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Original Research

Somatosensory changes at forearm donor sites following three different surgical flap techniques

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ABSTRACT

Background: The aim of this study was to investigate the somatosensory changes at the forearm donor region after using different types of modified flap surgical techniques.
Methods: Thirty-one patients, who underwent oral and maxillofacial reconstructive surgery involving the use of a traditional radial forearm flap (TRFF) or two modified radial forearm flap techniques (MRFF-I; MRFF-II), participated in the study. Cold detection threshold (CDT), warm detection threshold (WDT), cold pain threshold (CPT), heat pain threshold (HPT), pressure pain threshold (PPT), mechanical detection threshold (MDT), and mechanical pain threshold (MPT) were assessed at four sites of the forearms corresponding to the middle of the vascular pedicle (VP) area, the middle of the forearm flap area, and the corresponding contralateral sites (cVP and cFF) at about 5.0 ± 1.9 months after the surgery. Data were analysed with one-way ANOVA, and post-hoc tests were performed using Tukey's Honest Significant Difference test.
Results: Significant differences between the VP and cVP sites were detected for WDT ($P < 0.001$) in TRFF and for WDT ($P < 0.001$) and MDT ($P = 0.006$) in MRFF-I. Significant differences among TRFF, MRFF-I, and MRFF-II at the VP site were detected for CDT ($P = 0.022$), WDT ($P < 0.001$), and MDT ($P = 0.015$). MRFF-II was associated with significantly higher sensitivity compared to that of TRFF for WDT ($P = 0.017$) and higher sensitivity compared to that of MRFF-I for CDT ($P = 0.017$), WDT ($P < 0.001$), and MDT ($P = 0.013$).
Conclusions: Significant sensory loss was detected for all types of surgical procedures with free forearm flaps. However, the MRFF-II was associated with a better sensory recovery at short follow-up after surgery. These results suggest that a longer follow-up period and larger sample size should be included in future studies.

1. Introduction

With the rapid progress of microsurgical technology since the 1980s, free-tissue transfer has become an important technique for head and neck reconstruction after oncologic resections [1–4]. Since the first fasciocutaneous radial forearm flap (RFF) was introduced [5], RFF has been used extensively because of its superiority in plasticity, flexible texture, and adequate blood supply [6–8]. It has gradually become the main flap for reconstruction surgery in the head and neck, with a high success rate (approximately 94%–96%) [2,9]. In addition to the traditional methods of RFF (TRFF) (Fig. 1AD), which usually require an auxiliary longitudinal incision on the pedicle of the free vessel and repair with free skin grafting from another region, two modified methods have been frequently used in clinical practice. The first type of modified radial forearm flap (MRFF-I) (Fig. 1BE) is harvested with a proximal isosceles triangle full thickness skin, which has some elasticity and can be pulled distally to cover the surgical area of the forearm, and does not require an extra operative site from other regions [10]. The second type (MRFF-II) (Fig. 1CF) is prepared without the longitudinal incision of the traditional flap, owing to the use of ultrasonically activated shears (e.g. Harmonic Scalpel, HS; Ethicon Endo-Surgery, Cincinnati, OH, USA), which can maintain skin integrity and efficiently

