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Long-term donor site morbidity in head and neck cancer patients and its impact on quality of life: a cross-sectional study

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Abstract. Modern head and neck reconstructive surgery offers a multitude of different reconstructive options. In such cases, donor site morbidity is an important factor in the affected patient's decision-making. The aim of this study was to perform an objective comparison of donor site morbidity for the five most frequent microvascular donor sites in head and neck reconstructive surgery (radial forearm, anterolateral thigh, fibula, iliac crest, and scapula) using a uniform testing system. In this cross-sectional study, 117 donor sites were analyzed (106 for malignant disease and 11 for non-malignant disease): 73 radial forearm, 14 scapula, 12 anterolateral thigh, 10 fibula, and eight iliac crest. Testing consisted of range of motion, muscle strength, and sensation. The non-affected side served as the control. Quality of life was assessed using the Washington Quality of Life Questionnaire version 4 in its German translation. Range of motion was restricted in 15 cases (12.8%). Muscle strength was decreased in 58 cases (49.6%). Sensation was reduced in 70 cases (60%). Concerning quality of life, 31.2% of patients were limited in their daily activities. The scapula flap showed the highest incidence of overall donor site morbidity. However, correlation between objective and subjective donor site impairment was weak and the majority of patients experienced only minor limitations.

Key words: donor site morbidity; QOL; head and neck cancer; microsurgery.

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Microvascular reconstruction has become the most important treatment modality in reconstructive head and neck surgery and was defined as the gold standard for reconstruction in head and neck surgical oncology in the United Kingdom National Multidisciplinary Guidelines of 2016[1]. The workhorse for soft tissue reconstruction is the radial forearm flap (RFFF) and the flap most frequently used for bony reconstruction of the mandible is the fibula free flap (FF), with the most frequent

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alternatives being the anterolateral thigh flap (ALTF) for soft tissue and the iliac crest flap (ICF) and scapula free flap (SF) for bony reconstruction[2]. Although the recipient site, previous operations, and comorbidities (e.g., vascular disease, obesity) often define the ideal choice of microvascular transplant, there remain cases in which there are alternative, equivalent reconstructive options. In such cases, the incidence and severity of donor site morbidity is the most important factor for decision-making.

To date, there are no reliable data on donor site morbidity for the different donor sites, as studies have focused on single sites or have compared two different donor sites. Therefore, the aim of this study was to compare the donor site morbidity of the five most frequently used microvascular donor sites in head and neck reconstructive surgery (RFFF, FF, ALTF, ICF, SF) using a uniform testing system and to correlate findings with the patients' subjective quality of life (QOL) impairment.

Materials and methods

Study population

This cross-sectional study was approved by the local ethics committee and was performed in accordance with the Declaration of Helsinki. All patients treated at Heidelberg University Hospital with combined ablative and microsurgical reconstructive surgery, between January 1, 2009 and April 30, 2016, were included. A minimum follow-up period of 6 months post-surgery was required, and all had to provide written consent for participation in the trial. All patients completed the University of Washington Quality of Life Questionnaire version 4 (UW-QOL v4), German translation, and underwent standardized clinical evaluations of donor site morbidity.

Data acquisition

Donor site morbidity was evaluated with regard to range of motion, muscle strength, and sensation. Range of motion was determined by neutral zero method and documented using the standardized test sheets of the German statutory accident insurance: spine (F6222), upper extremity (F4222), lower extremity (F4224), and fingers (F4220). Muscle strength was determined according to the Medical Research Council (MRC) Muscle Scale, with permission from the Medical Research Council (UK). No changes were made. Sensation was tested by two-point discrimination, sharp–blunt testing, Semmes–Weinstein filament, and hot–cold differentiation with a Tip Therm device (Tip Therm GmbH, Wischhafen, Lower Saxony, Germany). For all tests, the non-affected side of the patient served as the reference and control. Patients with a known preoperative impairment of the donor site were excluded from the analysis.

QOL was assessed with the UW-QOL v4, German translation, simultaneously with the clinical examination.

Statistical analysis

The paired *t*-test and correlation were used to compare the donor site and the contralateral side, different donor sites, and the correlation between donor site morbidity and QOL. The significance level was set at $P < 0.05$. The statistical analysis was performed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA).

The UW-QOL v4 results were analyzed in accordance with the recommendations of Lowe and Rogers[3].

