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Radial Forearm Flap Donor Site Morbidity: A Systematic Review

Suma Yalamanchili, Robert M. Rotatori, Fernando Ovalle Jr. and Ryan M. Gobble*

University of Cincinnati Medical Center, Division of Plastic and Reconstructive Surgery, 231 Albert Sabin Way, Cincinnati, OH, 45267, USA.

***Corresponding author:**
Ryan M. Gobble, M.D., FACS

gobblern@ucmail.uc.edu

Tel: +1 513-558-0984 (Office); +1 513-558-0570 (Fax)

University of Cincinnati College of Medicine, 231 Albert Sabin Way, Mail Location 0513 Cincinnati, OH 45267.

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Abstract

Purpose: The reconstructive workhorse radial forearm flap has a known but not well-quantified donor site morbidity rate. This systematic review explores the incidence of functional and aesthetic radial forearm flap donor site morbidity.

Methods: A systematic review was performed of PubMed, Cochrane, Scopus, and Embase databases utilizing the terms "radial forearm flap" and "donor site." Only English language, prospective studies from 1981 to present with more than 7 patients were included. Measures of flap characteristics, donor site treatment and functional/ aesthetic morbidity were pooled and analyzed.

Results: The search identified 777 unique studies, 30 of which were qualifying prospective studies – 9 randomized controlled trials and 21 cohort studies. A total of 1446 flaps were included. All were free flaps; 318 (22%) were cutaneous, 637 (44%) fasciocutaneous, 61 (4%) osteocutaneous, and 430 (30%) were unspecified free flap. Mean follow up was 11 months. A mean donor defect size of 48 cm^2 was most commonly closed with full- (50%) or split- (40%) thickness skin grafting. The most common wound-related donor site morbidities were partial graft loss (10%), hematoma/seroma (6%), and tendon exposure (5%). Osteocutaneous flaps had a 6% rate of pathologic fractures. Functional donor site morbidities included dysesthesia (27%), unacceptable appearance (16%), and decreased range of motion (12%) and decreased strength (10%).

Conclusion: Donor site morbidity of the radial forearm flap is low, yet rates of functional impairments in sensation, range of motion, and strength are not negligible. Understanding the incidence of these impairments enables surgeons to counsel patients about postoperative donor site expectations.

Keywords: Radial forearm; Flap; Donor site; Morbidity complications

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Introduction

The radial forearm free flap was pioneered in China in the 1970s and originally described in the literature by Yang et al. in 1981 [1]. Soon after, it became a common flap of choice for many head and neck reconstructive surgeons. The flap is extremely versatile due to its pliability, ease of flap harvest, reliable anatomy, and long and high-caliber vascular pedicle [2]. Although it has become a common reconstructive workhorse, the radial forearm flap has a known but not well-quantified donor site morbidity. Donor site aesthetics are a concern for many as well as functional considerations including sensation, range of motion, and grip strength [3,4]. Despite numerous prospective and randomized controlled studies regarding donor site outcomes in radial forearm flaps, there is no clear consensus on the incidence of donor site complications, functional limitations, or overall aesthetic dissatisfaction by the patient. Given the limitations of the existing literature regarding radial forearm flap donor sites, reconstructive surgeons are unable to fully counsel patients on expected donor site outcomes after use of this flap. Furthermore, as the flap becomes increasingly popular for phalloplasty reconstruction, donor site aesthetic becomes even more crucial to the decision-making process. To our knowledge, there are no systematic reviews of the radial forearm flap's donor site morbidity. Therefore, the aim of this study was to perform a systematic review of the English language medical literature to determine the incidence of radial forearm flap donor site morbidity.

Literature Review

A literature search was performed using the PubMed, Scopus, Embase, CINAHL, and Cochrane databases with the search terms "radial forearm flap" and "donor site". Article selection was limited to English publications between January 1981 and December 2016. The 1981 starting date was chosen because this was the first year of publication for the radial forearm flap. Inclusion criteria were: prospective design, results published in English, and a study population of greater than 7 human patients who had undergone reconstruction with a radial forearm flap. Studies not related to the radial forearm flap and those not presenting donor-site morbidity were excluded. Case reports, systematic reviews, meta-analyses, and articles in languages other than English were also excluded. The data was collected into an electronic database (Microsoft Excel; Microsoft Corp., Redmond Wash.) by the first reviewer. The second reviewer checked the extracted data to avoid any omissions or inaccuracies in the data extracted. Disagreements on potential relevance were discussed and a decision on inclusion was made by the senior author. Studies that appeared relevant or did not provide enough information to make a clear judgment received a full article review. References from selected articles were further screened, with any additional relevant articles included for review. Duplicate publications were identified and only the latest publication was included.