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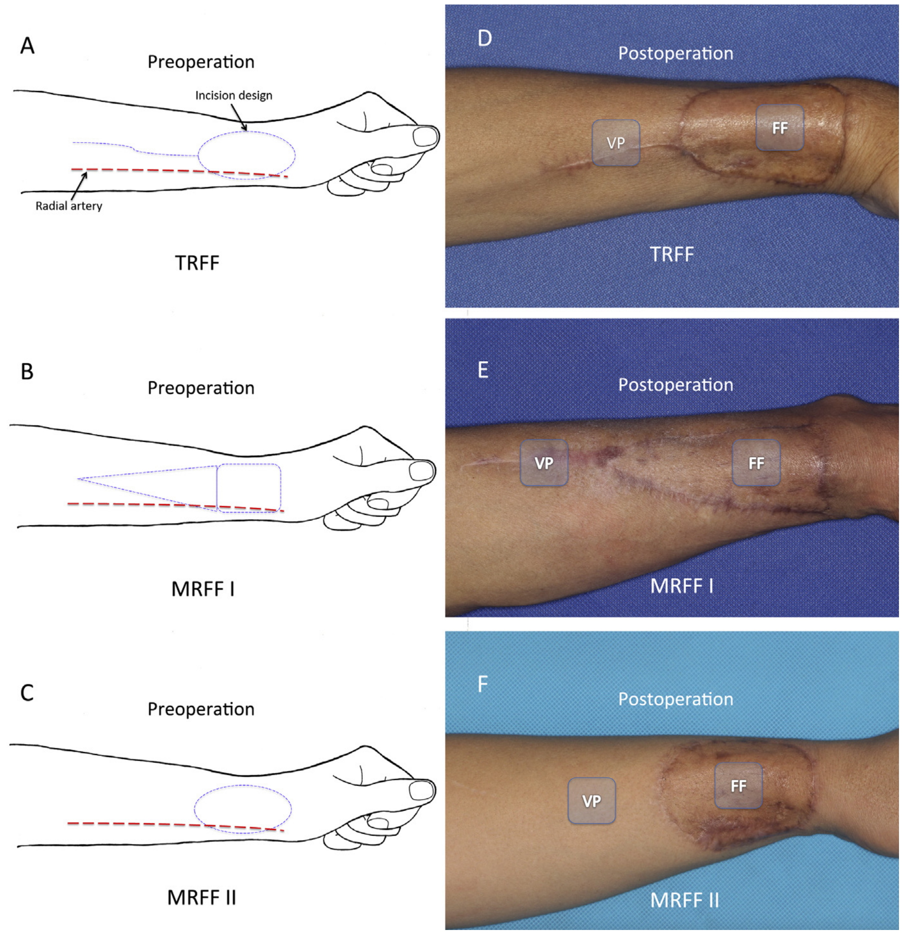

Fig. 1. The blue dotted line illustrates the incision line of the flap. The red line shows the surface projection of the radial artery, which should be harvested with the flap and used to supply blood to the flap. Compared with TRFF (A), MRFF-I (B) harvesting should add a proximal isosceles triangle incision, and this full thickness skin can be pulled distally to cover the area of the flap. MRFF-II (C) omits the longitudinal incision of the traditional flap, and uses the ultrasonically activated shears to harvest the vascular pedicle.
Sensory testing of patients undergoing TRFF (D), MRFF-I (E), and MRFF-II (F) were performed at the vascular pedicle (VP) and forearm flap (FF) area of the skin. TRFF, traditional radial forearm flap; MRFF I, modified radial forearm flap I; MRFF II, modified radial forearm flap II. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Patient information. TRFF, traditional radial forearm flap; MRFF-I, modified radial forearm flap I; MRFF II, modified radial forearm flap II.

	TRFF	MRFF-I	MRFF-II	Total patients
Follow-up time (month)	5.0 ± 1.9 (2–8)	5.3 ± 1.6 (3–8)	4.8 ± 2.2 (2–9)	5.0 ± 1.9 (2–9)
Age (years)	59.6 ± 5.2 (51–67)	61.0 ± 6.8 (45–70)	58.4 ± 5.8 (45–67)	59.7 ± 5.9 (45–70)
Sex (male)	(7/12)	(6/10)	(6/9)	(19/31)

harvest the vascular pedicle (VP) with good haemostasis [11].

Many studies have reported on reduced or abnormal somatosensory function at the donor site of the forearm corresponding to the innervation in the area of distribution of the radial nerve or the lateral and medial cutaneous nerves after flap surgery [12–15]. However, few studies on the effects of different surgical procedures on somatosensory functions of the forearm have been reported. Quantitative sensory testing (QST), a set of standardised psychophysical tests using well-defined and quantifiable somatosensory stimuli and assessments of sensory or pain thresholds or magnitude ratings from the participants, is a mature diagnostic instrument to assess thermal and mechanical somatosensory functions with implications for better understanding of the underlying neurobiological mechanisms. The German Research Network on Neuropathic Pain (DFNS) studied the effectiveness, adaptability, and application of QST in 2006, and the sensitivity, specificity, reliability, and repeatability of the psychophysical technology have been reported [16,17].

The objective of this study was to evaluate somatosensory changes at the forearm donor site following different types of fasciocutaneous radial forearm flaps using a standardised QST protocol with the aim to identify the technique with the least interference and best recovery in terms of somatosensory functions of the patients.