Results

During the study period, a total of 841 microsurgical reconstructions were performed. A total of 101 patients with 117 different donor sites (13.9%) fulfilled the inclusion criteria, were able and willing to participate, and were included in the analysis. Ninety-four patients suffered from malignant disease and seven from non-malignant disease (106 sites for malignant disease and 11 sites for non-malignant disease). The donor site distribution was as follows: 73 RFFF, 14 SF, 12 ALTF, 10 FF, and eight ICF (Figs. 1–5). Overall, range of motion was restricted in 15 cases (12.8%), muscle strength was decreased in 58 cases (49.6%), and sensation was reduced in 70 cases (60%). Concerning quality of life, 31.2% of patients were limited in their daily activities.

Donor site morbidity

Radial forearm

All patients had full and symmetric range of motion of the lower arm, hand, and fingers (extension and flexion of elbow, pronation and supination of lower arm, extension, flexion, ulnar and radial tilt of wrist, extension and flexion of thumb basal and distal joint, abduction of thumb, hand span) (Table 1). There were no significant differences in arm circumference between the operated and non-operated sides. Circumference was symmetric 15 cm superior to the lateral humerus condyle, at the level of the elbow, 10 cm inferior to the lateral humerus condyle, at the level of the wrist, and at the metacarpus.

Muscle strength rated by MRC Muscle Scale was normal in 41 patients and decreased in 32 patients (Table 1).

Sensation was affected in the majority of patients: two-point discrimination was significantly worse on the operated side than on the non-operated side ($P < 0.0001$). Sharp–blunt discrimination was physiological in all patients on the non-affected side and decreased in six patients on the affected side. Monofilament sensation was decreased in two patients on the non-affected side and in eight patients on the affected side. Temperature differentiation was decreased in one patient on the non-operated side and in 10 patients on the operated side (Table 1). One patient reported tingling; one patient

Fig. 1. Radial forearm flap (RFFF) donor site: (a) full thickness skin graft, (b) secondary wound healing.

Fig. 2. Anterolateral thigh flap (ALTF) donor site.

reported numbness of the thumb (1.4% each).

Anterolateral thigh

Range of motion was unrestricted and symmetric for flexion, extension, adduction and abduction, inward and outward rotation of the extended and 90° flexed hip joint, and for extension and flexion of the knee joint for all patients. Two patients showed slightly decreased flexion of 90° of the hip joint symmetrically on the operated and non-operated side (Table 1). Leg circumference was significantly smaller on the operated side than on the non-operated side 20 cm superior to the knee joint space (45.5 ± 2.7 cm vs. 46.5 ± 3.0 cm, $P < 0.0001$), and slightly smaller 10 cm superior to the knee joint space (40.2 ± 2.5 cm vs. 40.5 ± 2.4 cm). For the middle of the patella, 15 cm inferior to the knee joint space, and at the height of the ankle, no differences between the sides were found, with a mean of 24.8 ± 2.15 cm on the non-operated side and 25.2 ± 2.16 cm on the operated side. The leg length difference between the operated and non-operated legs was 0.9 ± 1.2 cm (range 0–5 cm, median 0 cm).

Muscle strength rated by MRC Muscle Scale was normal in six patients and decreased in the other six patients compared with the non-operated side (Table 1).

Sensation was affected in the majority of patients: two-point discrimination was significantly worse on the operated side than on the non-operated side ($P < 0.0001$). Sharp–blunt discrimination and monofilament sensation were physiological in all patients on the non-affected side. On the operated side, a total of three patients showed decreased sharp–blunt differentiation and two showed negative sharp–blunt discrimination. On the operated side, five patients showed decreased monofilament sensation and one showed negative monofilament sensation, and six patients showed decreased temperature sensation and one patient showed negative temperature sensation (Table 1).

None of the patients used a walking aid.

Iliac crest

Range of motion was unrestricted and symmetric for flexion, extension, adduction and abduction, and inward and outward rotation of the extended and 90° flexed hip joint for all patients. One patient showed slightly decreased flexion of 90° of the hip joint symmetrically on the operated and non-operated side (Table 1). Leg circumference was symmetrical 20 cm and 10 cm superior to the knee joint space, at the middle of the patella, 15 cm inferior to the knee joint space, and at the height of the ankle. The leg length difference between the operated and non-operated legs was 0.5 ± 0.5 cm.