The articles were analyzed to obtain demographic information, indications for surgery, and rate of donor site morbidity. Donor site wound complications include partial necrosis, tendon exposure, total graft loss, secondary grafting, dehiscence, hematoma, seroma, infection, and other wound complications. Functional and aesthetic complications include radius fracture, decreased wrist range of motion, decreased grip and pinch strength, change in sensation, chronic pain, hypertrophic scarring, and poor aesthetic outcome [5]. The number of reported complications was pooled across all studies and divided by the total number of flap donor sites to arrive at an incidence rate.

Results

The electronic database search performed on 12/20/2016 yielded 528 results from Pubmed, 684 from Scopus, 669 from Embase, 48 from CINAHL, and 26 from The Cochrane Library. With the addition of four articles from manual reference search, a total of 777 unique articles were screened. Full-texts of 57 articles were evaluated for donor-site complications and assessed for inclusion. **Figure 1** demonstrates the literature search flow diagram and reasons for exclusion.

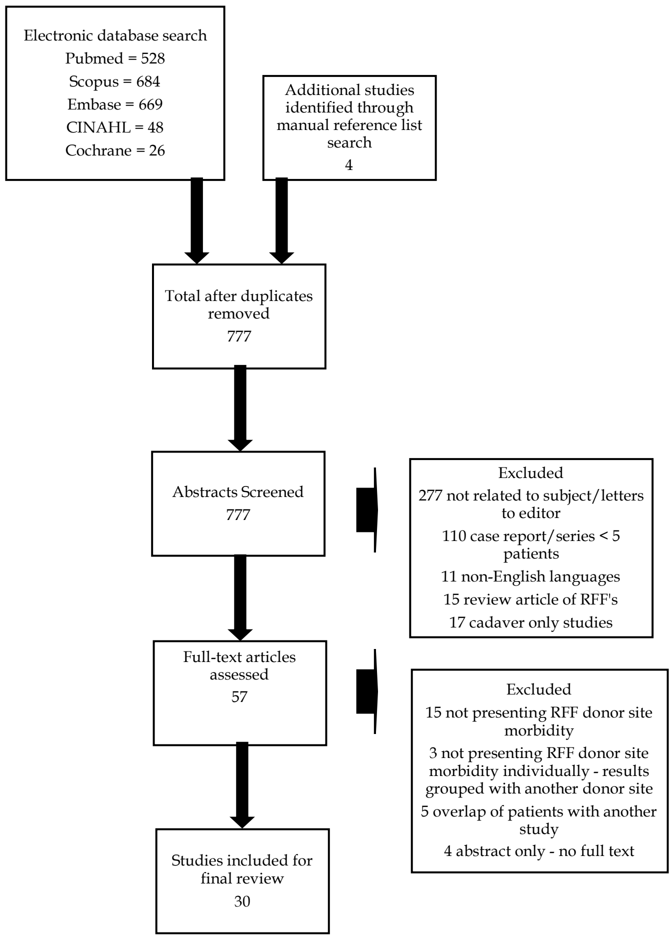

Figure 1 Flowchart of study selection process (*Articles not listed as retrospective or prospective in the abstract had full-text examination).

Article characteristics

Among the 30 selected articles, 9 were randomized controlled trials and 21 were prospective cohort studies. A total of 1446 flaps were pooled and analyzed. All were free flaps and 318 (22%) were cutaneous, 637 (44%) fasciocutaneous, 61 (4%) osteocutaneous, and 430 (30%) were an unspecified type of free flap. The majority of flaps were indicated for head and neck reconstruction in patients with a mean age of 58 years. Mean follow up was 11 months. A mean donor defect size of 48 cm^2 was most commonly closed with full-thickness (50%) or split-thickness (40%) skin grafting, and less commonly a biologic matrix (6%) or primary closure (4%) **(Table 1)** [6-37].

Wound complications

The most common donor site complications were partial graft loss (10%), hematoma (6%), seroma (6%), and tendon exposure (5%). Infection (2%), dehiscence (2%), complete graft loss (1%), and need for secondary grafting were relatively uncommon occurrences **(Table 2)** [6-37]. Of note, Schwarzer et al. [32] combined the occurrence of partial necrosis, tendon exposure, dehiscence, seroma, and infection into an overall complication rate of 38% in their population.

