when neck resurfacing was conducted. In our experience, the implantable Doppler is often prone to malfunction and misinterpretation as it is exposed to artifacts in the narrow neck. Authors have assessed its use in a total of 100 free flaps [21]. Sensitivity was 87.1%, and specificity was 85.7%. Positive predictive value was 98.8%, and negative predictive value was 33.3%. False-negative and false-positive rate were 1.0% and 12.0%, respectively. The exploration rate was 12%, with no flap loss and two partial debridements. The implantable Doppler was helpful in management in 9% of cases and was clinically unhelpful in 11% of cases, with 10 of 11 abnormal signals ignored [21]. In general, it can be seen as a helpful adjunct to clinical monitoring. However, another problem with an implantable Doppler is that it is not always available, and it is an expensive device.

Our study has some limitations. The review yielded a small series of retrospective cohorts and case reports on this topic, so that the data and the conclusions may be considered weak. Case heterogeneity and less numbers prevented a

proper metaanalysis. Our methodology may have not captured all relevant articles. It seems obvious that there is a need for more high value research in this field, e.g., larger scale prospective, comparative outcome studies. Unfortunately, the average range of dimensions of the two skin paddles were not reported in most of the articles. In future articles, the average range of dimensions of the split flap parts need to be addressed in more detail to provide guidance when planning the flap.

Conclusion

The free sALT (one pedicle, two perforators) in reconstruction of extremities and of the head and neck is associated with a low number of overall complications, whilst providing reliable outcomes. Although frequently applied and accepted as a solid procedure, the evidence in literature about its safety and efficacy is scarce. The heterogenous group of reconstructive locations and the small overall number of cases in existing studies must be considered as a confounding factor to establish solid conclusions. Allowing simultaneous neck resurfacing and facilitating external monitoring of deeper lying pedicles reinforce the important role of sALT in pharyngeal reconstruction.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12262-022-03501-5>.

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Declarations

Ethics Approval No institutional review board approval was required to conduct this article.

Informed Consent Patient signed informed consent regarding publishing their data and photographs.

Competing Interests The authors declare no competing interests. =8

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