Muscle strength rated by MRC Muscle Scale was normal in five patients and decreased in the other three patients (Table 1).

Sensation was affected in the majority of patients: two-point discrimination was significantly worse on the operated side than on the non-operated side ($P < 0.0001$) (Table 1). Sharp–blunt and temperature discrimination and monofilament sensation were physiological in all patients on the non-affected side. On the operated side, a total of two patients showed negative sharp–blunt differentiation; one of them showed decreased monofilament sensation and the other showed negative monofilament sensation and negative temperature sensation (Table 1).

None of the patients used a walking aid.

Fibula

None of the patients showed restrictions of motion for extension, flexion, internal and external rotation of the knee joint, and extension and flexion of the upper ankle joint, either on the operated side or on the non-operated side. One patient showed limited range of supination of the lower ankle joint on the operated side (70% of non-affected side) and one patient on the non-operated side (80% of the contralateral side) (Table 1). There were no signif-

Fig. 3. Fibula flap (FF) donor site: (a) split thickness skin graft, (b) secondary wound healing, (c) primary closure.

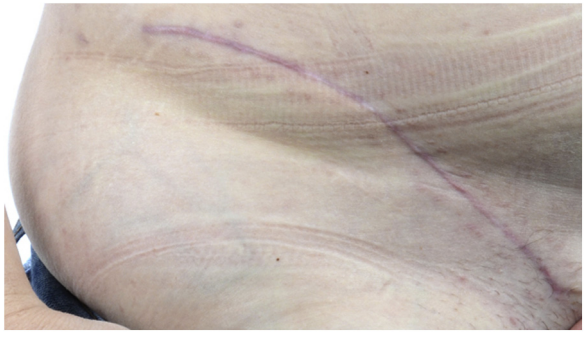

Fig. 4. Iliac crest flap (ICF) donor site.

icant differences in leg circumference between the operated and non-operated sides at 20 cm and 10 cm superior to the knee joint space, at the middle of the patella, and 15 cm inferior to the knee joint space. However, a significant difference in leg circumference was found at the height of the ankle ($P < 0.0001$), with a mean of 24.8 ± 2.1 cm on the non-operated side and 25.2 ± 2.2 cm on the operated side. The leg length difference between the operated and non-operated legs was 0.7 ± 1.1 cm (range 0–3 cm, median 0 cm).

Muscle strength rated by MRC Muscle Scale was normal in five patients and decreased in the other five patients compared with the non-operated side (Table 1).

Sensation was affected in the majority of patients: two-point discrimination was significantly worse on the operated side than on the non-operated side ($P < 0.0001$) (Table 1). Sharp–blunt discrimination and monofilament sensation were physiological in all patients on the non-affected side. On the operated side, a total of two patients showed decreased sharp–blunt differentiation and monofilament sensation; one of them showed decreased temperature discrimination and the other showed negative temperature differentiation. One patient showed negative sharp–blunt and temperature differentiation and monofilament sensation on the operated leg. One patient showed decreased temperature differentiation on both lower legs, but normal sharp–blunt and monofilament sensation (Table 1). The same patient reported dysesthesia of the scar.

None of the patients used a walking aid.

Scapula

Nine patients showed full range of motion for forward, backward, sideward tilt, and left and right rotation of the cervical spine. One patient showed decreased backward tilt (20°), one limited rotation to the operated side (35°), and one limited rotation to the non-operated side (50°). One patient had marked limitations of cervical spine movement on backward (15°) and sideward (20° both sides) tilt, rotation to the operated side (15°) and to the non-operated side (20°). The same patient also had decreased mobility of the thoracic and lumbar spine on sideward tilt and rotation (20° each) and severe limitations of shoulder movement. The other patients showed full range of movement of the thoracic and lumbar spine.

Only two patients showed full range of motion of the shoulder joint on the affected side. The other patients showed varying degrees of limitation of sideward elevation on the operated side (mean 130°, range 60–170°); four patients showed limited sideward elevation of the non-operated side (70°, 80°, 90°, 100°). Seven patients showed limited forward elevation of the arm (mean 105°, range 50–140°) (Table 1). The patient with the worst shoulder function had limited sideward (60°/80°), backward (20°/20°), and forward elevation (50°/90°) and outward rotation (30°, 30°) of both shoulders; however, these results were most likely not due to the SF but to a pectoralis flap in this patient.