Table 1: Details of included articles.

References	Study Design	No. RFF enrolled	Indication	Mean Age (yr)	Mean follow up (mo)	Radial Forearm Free Flap Type				Mean Flap Size (cm^2)
						Cutaneous	Fasciocutaneous	Osteocutaneous	Not specified	
Ahmad et al. (2007) [6]	Prospective	13	Head and neck	61	n/r	n/r	n/r	n/r	13	n/r
Avery et al. (2007) [7]	Prospective	121	Head and neck, extremity	57	16*	121	0	0	0	38*
Boahene et al. (2011) [8]	Prospective	16	Head and neck	n/r	1	0	16	0	0	54
Bonaparte et al. (2011) [9,10]	RCT	29	Head and neck	63	10		29	0	0	36
Bonaparte et al. (2013) [11]	Prospective	177	Head and neck	63	12	23	154	0	0	39
Boyd et al. (1995) [12]	Prospective	71	Head and neck	63	20	0	56	15	0	n/r
Brown et al. (1999) [13]	Prospective	11	Head and neck	49*	5	0	11	0	0	n/r
Byun et al. (2016) [14]	Prospective	10	Head and neck	64	6	0	10	0	0	28
Chambers et al. (1997) [15]	Prospective	21	Head and neck	n/r	3	0	21	0	0	n/r
Chang et al. (2010) [16]	Prospective	12	Head and neck	50	9	n/r	n/r	n/r	12	49
Chau et al. (2009) [17]	RCT	62	Head and neck	59	12	30	32	0	0	96
Chio et al. (2010) [18]	RCT	54	Head and neck	60	1	n/r	n/r	n/r	54	71
Cigna et al. (2015) [19]	RCT	15	Head and neck	n/r	24	15	0	0	0	n/r
Faisal et al. (2013) [20]	RCT	30	Head and neck	42	6	n/r	n/r	n/r	30	n/r
Garaffa et al. (2010) [21]	Prospective	27	Phalloplasty	40	9*	n/r	n/r	n/r	27	68
Ghanem et al. (2009) [22]	Prospective	63	Head and neck	n/r	n/r	0	60	3	0	37
Harris et al. (2016) [23]	Prospective	10	Head and neck	58	6	n/r	n/r	n/r	10	n/r
Kesting et al. (2011) [24]	Prospective	116	Head and neck	62*	n/r	n/r	n/r	n/r	116	29
Lutz et al. (1999) [25]	Prospective	95	Head and neck	50	6	95	0	0	0	78
Moazzam et al. (2003) [26]	RCT	20	Head and neck, extremity	58	3	0	20	0	0	n/r
Moreno-Sanchez et al. (2016) [27]	Prospective	100	Head and neck	60	36	n/r	n/r	n/r	100	25
Morrissey et al. (2010) [28]	RCT	9	Head and neck	66	11	9	0	0	0	n/r
Richardson et al. (1997) [29]	Prospective	103	Head and neck	60	12	0	68	35	0	45
Riecke et al. (2015,2016) [30,31]	Prospective	30	Head and neck	62	27	0	30	0	0	25
Schwarzer et al. (2016) [32]	RCT	50	Head and neck	64	3	25	25	0	0	n/r
Sidebottom et al. (2000) [33]	RCT	68	Head and neck	n/r	12	n/r	n/r	8	56	n/r
Sinha et al. (2002) [34]	Prospective	52	Head and neck	n/r	14	0	52	0	0	n/r
Wagstaff et al. (2015) [35]	Prospective	8	Head and neck	57	12	n/r	n/r	n/r	8	n/r
Wax et al. (2001) [36]	Prospective	40	Head and neck	62	6	0	40	0	0	n/r
Wirthman et al. (2014) [37]	Prospective	13	Head and neck, extremity, phalloplasty	52	24	0	13	0	0	n/r
Total	**Total: 30 RCT: 9 Prospective: 21**	**1446**		**58 ± 7**	**11 ± 9**	**318 (22%)**	**637 (44%)**	**61 (4%)**	**430 (30%)**	**48 ± 21**

*Study did not document a mean, the published median was used, †Both studies looked at same population thus were combined, n/r not reported

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Table 2: Wound complications.