2. Materials and methods

2.1. Study participants

Thirty-one patients (19 male, 12 female, age: 45–70 years) participated in the study. Among them, 12 (7 male), 10 (6 male), and 9 (6 male) underwent different types of flap surgery: TRFF, MRFF-I, and MRFF-II, respectively, for oral and maxillofacial reconstruction. The results in terms of changes in somatosensory function of the tongue following the reconstructive procedures have previously been published [18]. The follow-up schedule of the patients is shown in Table 1.

The inclusion criteria of patients were as follows: 1) Patients scheduled for RFF procedure of the left forearm as part of the reconstruction of oncological defects in about 5.0 ± 1.9 months after the surgery; 2) the lateral antebrachial cutaneous nerves were protected during harvesting the RFFs; 3) no serious infection and trauma occurred to the forearm after the surgery; 4) patients were cooperative.

The exclusion criteria were as follows: 1) Patients who had any internal or neurological diseases including peripheral or central neurological dysfunction; 2) patients who had a history of psychiatric substance abuse; 3) patients who had systemic dermatological diseases; 4) patients who were pregnant or nursing. This study has been reported

Table 2
Absolute values of raw QST data. TRFF, traditional radial forearm flap; MRFF-I, modified radial forearm flap I; MRFF-II, modified radial forearm flap II. VP, vascular pedicle; FF, forearm flap; cVP, contralateral side of VP; cFF, contralateral side of FF; CDT, cold detection threshold; WDT, warm detection threshold; CPT, cold pain threshold; HPT, heat pain threshold; PPT, pressure pain threshold; MDT, mechanical detection threshold; MPT, mechanical pain threshold; QST, Quantitative Sensory Testing.

		CDT(°C)	WDT(°C)	CPT(°C)	HPT(°C)	PPT(kPa)	MDT(g)	MPT(mN)
TRFF	VP	27.0 ± 3.7	38.3 ± 2.3	15.1 ± 6.1	45.7 ± 3.6	190.2 ± 54.6	0.04 ± 0.05	2.3 ± 2.0
	FF	12.2 ± 4.8	49.1 ± 0.9	2.3 ± 3.8	49.6 ± 0.6	216.9 ± 46.7	1.04 ± 1.38	38.8 ± 21.6
	cVP	30.0 ± 0.4	35.0 ± 0.6	20.4 ± 3.4	42.4 ± 2.9	236.2 ± 61.5	0.01 ± 0.01	1.2 ± 0.6
	cFF	30.1 ± 0.4	35.1 ± 0.6	20.7 ± 2.3	42.0 ± 3.0	241.1 ± 53.2	0.01 ± 0.01	1.4 ± 0.7
MRFF-I	VP	25.2 ± 2.6	40.8 ± 3.3	14.5 ± 5.0	46.1 ± 4.2	237.6 ± 54.2	0.36 ± 0.47	8.2 ± 18.5
	FF	13.6 ± 9.1	46.9 ± 3.7	5.0 ± 5.8	50.0 ± 0.2	237.5 ± 69.3	1.65 ± 1.66	28.4 ± 27.9
	cVP	29.3 ± 1.5	35.2 ± 1.3	16.6 ± 4.6	44.1 ± 3.4	260.9 ± 74.9	0.01 ± 0.00	2.6 ± 3.7
	cFF	29.4 ± 1.0	35.5 ± 1.3	16.3 ± 5.1	43.7 ± 3.6	265.1 ± 69.9	0.01 ± 0.00	2.7 ± 4.4
MRFF-II	VP	29.2 ± 0.9	35.2 ± 1.0	21.1 ± 3.2	42.6 ± 1.5	223.9 ± 47.5	0.01 ± 0.00	0.9 ± 0.1
	FF	13.7 ± 4.8	47.4 ± 2.0	5.5 ± 4.1	49.5 ± 0.6	209.6 ± 34.8	0.82 ± 0.55	17.7 ± 12.0
	cVP	29.5 ± 0.8	35.1 ± 0.8	20.7 ± 2.4	41.9 ± 1.3	245.3 ± 42.7	0.01 ± 0.00	0.8 ± 0.1
	cFF	29.3 ± 1.0	35.4 ± 1.4	21.1 ± 2.4	42.4 ± 1.4	247.6 ± 34.8	0.01 ± 0.00	0.9 ± 0.1

in line with the STROCSS criteria [19].