Muscle strength rated by MRC Muscle Scale was normal in one patient and decreased in 13 patients (Table 1).

Sensation was not affected in the majority of patients: two-point discrimination was equal on both sides. Sharp–blunt and temperature discrimination and monofilament sensation were physiological in all patients on the non-affected side. On the operated side, two patients showed decreased sharp–blunt differentiation and four patients had decreased monofilament sensation, one had negative monofilament sensation. Two patients had decreased and one negative temperature differentiation (Table 1).

Quality of life

There were no major differences concerning activity level and health-related QOL between the different donor sites. With regard to appearance, the highest scores were achieved following RFFF and the lowest following ALTF and FF. Shoulder function was best following ICF and FF, and overall QOL was best following ALTF. A detailed analysis of QOL ratings for the different donor sites is given in Table 2.

Discussion

This study is novel in systematically comparing objective deficits of donor site morbidity for five different donor sites and comparing these results with subjective patient QOL. Previous studies with large numbers of patients comparing different donor sites have focused on success

Fig. 5. Scapula flap (SF) donor site.

rates and perioperative complications and not on long-term donor site complications[4]. Despite the relatively small number of patients and the cross-sectional study design, a number of conclusions can be drawn from these first results: SF led to the highest incidence of motor deficits, both concerning range of motion and muscle strength; sensation was most frequently affected following ALTF; RFFF had the lowest rate of overall motor and sensory impairment.

However, these results may have been influenced by confounding factors. The limited range of sideward elevation following SF does not necessarily reflect donor site morbidity of SF but may also be due to the sequelae of neck dissection. In a direct comparison of shoulder range of motion following SF and following all other reconstructive options in the study patients, the incidence of limitations of sideward elevation was significantly higher in SF (85.7% vs. 4.9%, $P < 0.0001$). The same was true when comparing sideward elevation in all patients with SF to the non-operated scapula side (85.7% vs. 28.6%, $P < 0.0001$). Furthermore, only four of the 14 patients had undergone neck dissection on the ipsilateral side to the scapula donor side.

Evidence on motor deficits following scapula reconstruction is sparse and there are conflicting reports in the literature: while Ferrari et al. reported varying degrees of impairment in all 19 patients following SF[5], Bianchi et al. reported normal function[6]. However, the differing Constant–Murley scores and DASH scores (disabilities of the arm, shoulder and hand) in the analysis of Ferrari et al. demonstrate a potential reason for the controversial results in the literature: depending on the method of evaluation, motor deficits may not be perceived. This is in line with the fact that although almost 90% of the present study patients had some degree of range of motion deficit, only 42% of patients reported deficits of shoulder function in the UW-QOL v4 shoulder domain, and the amount of range of motion did not correlate with the subjective amount of impairment or activity level in the UW-QOL v4 activity domain (Tables 1 and 2).

Interestingly, the MRC Muscle Scale was a very sensitive tool to identify motor impairment in the present analysis (Table 1) and identified a higher incidence of motor impairment than various other methods in the literature (Tables 3–7[4–48]). This may be true because patients are able to distinguish even fine differences in functional impairments in comparison to preoperatively, but may also be due to methodological weaknesses, with small numbers of patients failing to provide statistically significant differences or only subjective patient-based reporting in the literature. For example, the largest prospective patient series in the literature for ALTF with 220 patients described by Hanasono et al.[7] examined muscle strength by ''reported leg weakness''.

With regard to sensation, the analysis was able to demonstrate that regardless of the donor site, two-point discrimination was affected in all patients. As well as elevated two-point discrimination, the present study and previous studies reported in the literature have shown frequent limited sharp–blunt discrimination, monofilament sensation, and temperature sensation at the donor site. In the literature, RFFF, ALTF, and FF have shown the highest incidences of sensory deficit (Tables 3–5). The differing results for RFFF in the present analysis may be explained by the absence of split thickness skin grafts for forearm closure in the study cohort. Results in the literature have shown high rates of anaesthesia following split thickness skin grafts[8–10,49]. The low incidence of sensory deficits in RFFF and the relatively high rate of sensory deficits in ALTF in the present study analysis are in contrast to the findings of a meta-analysis by Chen et al.[50]. Again, evidence in the literature is sparse; e.g., the largest prospective study on donor site morbidity in patients with FF ($n = 157$) described by Momoh et al.[11] does not give any information on sensation.