References	No. RFF Donor Sites Analyzed	Partial Necrosis (%)	Tendon Exposure (%)	Total Graft Loss (%)	No. secondary grafting (%)	Dehiscence (%)	Hematoma (%)	Seroma (%)	Infection (%)	Wound Complication Not Specified
Ahmad et al. (2007) [6]	13	0 (0)	n/r	0 (0)	0 (0)	0 (0)	n/r	n/r	1 (7.7)	1 (7.7)
Avery et al. (2007) [7]	116	11 (9.5)	3 (2.6)	2 (1.7)	6 (5.2)	n/r	n/r	n/r	6 (5.2)	n/r
Boahene et al. (2011) [8]	16	1 (6.3)	1 (6.3)	0 (0)	0 (0)	n/r	n/r	n/r	n/r	n/r
Bonaparte et al. (2011) [9,10]	29	5 (17.2)	2 (6.9)	2 (6.9)	n/r	n/r	0 (0)	0 (0)	0 (0)	n/r
Bonaparte et al. (2013) [11]	177	2 (1.1)	2 (1.1)	2 (1.1)	n/r	0 (0)	n/r	n/r	1 (0.6)	n/r
Boyd et al. (1995) [12]	67	19 (28.4)	1 (1.5)	1 (1.5)	2 (3.0)	n/r	n/r	n/r	n/r	n/r
Brown et al. (1999) [13]	10	2 (20)	1 (10)	0 (0)	1 (10)	n/r	n/r	n/r	n/r	n/r
Byun et al. (2016) [14]	10	0 (0)	0 (0)	0 (0)	0 (0)	n/r	n/r	n/r	0 (0)	n/r
Chambers et al. (1997) [15]	21	0 (0)	0 (0)	0 (0)	0 (0)	n/r	n/r	n/r	n/r	n/r
Chang et al. (2010) [16]	7	n/r	0 (0)	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Chau et al. (2009) [17]	58	n/r	7 (12)	0 (0)	n/r	n/r	n/r	n/r	n/r	n/r
Chio et al. (2010) [18]	50	23 (46)†	†	0 (0)	n/r	n/r	n/r	n/r	n/r	n/r
Cigna et al. (2015) [19]	15	2 (13.3)	3 (20)	0 (0)	0 (0)	0 (0)	0 (0)	n/r	0 (0)	n/r
Faisal et al. (2013) [20]	25	0 (0)	n/r	0 (0)	0 (0)	2 (8)	n/r	n/r	0 (0)	n/r
Garaffa et al. (2010) [21]	27	3 (11.1)	n/r	0 (0)	0 (0)	n/r	n/r	n/r	n/r	n/r
Ghanem et al. (2009) [22]	63	n/r	13 (20)	n/r	1 (1.6)	n/r	n/r	n/r	0 (0)	n/r
Harris et al. (2016) [23]	10	0 (0)	0 (0)	0 (0)	0 (0)	n/r	0 (0)	0 (0)	0 (0)	n/r
Kesting et al. (2011) [24]	116	11 (9.5)	n/r	n/r	n/r	n/r	n/r	n/r	0 (0)	3 (2.6)
Lutz et al. (1999) [25]	95	6 (6.3)	0 (0)	0 (0)	0 (0)	n/r	5 (5.3)	n/r	n/r	n/r
Moazzam et al. (2003) [26]	18	2 (11.1)	1 (5.5)	1 (5.5)	1 (5.5)	n/r	n/r	n/r	n/r	n/r
Moreno-Sanchez et al. (2016) [27]	100	7 (7)	2 (2)	0 (0)	0 (0)	5 (5)	15 (15)	n/r	1 (1)	n/r
Morrissey et al. (2010) [28]	9	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	n/r	n/r	n/r	n/r
Richardson et al. (1997) [29]	86	14 (16)	11 (13)	0 (0)	0 (0)	n/r	n/r	n/r	n/r	n/r
Riecke et al. (2015,2016) [30,31]	30	1 (3.3)	1 (3.3)	0 (0)	0 (0)	n/r	n/r	n/r	n/r	n/r
Schwarzer et al. (2016) [32]	42	n/r	n/r	1 (2.4)	n/r	n/r	n/r	n/r	n/r	16 (38)‡
Sidebottom et al. (2000) [33]	64	8 (12.5)	n/r	0 (0)	n/r	n/r	n/r	n/r	8 (12.5)	n/r
Sinha et al. (2002) [34]	52	0 (0)	0 (0)	0 (0)	0 (0)	n/r	0 (0)	5 (1.9)	0 (0)	n/r
Wagstaff et al. (2015) [35]	7	0 (0)	n/r	0 (0)	n/r	n/r	n/r	n/r	0 (0)	n/r
Wax et al. (2001) [36]	40	6 (15)	6 (15)	0 (0)	0 (0)	n/r	0 (0)	n/r	n/r	n/r
Wirthman et al. (2014) [37]	13	2 (15.4)	0 (0)	0 (0)	0 (0)	n/r	n/r	n/r	0 (0)	n/r
Total (%)	**1392**	**125 (10)**	**54 (5)**	**9 (1)**	**11 (1)**	**7 (2)**	**20 (6)**	**5 (6)**	**17 (2)**	**20 (11)**
No. Articles	**30**	**26**	**22**	**27**	**21**	**6**	**7**	**3**	**15**	**3**