2.2. Study protocol

The somatosensory function was tested in the innervated areas of the lateral antebrachial cutaneous nerve. Two sites at the donor forearm corresponding to the middle of the vascular pedicle (VP) area, and the middle of the forearm flap (FF) area were examined after 3 different types of procedures (Fig. 1DEF). QST were performed at the VP and FF sites at both forearms after surgery by the same trained examiner in a quiet room with a temperature of 25 °C.

2.3. Quantitative sensory testing

Thermal detection thresholds for the perception of cold (CDT) and warm (WDT) stimuli as well as thermal pain thresholds for cold pain (CPT) and heat pain (HPT) stimuli were assessed with the use of a thermal stimulator (MEDOC TSA-2001 apparatus; Medoc Ltd, Ramat-Yishai, Israel). The test thermode had a contact area of $30 \times 30\,mm^2$. CDT and WDT were measured first, followed by CPT and HPT. The temperature of the thermode started from a baseline of 32 °C and heated-up or cooled-down at a rate of 1 °C/s to the upper limits of 50 °C or lower limits of 0 °C. Participants were instructed to press a button as soon as they perceived the respective thermal sensation or pain. The procedure then ended and the temperature returned to baseline. Each test was repeated three times; and the mean threshold temperatures were calculated [16].

Mechanical detection threshold (MDT) was measured with a standardised set of Semmes-Weinstein monofilaments (North Coast Medical, Gilroy, CA, USA) that exert forces upon bending between 0.008 and 300 g. The filaments were applied perpendicular to the test site for about 1–2 s and the participants were asked if the filament was perceived: "yes" or "no" [20,21]. Mechanical pain threshold (MPT) was measured using standardised and custom-made weighted pinprick stimuli as a set of seven weighted pinprick stimulators (Aalborg University, Aalborg, Denmark). The pinprick set consists of 7 defined stimulus intensities of 8, 16, 32, 64, 128, 256, 512 mN with flat contact area of 0.2 mm diameter [22]. The pinprick was applied perpendicularly and slowly at a rate of 2 s on and 2 s off, in a series of ascending and descending forces, until the first sensation of painful sharpness appeared or disappeared. Five threshold determinations were made, each with the ascending and descending stimulus intensities and the geometric mean of the five series thresholds was calculated.

Pressure pain threshold (PPT) was assessed with a digital pressure algometer (Algometer; Medoc, Ramat Yishai, Israel), applied to the test sites with a probe area of approximately $1\,cm^2$. The PPT was determined with a slowly increasing ramp of 30 kPa/s [23]. As soon as the participants felt the pressure stimulus painful, they pressed a button to stop the recording. The procedure was repeated three times for each site and with about 1-min interval between consecutive stimuli.

2.4. Data analysis

The sample size was calculated with risk of type I and type II errors of 5% and 20%, respectively. An estimate of the inter-individual variation was set at 25% and a minimal relevant difference to detect was set at 20%. A total of 31 patients were recruited in the present study.

Descriptive statistics were used to summarise the data. The necessary logarithmic transformation was performed when the data was not normally distributed. The mean values and SD of the CDT, WDT, CPT, HPT, PPT, MDT and MPT at each region were calculated. A one-way analysis of variance (ANOVA) test was used to analyse the different outcome parameters of CDT, WDT, CPT, HPT, PPT, MDT and MPT at the test sites, amongst different regions and surgical techniques. Post-hoc tests were performed using Tukey's Honest Significant Difference test with corrections for multiple comparisons. The significance level was set at 0.05.

Z-scores were adopted to demonstrate the degree of differences between QST data from these types of surgeries and surgical sites [16,24]. The data from the right control forearm were used as the reference values. The data of WDT, HPT, MDT, MPT, PPT from the left side (VP and FF) were transformed using the following formula: Z-score $= (\text{Value}_{\text{control}} — \text{Value}_{\text{surgery}})/\text{SD}_{\text{control}}$, and Z-score $= (\text{Value}_{\text{surgery}} — \text{Value}_{\text{control}})/\text{SD}_{\text{control}}$ for CDT and CPT. A Z-score between -1.96 and $+1.96$ corresponds to the 95% confidence interval and can be considered normal, whereas a Z-score below -1.96 indicates a loss of somatosensory function. The statistical analysis was performed using the Statistical Package for Social Sciences, version 23.