Evidence on donor site morbidity in the literature is best for RFFF (Table 3), followed by ALTF (Table 4) and FF (Table 5). Very little evidence is found on ICF and SF (Tables 6 and 7). Apart from the limitations discussed, cold intolerance is frequently described following RFFF[9,12–18] and should be evaluated in future studies. In FF, mild oedema of the donor leg is a relevant donor site morbidity[19–21] and in line with the present study finding of increased leg circumference at the height of the ankle of the donor leg (Table 5).

The importance of donor site morbidity is underlined by the fact that activity was the most important QOL factor for 40 patients in this analysis. Although the overall incidence of donor site morbidity was relatively high, the majority of patients reported that their QOL was good

Table 1. Objective donor site morbidity for the different donor sites.

	Donor site				
	Radial forearm	Anterolateral thigh	Iliac crest	Fibula	Scapula
Number	73	12	8	10	14
Range of motion (%)					
Normal	100	83.3	87.5	90	14.3
Restricted	0	16.7[a]	12.5[a]	10[b]	85.7[c]
Strength, MRC muscle scale (%)					
5	56.2	50	62.5	50	7.1
4	43.8	50	37.5	50	64.3
3	0	0	0	0	28.6
2	0	0	0	0	0
1	0	0	0	0	0
Two-point discrimination (cm), mean ± SD					
Operated side	3.1 ± 0.8	3.5 ± 1.4	4.8 ± 1.4	5.1 ± 0.8	3.5 ± 1.0
Non-operated side	2.6 ± 0.8	2.8 ± 1.3	4.2 ± 1.3	4.7 ± 0.6	3.5 ± 1.0
Sharp–blunt discrimination (%)					
Positive	91.8	58.3	75	70	85.7
Restricted	8.2	25	0	20	14.3
Negative	0	16.7	25	10	0
Temperature discrimination (%)					
Positive	86.3	41.7	75	60	78.6
Restricted	13.7	50	12.5	20	14.3
Negative	0	8.3	12.5	20	7.1
Monofilament sensation (%)					
Positive	89.0	50	75	70	64.3
Restricted	11.0	41.7	12.5	20	28.6
Negative	0	8.3	12.5	10	7.1

SD, standard deviation.
[a] Slightly restricted hip flexion, symmetrical on operated and non-operated side.
[b] Eighty percent supination of the lower ankle joint in comparison to the contralateral side.
[c] Varying degrees of limitation of sideward elevation.

Table 2. Subjective quality of life (UW-QOL v4, in German) for the different donor sites.

Donor site	*n*	Appearance (%)						Activity (%)						Shoulder (%)					Health-related QOL (%)							Overall QOL (%)						
		100	75	50	25	0	x̄	100	75	50	25	0	x̄	100	70	30	0	x̄	100	80	60	40	20	0	x̄	100	80	60	40	20	0	x̄
RFFF	74	32	57	11	0	0	80	32	37	28	3	0	75	64	13	8	15	75	7	16	37	32	8	0	56	10	22	30	27	12	0	58
ALTF	12	0	50	42	8	0	61	25	33	42	0	0	71	58	17	25	0	78	8	17	8	67	0	0	53	8	17	25	42	8	0	65
ICF	8	0	63	25	12	0	72	12	63	25	0	0	72	76	12	12	0	88	12	25	13	25	25	0	55	12	25	12	25	25	0	55
FF	10	0	50	30	20	0	58	30	40	30	0	0	75	70	20	10	0	87	10	20	30	30	10	0	58	10	20	40	20	10	0	60
SF	14	7	71	22	0	0	71	29	35	29	7	0	71	58	21	21	0	79	14	21	21	30	14	0	59	7	21	21	43	7	0	56

x̄, mean value; QOL, quality of life; RFFF, radial forearm flap; ALTF, anterolateral thigh flap; ICF, iliac crest flap; FF, fibula flap; SF, scapula flap.

and 68% had no or only rare limitations of daily activity level (Table 2).