% calculations were based on total reported population for each outcome; †Included partial STSG failure or tendon exposure; ‡Included any complication (partial necrosis, tendon exposure, dehiscence, seroma, infection) n/r not reported

Functional and aesthetic complications

Fracture: Three articles involving a total of 82 osteocutaneous flaps found an 8.5% rate of pathologic fractures **(Table 3)** [6-37]. Richardson et al. [29] reported fractures in 6 out of 35 composite flaps (17%). Four of these fractures were in female patients, which was statistically significant (p=0.046).

Subjective ROM/Function: Subjective evaluation of range of motion and function was determined by patient interviews and surveys. A total of 11 articles with 294 patients noted decreased range of motion in 12% of patients **(Table 3).** Riecke et al. [30,31] measured Mayo wrist scores and Disabilities of the Arm, Shoulder, and Hand (DASH) [5] scores in 30 donor arms at three months post-operatively. They found on average a 9.4 point (-12.9%) decrease in the Mayo wrist score and a 16.1 point (+35.5%) increase in DASH score compared with pre-operative assessments (p<0.001). Cigna et al. [19] found that pronation at the wrist and manual dexterity were reduced in 2/15 patients (13.3%) and 5 patients (33.3%) had slower manual dexterity on the donor side. Only one patient (6.7%) reported a difference in their ability to perform normal tasks. Richardson et al. [29] found that 16% of patients who underwent fasciocutaneous flaps had self-reported restricted forearm function. However, when an osteocutaneous flap was used, 36% of patients without a radius fracture and 100% of patients with a radius fracture reported restricted forearm function.

Objective ROM: Seven studies with 233 patients objectively measured wrist range of motion using a goniometer and five of these studies found a significant difference in range of motion **(Table 3).** Pooled data from the studies found a mean loss of 1.5 degrees of flexion and 6.2 degrees of extension. Bonaparte et al. [9-11] found that the operated arm had decreased wrist extension by 15.2 degrees (p<0.001). Riecke et al. [30,31] found only a limitation of dorsal extension (-12.5 degrees) at long

Table 3: Functional and aesthetic complications.