3. Results

The clinical information is shown in Table 1. Absolute values of all parameters are shown in Table 2, and summary statistics of CDT, WDT, CPT, HPT, PPT, MDT, and MPT are shown in Tables 3 and 4.

Significant differences between the VP site and contralateral site were shown for WDT ($P < 0.001$) in TRFF, and for WDT ($P < 0.001$) and MDT ($P = 0.006$) in MRFF-I. No significant difference was found for any parameter between the VP and cVP in patients who underwent MRFF-II. Significant differences between forearm flap regions and the contralateral sides were observed for all the parameters, except for PPT, for the three types of surgeries (Table 3). All data, except for PPT, were also significantly different between the forearm flap regions and the VP regions (Table 4).

Significant differences amongst TRFF, MRFF-I, and MRFF-II at the

Table 3
Comparison between VP and FF in 3 different surgery types. TRFF, traditional radial forearm flap; MRFF-I, modified radial forearm flap I; MRFF-II, modiied radial forearm flap II. VP, vascular pedicle; FF, forearm flap; cVP, contralateral side of VP; cFF, contralateral side of FF; CDT, cold detection threshold; WDT, warm detection threshold; CPT, cold pain threshold; HPT, heat pain threshold; PPT, pressure pain threshold; MDT, mechanical detection threshold; MPT. The parameters were tested with the one-way ANOVA. Post-hoc tests were performed with Tukey Honestly Significant Difference test with corrections for multiple comparisons.

		ANOVA	VP × cVP	FF × cFF	VP × FF	cVP × cFF
TRFF (n = 12)	CDT	< 0.001	NS	< 0.001	< 0.001	NS
	WDT	< 0.001	< 0.001	< 0.001	< 0.001	NS
	CPT	< 0.001	NS	< 0.001	< 0.001	NS
	HPT	< 0.001	NS	< 0.001	0.006	NS
	PPT	NS	NS	NS	NS	NS
	MDT	< 0.001	NS	< 0.001	< 0.001	NS
	MPT	< 0.001	NS	< 0.001	< 0.001	NS
MRFF-I (n = 10)	CDT	0.002	NS	0.005	0.015	NS
	WDT	< 0.001	< 0.001	< 0.001	< 0.001	NS
	CPT	< 0.001	NS	< 0.001	< 0.001	NS
	HPT	< 0.001	NS	< 0.001	0.003	NS
	PPT	NS	NS	NS	NS	NS
	MDT	< 0.001	0.006	< 0.001	0.001	NS
	MPT	0.002	NS	0.005	0.033	NS
MRFF-II (n = 9)	CDT	< 0.001	NS	< 0.001	< 0.001	NS
	WDT	< 0.001	NS	< 0.001	< 0.001	NS
	CPT	< 0.001	NS	< 0.001	< 0.001	NS
	HPT	< 0.001	NS	< 0.001	< 0.001	NS
	PPT	NS	NS	NS	NS	NS
	MDT	< 0.001	NS	< 0.001	< 0.001	NS
	MPT	< 0.001	NS	< 0.001	< 0.001	NS

Table 4
Comparison of 3 different surgery types. TRFF, traditional radial forearm flap; MRFF-I, modified radial forearm flap I; MRFF-II, modified radial forearm flap II. VP, vascular pedicle; FF, forearm flap; cVP, contralateral side of VP; cFF, contralateral side of FF; CDT, cold detection threshold; WDT, warm detection threshold; CPT, cold pain threshold; HPT, heat pain threshold; PPT, pressure pain threshold; MDT, mechanical detection threshold; MPT, mechanical pain threshold. The parameters were tested with the one-way ANOVA. Post-hoc tests were performed with Tukey Honestly Significant Difference test with corrections for multiple comparisons.