Therefore, the agreement between donor site morbidity and overall QOL should be interpreted with care. While severe donor site complications (which were absent in this collective) may influence overall QOL, there is a high likelihood that results of overall QOL for different donor sites may be biased: small soft tissue tumours with little impact on speech, chewing, swallowing, and appearance are most frequently reconstructed with a RFFF, while larger tumours with a high risk of deterioration of speech, chewing, swallowing, and appearance will require reconstruction with an ALTF, FF, SF, or ICF[2]. This is in line with the present study findings that appearance was rated best following RFFF reconstruction, worse following ICF and SF, and worst following ALTF and FF. However, health−related QOL in this cohort showed no major differences between the different donor sites (Table 2). This may be due in part to the fact that, although resulting in the lowest motor and sensory deficit, the RFFF is the most visible donor site and may therefore be less popular, especially in young female patients. Furthermore, health−related QOL will also be affected by the amount of neck dissection, the exact tumour location, and the use of (neo-)adjuvant treatment, as shown previously for this cohort[51].

Studies comparing objective and subjective perception of donor site morbidity are in line with the present study findings: both objective deficits without subjective impairment in RFFF[12,52] and subjective impairment without objective loss of function in RFFF[9] and the lack of correlation between subjective and objective complaints in FF[22] have been reported. At the same time, the enormous range of incidence of different aspects of donor site morbidity (Tables 3–7) underlines both this phenomenon and the impact of the evaluation tool used.

Despite these promising results, the authors are aware of a number of limitations of this study. Due to the cross-sectional and long-term design, along with

Table 3. Donor site morbidity of radial forearm flaps reported in the literature.

Author	Year	*n*	Range of motion (%)		Muscle strength (%)		Sensation (%)			Pain (%)		Subjective appearance (%)		Other
			Normal	Restricted	Normal	Restricted	Normal	Hypesthesia	Anaesthesia	No	Yes	Acceptable or better	Poor	
Avery et al.[23]	2001	25	100	0	100	0	68	28	4	NS	NS	92	8	–
Byun et al.[24]	2016	10	100	0	90	10	80	20	0	80	20	NS	NS	–
de Bree et al.[9]	2004	37	100	0	75.7	24.3	54.0	0	46.0	NS	NS	86.5	13.5	16.2% cold intolerance, 9/37 subjective slightly impaired function with objective normal ROM
de Vicente et al.[25]	2008	10	NS	NS	NS	NS	90	10	0	NS	NS	NS	NS	–
de Witt et al.[14]	2007	50	NS	NS	NS	NS	78	0	22	NS	NS	74	26	8% cold intolerance, pinch slightly lower at donor site
Huang et al.[8]	2004	20	NS	NS	NS	NS	0	0	100[a]	NS	NS	90	10	–
Kim et al.[26]	2007	40	100	0	100	0	NS	NS	NS	NS	NS	NS	NS	–
Lane et al.[15]	2013	31	96.8	3.2	NS	NS	59.1	41.9		NS	NS	NS	NS	16.1% cold intolerance Appearance: VAS 0.8 vs. 3.0
Lee et al.[27]	2013	23	83	17	83	17	70	30		NS	NS	52	48	–
Moreno-Sanchez et al.[28]	2016	100	NS	NS	99	1	98	2[b]	0	NS	NS	NS	NS	–
Nehrer-Tairych et al.[13]	2002	35	77.1	22.9	82.9	17.1	86	14	0	NS	NS	77.1	22.9	3/35 cold intolerance
Novak et al.[16]	2007	19	NS	NS	NS	NS	73.7	15.8	10.5	63.2	36.8	100	0	5/19 cold intolerance
Orlik et al.[17]	2014	9	77.8	22.2	78.8	22.2	NS	NS	NS	NS	NS	66.7	33.3	44.4% cold intolerance
Riecke et al.[29]	2015	20	100	0	100	0	NS	NS	NS	NS	NS	NS	NS	Short-term (3–6 months) differences in both arms preop./postop.; long-term no difference
Schwarzer et al.[30]	2016	39	97.4	2.6	97.4	2.6	43.6	56.4		82.1	17.9	NS	NS	–
Smith et al.[31]	2006	63	92.1	7.9	92.1	7.9	87.3	12.7		NS	NS	9.5	90.5	–
Suominen et al.[18]	1996	18	NS	NS	NS	NS	44.4	55.6		NS	NS	77.8	22.2	Overall decreased grip strength of donor hand 38.9% cold intolerance
Toschka et al.[12]	2001	35	88.6	11.4	88.6	11.4	5.7	85.7	NS	NS	NS	90.9	9.1	31.4% cold intolerance Slight motor and sensory deficits, clinically not relevant
Yun et al.[10]	2015	171	NS	NS	98.2	1.8	95.7	2.9	NS	NS	NS	NS	NS	Average aesthetic score 8.05 (0–10; 7–8 = good, 9–10 = excellent)
Zhang et al.[32]	2015	15	80	20	80	20	40	60		NS	NS	NS	NS	–
Mean			92.4	7.6	93.7	6.3	74.3	18.4		76.4	23.6	66.5	35.5	19.2% cold intolerance
Current study	2018	73	100	0	57	43	86.3	13.7		62	38	89	11	–