References	No. of RF Donor Sites Analyzed	No. Fractures (%)	No. Decreased ROM/Function (%)	Objective Decreased ROM (goniometer) significant difference (Y or N)	Change in Range of Motion Flexion/ Extension (degrees) (SD)	No. Decreased Strength (%)	Objective Decreased Strength (dynamometer)	Change in Strength: Grip/ Pinch (kg)	Sensory Deficit (%)	Chronic Pain (%)	Hypertrophic Scarring (%)	Aesthetic Outcome (no. with poor/ unsatisfactory outcome) (%)
Ahmad et al. (2007) [6]	n/a	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Avery et al. (2007) [7]	120	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Boahene et al. (2011) [8]	16	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	0 (0)	n/r
Bonaparte et al. (2011) [9,10]	29	n/a	*	Y	*/15.2˚ (18.1˚)	*	n/r	n/r	n/r	*	*	*
Bonaparte et al. (2013) [11]	177	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Boyd et al. (1995) [12]	45	0 (0)	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Brown et al. (1999) [13]	10	n/a	0 (0)	Y	-7.1˚/-0.3˚	n/r	Y	-6.8/-0.8	7 (70)	n/r	n/r	n/r
Byun et al. (2016) [14]	10	n/a	0 (0)	N	+4.4˚/+0.1˚	1 (10)	n/r	n/r	10 (100)	0 (0)	0 (0)	*
Chambers et al. (1997) [15]	21	n/a	n/r	n/r	n/r	20 (95.2)	n/r	n/r	15 (71)	4 (18)	0 (0)	0 (0)
Chang et al. (2010) [16]	7	n/a	0 (0)	*	*	n/r	*	*	7 (100)	n/r	n/r	*
Chau et al. (2009) [17]	58	n/a	*	*	*	n/r	n/r	n/r	*	*	*	*
Chio et al. (2010) [18]	50	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Cigna et al. (2015) [19]	15	n/a	2 (13)	n/r	n/r	n/r	n/r	n/r	5 (33)	n/r	*	n/r
Faisal et al. (2013) [20]	25	n/a	2 (8)	n/r	n/r	n/r	n/r	n/r	5 (20)	n/r	n/r	5 (20)
Garaffa et al. (2010) [21]	27	n/a	0 (0)	n/r	n/r	n/r	n/r	n/r	0 (0)	n/r	n/r	0 (0)
Ghanem et al. (2009) [22]	n/a	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Harris et al. (2016) [23]	n/a	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Kesting et al. (2011) [24]	n/a	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
Lutz et al. (1999) [25]	50	n/a	n/r	Y	-3.8˚/-3.2˚	n/r	Y	+0.1/-0.1	27 (54)	n/r	n/r	n/r
Moazzam et al. (2003) [26]	18	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r	*
Moreno-Sanchez et al. (2016) [27]	100	n/a	n/r	n/r	n/r	1 (1)	n/r	n/r	2 (2)	n/r	n/r	*
Morrissey et al. (2010) [28]	8	n/a	n/r	n/r	n/r	n/r	n/r	n/r	0 (0)	*	n/r	4 (50)
Richardson et al. (1997) [29]	74	6 (17)	24 (32)	Y	*	n/r	Y	*	24 (32)	n/r	n/r	25 (29)
Riecke et al. (2015,2016) [30,31]	20	n/a	5 (17)	Y	+0.4˚ (14˚)/-12.5˚ (14˚)	n/r	N	-2.7 (5.5)/-2.1 (3.6)	4 (20)	0 (0)	n/r	2 (7)
Schwarzer et al. (2016) [32]	41	n/a	1 (2)	n/r	n/r	1 (2)	n/r	n/r	22 (54)	7 (17)	n/r	4 (10)
Sidebottom et al. (2000) [33]	37	1 (3)	n/r	n/r	n/r	n/r	n/r	n/r	n/r	*	n/r	*
Sinha et al. (2002) [34]	52	n/a	0 (0)	n/r	n/r	0 (0)	n/r	n/r	0 (0)	n/r	0 (0)	n/r
Wagstaff et al. (2015) [35]	4	n/a	n/r	n/r	n/r	n/r	n/r	n/r	n/r	0 (0)	*	n/r
Wax et al. (2001) [36]	40	n/a	n/r	n/r	n/r	n/r	n/r	n/r	4 (10)	n/r	n/r	n/r
Wirthman et al. (2014) [37]	13	n/a	0 (0)	N	*	1 (8)	n/r	n/r	7 (54)	n/r	0 (0)	2 (15)
Total (%)	**1067**	**7 (8.5)**	**34 (12)**	**5 studies (71); 84 pts. (41)**	**-1.5/-6.2 weighted: -1.9/0.1**	**24 (10)**	**3 studies (75); 55 pts. (46)**	**-3.1/-1.0 weighted:**	**139 (27)**	**11 (9)**	**0 (0)**	**42 (16)**
No. Articles	**24**	**3**	**11**	**7**	**5**	**6**	**4**	**3**	**16**	**5**	**5**	**8**

% calculations were based on total reported population for each outcome; n/a not applicable; n/r not reported; *Data point was assessed with different or incomplete measuring metrics such that data was not able to be extracted for analysis term follow up (2.2 years), which was significant (p<0.001). Richardson et al. [29] found a 20-degree decreased wrist extension in fasciocutaneous radial forearm flaps and composite radial forearm flaps without a radius fracture. Patients who had a fracture of their radius after a composite flap had even more limitation of their range of motion. Lutz et al. [25] found that skin graft take at the donor site influenced post-operative range of motion, where five out of six patients who had delayed wound healing had significant decrease in wrist flexion (p=0.03).