		CDT	WDT	CPT	HPT	PPT	MDT	MPT
TRFF × MRFF-I × MRFF-II (ANOVA)	VP	0.022	< 0.001	NS	NS	NS	0.015	NS
	FF	NS	NS	NS	NS	NS	NS	NS
	cVP	NS	NS	NS	NS	NS	NS	NS
	cFF	NS	NS	NS	NS	NS	NS	NS
TRFF × MRFF-I	VP	NS	NS	NS	NS	NS	NS	NS
	FF	NS	NS	NS	NS	NS	NS	NS
	cVP	NS	NS	NS	NS	NS	NS	NS
	cFF	NS	NS	NS	NS	NS	NS	NS
TRFF × MRFF-II	VP	NS	0.017	NS	NS	NS	NS	NS
	FF	NS	NS	NS	NS	NS	NS	NS
	cVP	NS	NS	NS	NS	NS	NS	NS
	cFF	NS	NS	NS	NS	NS	NS	NS
MRFF-I × MRFF-II	VP	0.017	< 0.001	NS	NS	NS	0.013	NS
	FF	NS	NS	NS	NS	NS	NS	NS
	cVP	NS	NS	NS	NS	NS	NS	NS
	cFF	NS	NS	NS	NS	NS	NS	NS

VP site were observed for CDT ($P = 0.022$), WDT ($P < 0.001$), and MDT ($P = 0.015$) (Table 4). There were no significant differences between TRFF and MRFF-I. However, MRFF-II was associated with significantly higher sensitivity than TRFF for WDT ($P = 0.017$); and higher sensitivity than MRFF-I for CDT ($P = 0.017$), WDT ($P < 0.001$) and MDT ($P = 0.013$) (Table 4).

The Z-score profiles of the patients are shown in Fig. 2 and clearly demonstrate the loss of somatosensory function at the FF sites for CDT and WDT. Moreover, the Z-score profiles show loss of somatosensory function for TRFF and MRFF-I, but not for MRFF-II, considering CDT and WDT. Also note the difference in recovery of somatosensory functions related to the time, after surgery for the individual patients.

4. Discussion

The present study demonstrated for the first time the applicability and value of a standardised QST protocol to assess changes in somatosensory functions following RFF surgery. The somatosensory function at the donor site was impaired after all the types of surgeries. However, the recovery of somatosensory functions appeared to be the best after MRFF-II. These findings may have potential impact on quality of life for patients undergoing surgery and their recovery. Furthermore, QST data may help to better identify and monitor abnormalities in somatosensory function and development of neuropathic pain conditions.

4.1. Somatosensory loss at the forearm

Abnormal sensations at the donor site in the radial nerve or the lateral and medial cutaneous nerve distribution, after forearm flap surgery, have previously been reported [25]. Since the preparation of flaps damages the superficial branch of the radial nerve in each surgical type, the numbness in the palm area, to some extent, did not correlate to different types of surgical procedures [25]. However, somatosensory loss in the proximal area of the forearm flap was significantly different among different areas and surgeries in the present study. The somatosensory function at the lateral area of the forearm is primarily innervated by the lateral antebrachial cutaneous nerve. It has been shown that the sensitivity at the test site reflects mostly the peripheral factors for the thermal and mechanical test items, such as peripheral nerve fibres and receptor density. Moreover, nerve fibres and receptor damage result in dysesthesia or numbness of the test area [16]. Therefore, the threshold changes assessed by QST can reflect the degree of damage to the lateral antebrachial cutaneous nerve.

In accordance with previous experimental results, impaired thermal and mechanical sensations occurred in the surgical side after nerve injury unilaterally [26]. As observed in the patient population in this study, almost all somatosensory modalities in the flap regions revealed a large impairment, indicating significant neurophysiological deficits at the FF sites. Additionally, a previous study has reported that the tissue injury and scar tissue formation lead to the difference in somatosensory function between the surgical and contralateral sides [26]. Therefore, reducing tissue trauma during the operation appears to be critical for recovery of somatosensory function.

4.2. Differences in somatosensory function between types of surgeries and sides

All QST parameters in this study showed significant differences between the surgical flaps and contralateral regions except for PPT. Besides, WDT in TRFF, and WDT and MDT in MRFF-I at the VP regions, were significantly different. Our results indicated that there might have been a larger injury to the nerve fibres of the forearms undergoing MRFF-I in comparison to the contralateral sites. However, less significant differences were found in the VP regions of the MRFF-II, indicating less trauma in the forearm after MRFF-II surgery [27]. Further, we found that all QST parameters at the left forearm were less sensitive, except for lower PPT (more sensitive) at the surgical sites. PPT, mediated by both C-fibres and Aδ-fibres, is considered to evaluate the deep tissue pain sensitivity [16]. The forearm flap was generally prepared above the fascia without injury to the deep muscle tissues and nerve fibres. Therefore, only small differences in PPT values may have been detected at the donor sites.