NS, not specified; ROM, range of motion; VAS, visual analogue scale.

[a] Skin graft.

[b] Transient.

Table 4. Donor site morbidity of anterolateral thigh flaps reported in the literature[a].

Author	Year	*n*	Range of motion (%)		Muscle strength (%)		Sensation (%)			Pain (%)			Subjective appearance (%)		
			Normal	Restricted	Normal	Restricted	Normal	Hypesthesia	Anaesthesia	No	Mild	Severe	Good	Acceptable	Poor
de Vicente et al.[25]	2008	10	100	0	100	0	100	0	0	NS	NS	NS	NS	NS	NS
Fischer et al.[33]	2017	40	100	0	100	0	77.5	22.5	0	NS	NS	NS	NS	NS	NS
Hanasono et al.[7]	2010	220	100	0	100	0	52	48	0	NS	NS	NS	NS	NS	NS
Kimata et al.[34]	2000	37	75.7	24.3	54.1	45.9	12.5	59.4	28.1	NS	NS	NS	68.8	18.8	12.5
Maruccia et al.[35]	2017	60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Novak et al.[16]	2007	18	NS	NS	NS	NS	83.3	5.6	11.1	83.3	16.7	0	NS	NS	NS
Townley et al.[36]	2011	68	89.7	10.3	100	0	41.2	58.8[b]		NS	NS	NS	NS	NS	NS
Tsuji et al.[37]	2008	12	NS	NS	100	0	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wang et al.[38]	2013	53	NS	NS	96.2	3.8	95.3	5.7	0	NS	NS	NS	100		0
Wu et al.[39]	2016	23	91.3	8.7	82.6	17.4[c]	NS	NS	NS	NS	NS	NS	69.6	21.7	8.7
Mean			95.5	4.5	95.0	5.0	56.7	38.3	5.0	–	–	–	–	–	–
Current study	2018	12	83.3	16.7[c]	50	50	41.7	50	8.3	80	6.7	13.3	50	0	50

NS, not specified.
[a] No 'Other' comments to report for this table.
[b] Excluded from mean.
[c] Temporary.

Table 5. Donor site morbidity of fibula flaps reported in the literature.

Author	Year	*n*	Range of motion (%)		Muscle strength (%)		Sensation (%)			Pain (%)			Subjective appearance (%)			Other
			Normal	Restricted	Normal	Restricted	Normal	Hypesthesia	Anaesthesia	No	Mild	Severe	Good	Acceptable	Poor	
Anthony et al.[22]	1995	30	58.7	41.3	78	22	NS	NS	NS	78	22	0	NS	NS	NS	No correlation between subjective and objective complaints
Huang et al.[40]	2012	23	NS	NS	95.7	4.3	NS	NS	NS	95.7	4.3	0	50	50	0	No comparison between donor leg and non-affected leg
Momoh et al.[11]	2011	157	89.2	10.8	92.4	7.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	–
Papadopulos et al.[20]	2008	23	78.3	21.7	NS	NS	87	13	0	87	13	NS	NS	NS	NS	17.4% mild oedema
Sagalongos et al.[41]	2011	17	NS	NS	13.3	86.7	58.8	41.2	0	70.6	23.4	0	64.7	35.3	0	–
Shindo et al.[42]	2000	53	NS	NS	84.9	15.1	92.4	1.9	5.7	90.5	3.8	5.7	NS	NS	NS	–
Shpitzer et al.[21]	1997	41	92.7	7.3	87.8	12.2	NS	NS	NS	97.6	2.4	0	NS	NS	NS	4.9% mild oedema
Zimmermann et al.[19]	2001	38	79%	21.0	65.8	34.2	2.6	60.6	36.8	76.3	23.7	0	NS	NS	NS	23.6% oedema
Mean			84.4	15.6	72.7	27.3	61.1	29.0	9.9	86.2	12.0	1.8	–	–	0	14.7% mild oedema
Current study	2018	10	90	10	50	50	60	20	20	35.7	21.4	42.9	50	0	50	

NS, not specified.