Subjective decreased strength: Subjective evaluation of strength was determined by patient interviews. A total of six articles with 265 patients noted decreased strength in 10% of patients **(Table 3).** Chambers et al. [15] reported 19/21 (90.5%) patients with minimal weakness at the donor site. Schwarzer et al. [32] found that at 3 months post-operative, 1/21 (4.8%) of the subfascial and 0/18 of the suprafascial donor sites had impaired strength.

Objective decreased strength: A total of 4 studies with 177 patients objectively measured grip and pinch strength using a dynamometer. Overall there was a mean loss of 3kg in grip strength and 1kg in key pinch strength **(Table 3).** Brown et al. [13] found no difference in grip strength in the donor arm, however, pinch strength was significantly weaker by 0.4 kg (p=0.047). Lutz et al. [25] found a difference in grip strength only when there was incomplete take of the skin graft at the donor site (p=0.04). Riecke et al. [30,31] reported only decreased key pinch at long term follow-up, with an average difference of 1.4 kg between hands (p=0.002). Richardson et al. [29] found a 16% loss of grip strength in the fasciocutaneous donor arm, however, this was not seen in the composite group. Pinch strength was decreased in both groups.

Sensory deficit: Sensory deficits (defined as transient numbness, paresthesia, hypesthesia, hyperesthesia, dysesthesia, and anesthesia) were evaluated by 16 studies with 513 patients and was noted in 27% of patients **(Table 3).** A majority of the articles looked at sensory disturbances involving the superficial branch of the radial nerve (SBRN) and found improvement with time. Richardson et al. [29] evaluated 86 patients and found 75% had reduced sensation in the SBRN distribution at 3 months, 50% of patients at 6 months, and 32% of patients at 12 months. Byun et al. [14] reported that 2/10 patients (20%) with moderately impaired hand sensation at one month follow up had complete resolution by 6 month follow up. Wirthman et al. [37] found 7/13 patients (53.8%) had impaired sensation after a mean follow up of 23.8 months. Of note, Cigna et al. [19] assessed sensation using 2-point discrimination and found 5/15 patients (33.3%) had changes in sensation at long term follow up.

Chronic pain: Chronic pain (pain lasting greater than 3 months) was assessed by five studies with 124 patients and noted to occur in 8.9% of patients **(Table 3).** Chambers et al. [15] found that 3/17 patients (17.6%) who were closed with a full thickness graft had chronic pain and 1/5 patients (20%) closed with a split thickness skin graft had pain at three months, corresponding to a Visual Analog Score of 5-6. Schwarzer et al. [32] found that 6/21 of the subfascial donor sites (28.6%) had pain at three months compared to 1/19 of the suprafascial donor sites (5.3%).

Aesthetic outcome: Five studies with 112 patients did not find any evidence of hypertrophic scarring **(Table 3).** These studies varied in how the donor sites were treated. One study treated donor sites with a split thickness skin graft, another study utilized both full thickness and split thickness skin grafts, and three studies utilized biologic materials (Rapiderm, Alloderm, Integra) to treat donor sites.

A total of 8 studies with 260 patients looked at donor site appearance and found a 16% rate of poor or unsatisfactory donor site appearance **(Table 3).** These eight studies differed in how they closed the donor site. Faisal et al. [20] reported a 20% response rate of poor cosmetic appearance of the donor site out of 25 radial forearm flaps assessed. They preferred to primarily close the donor site if possible; otherwise a split thickness skin graft was used. Richardson et al. [29] similarly preferred primary closure of the donor site, and split thickness skin grafting only when necessary. 86 patients followed up at 3 months and 29% of patients rated their donor site as poor. Riecke et al. [30,31] closed their 30 donor sites with full thickness skin grafts and 2/30 (6.7%) were rated as poor. Schwarzer et al. [32] found that at 3 months, 10% of patients reported feeling "very unsatisfied" or "unsatisfied" about their donor site appearance as compared to 2.5% of the examiners. Wirthman et al. [37] used Integra and subsequent split thickness skin grafting to close their donor sites. They found a 23% rate of "very dissatisfied" or "somewhat dissatisfied". Of note, they mention that two of the three patients had unstable scars which could have influenced their opinion.