In general, TRFF, MRFF-I, and MRFF-II are the surgical options for oral and maxillofacial reconstruction, and the flap areas are similar in all three procedures. However, the specific conditions and rationale for

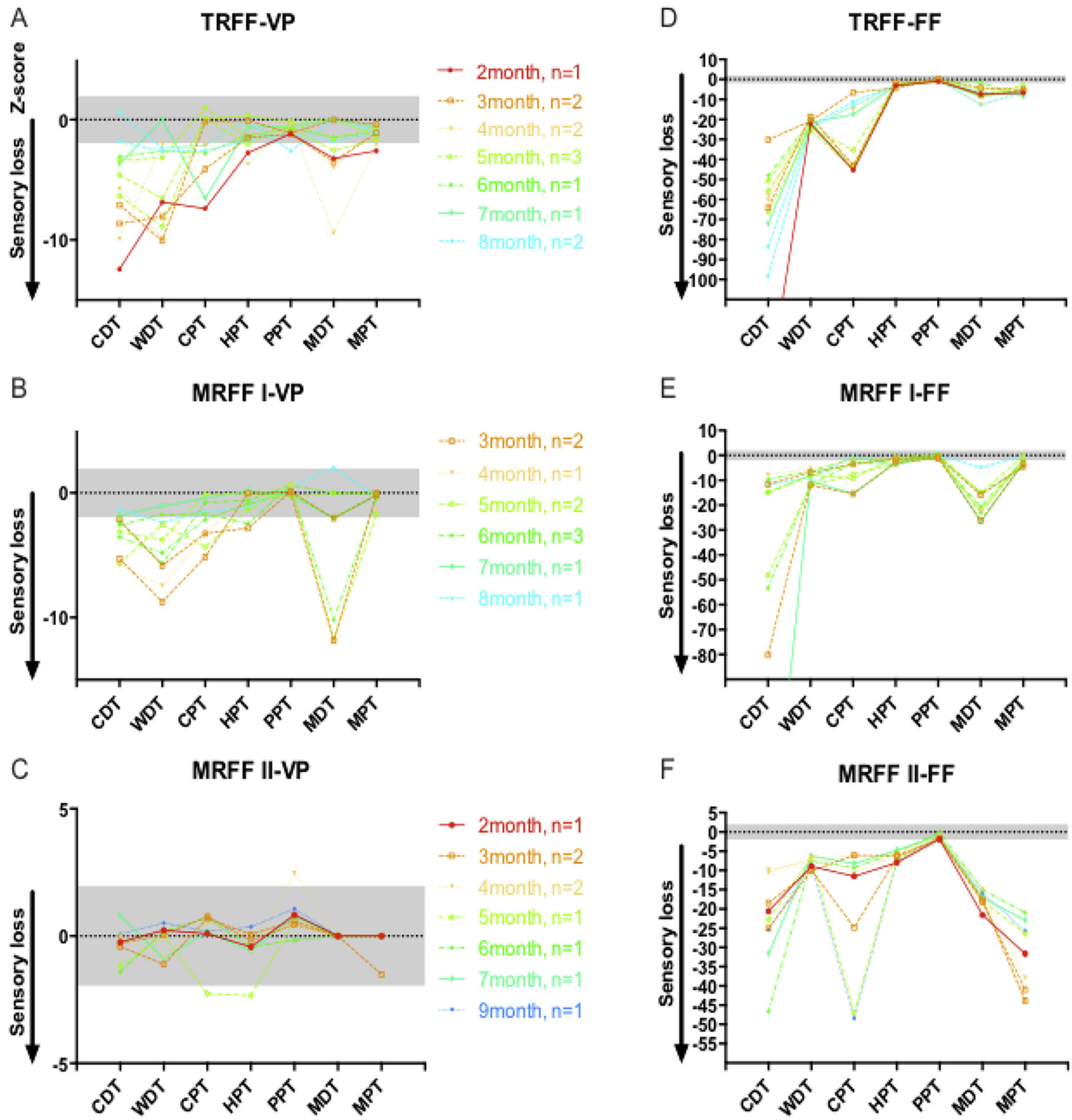

Fig. 2. The Z-score profile of all QST parameters at the vascular pedicle regions from 31 patients. The grey zone indicates a Z-score between −1.96 and + 1.96, representing the normal range as determined from the contralateral side, and the Z-score below-1.96 indicates a loss of somatosensory function. The different follow-up times are marked with different colors. CDT, cold detection threshold; WDT, warmth detection threshold; CPT, cold pain threshold; HPT, heat pain threshold; PPT, pressure pain threshold; MDT, mechanical detection threshold; MPT, mechanical pain threshold. TRFF, traditional radial forearm flap. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

flap selection have not been elaborated so far. Indeed, the three methods have their own advantages and disadvantages. First, both TRFF and MRFF-II require extra grafting, whereas MRFF-I eliminates this step, causing a greater damage in the operated forearm. Second, a longitudinal incision in TRFF and a triangular incision in MRFF-I are made to secure the best field of vision for the surgeons and may better protect the lateral antebrachial cutaneous nerve. The longitudinal incision is not performed in MRFF-II, but this technique requires better surgical instruments and sufficient proficiency of the surgeons. In this study, a direct comparison of the somatosensory function, as assessed by QST, was made among these flap techniques, and it appears that MRFF-II is better owing to fewer changes in somatosensory function.

The present study also proposed the use of Z-score profiles to evaluate the results in individual patients. In accordance with the group analyses, the Z-score profiles in MRFF-II indicated a better recovery for CDT, WDT and MDT with less impairment at the longer follow-up period (Fig. 2). Interestingly, almost all QST parameters were within the normal range even after a short postoperative time in MRFF-II.

Free flap tissue dissection was generally harvested with the use of electrocautery dissection and surgical clip appliers. The new ultrasonic anatomical surgical technique has been developed to convert high frequency ultrasound (55000 Hz) into mechanical energy by using a harmonic scalpel [28]. This new technique is widely used in many surgical specialties; many studies have reported a reduction in haematoma formation after using harmonic blades in plastic and reconstructive