Table 6. Donor site morbidity of microvascular iliac crest flaps reported in the literature.

Author	Year	*n*	Range of motion (%)		Muscle strength (%)		Sensation (%)			Pain (%)			Subjective appearance (%)			Other
			Normal	Restricted	Normal	Restricted	Normal	Hypesthesia	Anaesthesia	No	Mild	Severe	Good	Acceptable	Poor	
Gaggl et al.[43]	2011	12	100	0	100	0	75%	8.3%	16.7%	100	0		100	0	0	–
Moon[44]	2015	9	NS	NS	NS	NS	NS	NS	NS	100[a]	0		NS	NS	NS	All returned to normal daily activities
Muecke et al.[45]	2013	36	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	–
Pohlenz et al.[4]	2012	200	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	–
Qu et al.[46]	2013	33	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	''donor-site morbidity was moderate''
Valentini et al.[47]	2009	31	NS	NS	NS	NS	NS	NS	NS	74.2	25.8		61.3	0	38.7	1 fracture, 12 loss of anatomic hip profile, 6 disfiguring scars, 1 hernia
Mean	–	–	–	–	–	–	–	–	–	84.6	15.4		–	–	–	
Current study	2018	8	87.5	12.5	62.5	37.5	75	12.5	12.5	37.5	50	12.5	0	62.5	37.5	

NS, not specified.
[a] At >30 days postoperative.

Table 7. Donor site morbidity of microvascular scapula flaps reported in the literature[a].

Author	Year	*n*	Range of motion (%)		Muscle strength (%)		Sensation (%)			Pain (%)		Subjective appearance (%)		
			Normal	Restricted	Normal	Restricted	Normal	Hypesthesia	Anaesthesia	No	Yes	Good	Acceptable	Poor
Bianchi et al.[6]	2015	11	100	0	100	0	75%	8.3%	16.7%	100	0	100	0	0
Ferrari et al.[5]	2015	19	Constant–Murley score mean 92.2 (range 66–100[b]); DASH score mean 48.6 (range 39–85)											
Jacobson et al.[48]	2016	3	66	33	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean			85.7	14.3	–	–	–	–	–	–	–	–	–	–
Current study	2018	14	14.3	85.7	7.1	92.9	64.3	28.6	7.1	35.7	64.3	7	71	22

DASH, disabilities of the arm, shoulder and hand; NS, not specified.
[a] No 'Other' comments to report for this table.
[b] Two patients with a Constant–Murley score of 100.

only 13.9% of the total patient cohort participating in this study, selection bias is inevitable. Furthermore, there was an uneven distribution of donor sites in the cohort, with a large majority of RFFF donor sites and only small numbers of the other donor sites. Therefore, the results are considered only preliminary and may not reflect the full scope of potential complications. Nevertheless, this distribution may be representative of the incidence of the different donor sites when comparing numbers to data on the incidence of reconstructive choices in the literature[2]. Both the present results and the analysis of the literature demonstrate that evidence for the less frequently used donor sites is sparse.

As the aim of this analysis was to apply a uniform and comparable testing system for all five donor sites, site-specific considerations and testing modalities were not part of the evaluation and were missing in comparison to results from the literature.

In conclusion, studies reported in the literature and the present study show that range of motion and sensation are regularly impaired following the use of the most frequently applied microvascular transplants for head and neck reconstruction. Fortunately, the amount of sensation and motor impairment is negligible for the vast majority of patients. The five donor sites compared showed similar rates of overall donor site morbidity. Therefore, patient-specific considerations should be prioritized when selecting the ideal donor site.

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Competing interests

None.

Ethical approval

The study design was approved by the local ethics committee of the Medical Faculty of Heidelberg University (S-585/2015).

Patient consent

Not required.

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