Discussion

Radial forearm flaps are performed for a wide variety of reconstructive indications. Our systematic review found that most of the reported literature involves the use of radial forearm free flaps in head and neck reconstruction, and less commonly in extremity reconstruction as well as in genitourinary reconstruction. Fasciocutaneous flaps were more commonly performed than osteocutaneous, although 30% of flap types were not specified. The incidence of donor site wound complications was low overall. The most commonly noted wound complication was partial necrosis of the donor site (10%), however, only 1% of all patients needed secondary grafting.

Fractures after osteocutaneous radial forearm free flaps occurred in 6% of patients. Female sex appears to be a positive predictive factor where radius diameter and osteopenia may be influencing factors.

Subjective decreased range of motion occurred in 12% of patients. Overall, there was a high variability on how range of motion was assessed (i.e., patient self-reporting, smaller surveys, vs standardized surveys i.e., DASH/Mayo wrist score). Furthermore, not all of the articles that report on subjective decreased range of motion assess whether this posed any functional limitation to the patient. For example, Cigna et al. [19] found reduced manual dexterity in 7 out of 13 patients (53.8%), however, only one patient reported difficulty in performing normal tasks (7.6%).

Objective donor extremity range of motion was assessed using a goniometer in seven studies. There was variability in pre- and post-operative assessments among the included articles. Some studies performed a bilateral preoperative evaluation while other studies used the contralateral arm as the control.

Subjective decreased strength was noted in 10% of patients, however, this number was largely influenced by one paper. Chambers et al. [15] found that a majority of patients reported minimal weakness at the donor site (19/21, 90%) and only one patient reporting substantial weakness (1/21, 4.8%). Again, many of the studies do not comment whether this subjective decrease in strength posed any limitations to the patient from a functional standpoint. For example, Moreno-Sanchez et al. [27] reported that one patient out of 100 reported weakness; however, no patients reported any functional deficits.

While subjective decreased strength was a relatively low occurrence, objective decreased strength was noted in 46% of evaluated patients. As with the subjective strength, some studies tested bilateral upper extremities pre-op, while others used the unoperated arm as the control. Interestingly, Riecke et al. [30,31] found a decrease in grip strength in both the donor and the unoperated arm. Furthermore, hand dominance may affect pre-operative strength, and not all studies noted whether the dominant or non-dominant extremity was used as the donor.

Sensory deficit occurred in 27% of patients assessed. There was variability in how sensation was assessed ranging from patient self-reporting, two-point discrimination testing, and Semmes Weinstein testing. There was also variability in the follow up length, which is notable as some papers with longer follow-up times reported improved sensation over time. For example, Richardson et al. [29] found that 75% of patients had decreased sensation in the distribution of the superficial branch of the radial nerve (SBRN) at 3 months post-operatively, however, this decreased to 30% of patients by 12 months post-operatively.

Chronic pain (defined by pain lasting >3month) occurred in 9% of patients post-operatively. None of the articles discussed whether SBRN neuroma contributed to the chronic pain.

The appearance of the donor site has been one of the most common criticisms of the radial forearm free flap given its prominent location. Two studies reported an acceptable donor site in all patients and closed donor sites with either a split thickness or full thickness skin graft. However, of the six studies that had patients with an unacceptable donor site appearance, three studies closed donor sites with a split thickness skin graft, one study with Integra and a split thickness skin graft, and two studies with a full thickness skin graft. Unfortunately, due to the subjective nature of cosmetic appearance, it is hard to make a recommendation as far as donor site closure.

This review has several limitations. One limitation is the variability in donor site treatment as mentioned above. Each paper utilized one or more of the following: primary closure, split thickness grafting, full thickness skin grafting, or dermal matrices. Furthermore, it was not mentioned whether meshing was involved, which can result in a more noticeable wound. Another limitation is that time of last follow up was not always mentioned and was not uniform between studies. This may influence the overall assessment of donor site function, sensation, and appearance as many articles found that as time progressed many functional and sensory issues improved or resolved. Furthermore, from a wound healing standpoint we know that in general, over time scars will flatten and fade, which could result in improved patient satisfaction. Another limitation is how functional and aesthetic outcomes were assessed. Eleven articles evaluated subjective decreased range of motion; however, only Riecke et al. [30] used validated questionnaires [35-37].

Conclusion

In conclusion, only 7 articles objectively measured range of motion with a goniometer and only 4 articles objectively measured strength with a dynamometer. Lastly, aesthetic outcome was primarily based on patient perception. Despite these limitations, this review allows us to better qualify and quantify the morbidity associated with the radial forearm donor site thus enabling surgeons to more fully counsel patients regarding donor site expectations.

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