surgeries [29,30]. Owing to the ideal haemostatic function of the harmonic scalpel, the procedure of surgical knot is omitted [31]. Importantly, the mean surgical time has significantly shortened by applying the ultrasonically activated shears compared to electrocautery in a previous study [32]. This was significant in reducing the time of application of the tourniquet, which is usually used for forearm flap preparation. Therefore, the risks of neural injury were reduced [32]. Further, maintaining the integrity of the epidermis at the VP site can reduce the damage of the superficial nerve fibres, which might be the reason why somatosensory recovery in MRFF-II appeared to be better than that with TRFF and MRFF-I techniques.

4.3. Limitations of the study

Primarily, the study was a cross-sectional study with only around 2–9 months of follow-up. Therefore, the relationship between somatosensory changes at the VP site and long-term follow-up requires further exploration. Besides, the results of this study should be interpreted with caution. First, all QST assessments in this study were based on the patient's subjective judgments that could lead to response bias. Electrophysiological studies, in other aspect, e.g., using nerve conduction velocities and cortical evoked potentials, could further investigate objectively the somatosensory deficits in response to the flap procedures. Additionally, the total sample size and the sample size of each group were relatively small, which may affect the strength of the conclusion. A larger sample size should be used in future studies.

5. Conclusions

The present study tested the somatosensory changes at the forearm donor site after three different types of flap surgeries. Significant disturbances in somatosensory functions were detected after all types of surgical procedures. However, the MRFF-II was associated with a better sensory recovery. These results might contribute to decision-making in specific types of radial free flap procedures.

Ethical approval

The study was approved by the Nanjing Medical University Research Ethics Committee (PJ2017-035- 001) and all patients signed informed consent forms.

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Author contribution

Fang Wang: Study design, concept, writing; Xu Ding: Data collection, data analysis; Xiaomeng Song, Yunong Wu: Corresponding author; Jinglu Zhang: Review the data organization; Peter Svensson, Kelun Wang: Review the data management.

Conflicts of interest

There are no conflicts of interest to declare.

Guarantor

Xiaomeng Song.

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