

Reinnervation of Flaps and Grafts of the Face

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Background: The degree to which disruption of sensory innervation is affected by flaps and grafts on the face has not been explored. The decision to choose a flap or a graft for reconstruction may affect future sensation at the surgical site.

Objectives: To characterize the clinical recovery of sensory innervation after facial reconstructive surgery with flaps and grafts and to offer clinical guidelines on the recovery of sensation in reconstructed sites involving flaps and grafts of the face.

Methods: Seventy patients who underwent Mohs surgery and subsequent repair by either a flap or a graft were evaluated at different postoperative intervals. Fifty patients underwent flap reconstruction and 20 patients underwent graft reconstruction. Three principal modes of sensation were objectively assessed: light touch, temperature, and pinprick.

Results: Median time of evaluation after surgery was 11 months. The most common locations tested were the nose (36 patients) and the forehead (9 patients). Postoperative evaluation showed that flap sensation recovery to light

touch was present in 10% of patients before 3 months, 41% of patients from 3 to 12 months, 27% of patients from 1 to 2 years, and 75% of patients after 2 years. Graft sensation recovery to light touch was present in no patients evaluated less than 2 years after surgery and in 29% of patients evaluated more than 2 years after surgery. After adjustments for postoperative size and interval, patients with flaps were more likely than those with grafts to have touch sensation at the time of testing (adjusted odds ratio, 8.91; 95% confidence interval, 1.06-74.62; $P = .04$), to be able to distinguish between warm and cold (adjusted odds ratio, 3.99; 95% confidence interval, 1.05-15.16; $P = .04$), and to be able to distinguish between sharp and dull (adjusted odds ratio, 27.31; 95% confidence interval, 2.20-339.71; $P = .01$).

Conclusions: Predictable factors are associated with sensation recovery in patients with flaps and grafts. The recovery of sensory innervation after surgery is earlier with flaps than with grafts. Our data provide clinicians with guidelines for recovery of sensation that ultimately will reassure the patient.

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SENSORY CHANGES are a normal postoperative consequence of disruption of the neural network. The recovery of this neural network is required for restoration of normal sensation. Normal cutaneous sensation consists of the ability to perceive touch, pain, and temperature differences. The potential for loss of normal sensation in the operative area is often overlooked by the clinician; however, its effect on the patient can be substantial. Lack of cutaneous sensation compromises the skin's primary function to act as an adequate barrier. Sensory deficits and changes are especially disturbing on the face, where reconstructive surgery is commonly needed as a consequence of cutaneous malignant lesions. The face has been

shown to be the most sensitive area of the body for pressure sensitivity.¹

Testing for cutaneous sensation in dermatologic practices has evolved from testing in patients with leprosy.² Monofilament testing is an objective test for assessing light touch. This method has been shown to be reproducible in many clinical situations.³⁻⁵ Although subjective tests for sensation are useful, they are often not reproducible or are not correlated with objective testing.

The purpose of our study was to assess objectively and subjectively the degree of sensation and the timing of the return of sensation within the reconstructed site. We ultimately sought to provide clinically applicable guidelines for predicting the return of cutaneous sensation in patients with flaps and grafts of the head.

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PATIENTS AND METHODS

Seventy patients who had undergone reconstructive surgery after Mohs micrographic surgery for a neoplasm on the head agreed to participate in our study during routine follow-up visits. All provided informed consent after testing was fully explained. The study was conducted between September 1996 and February 1997. Operative and histological reports were reviewed for time from surgery in days, preoperative size of lesion removed, postoperative size of final closure, flap or graft size and type, anatomical site of surgery, and histological diagnosis.

A standardized questionnaire of subjective sensory loss or changes was completed before any objective testing was done on the patient. One of us (M.E.L.) performed all the sensory tests. Three methods of testing were used. Monofilament testing assessed light touch by use of the lightest monofilament detected on normal control skin. For temperature testing, the handle of a metal forceps was submerged in ice water and hot water. Pinprick testing assessed pain by application of the sharp, pointed end of the pin for sharp and the blunt, round end for dull. All testing was done on the same point of the reconstructed surface, either on the leading edge of a flap or from the middle of the graft; suture lines were avoided. Before formal sensory testing, each patient underwent control testing on normal skin from the opposite side of the face. If results of control testing were inaccurate with any method, that mode of testing was disregarded. The patient was asked to respond orally to the stimulus. Each maneuver was performed in triplicate for each patient. If 1 testing episode did not produce a reaction, that method of testing was considered to have failed in that patient.

Fisher exact tests were used to compare the 2 populations of flaps and grafts for categorical variables, and Wilcoxon rank sum tests were used to compare the 2 populations for the continuous variables (Table 1). Multivariate logistic regression analyses were used to control for preoperative size and number of months from surgery when results for flaps and grafts were tested, and adjusted odds ratios and 95% confidence intervals based on the logistic regression analyses were given.

RESULTS

Of 70 patients, 39 were men and 31 were women. The mean age was 70 years for each group. Twenty grafts and 50 flaps were tested. The histological diagnoses were as follows: 58 basal cell carcinomas, 9 squamous cell carcinomas, and 3 melanomas. Of all patients, 3 received radiation at the site of reconstruction (Table 1). In 2 patients with flaps, intraoperative resection of major sensory nerves was noted. The most common location tested (36 patients) was the nose (Table 2).

Of 50 patients with flaps, 2 failed the internal control with light touch testing, 5 failed the internal control with temperature testing, and 7 failed the internal con-

Table 1. Comparison of Patient Characteristics in Flap and Graft Groups

	Flap Group	Graft Group	P
Categorical variables, No. (%)			
Sex			.25
Male	30 (60)	9 (45)	
Female	20 (40)	11 (55)	
History of radiation treatment	3 (6)	0	.55
Basal cell carcinoma	42 (84)	16 (80)	.73
Squamous cell carcinoma	5 (10)	4 (20)	.21
Malignant melanoma	3 (6)	0	...*
Continuous variables, median (range)			
Age at surgery, y	70.9 (43-90)	70.3 (43-93)	.70
Preoperative size, cm ²	2.1 (0.5-35.3)	1.4 (0.2-64.4)	.33
Postoperative size, cm ²	3.5 (0.7-38.4)	2.0 (0.3-81.3)	.29

*Data not applicable.

trol with sharp and dull testing. Of the 20 patients with grafts, 1 failed the internal control with light touch and pinprick testing and 2 failed the internal control with temperature testing.

FLAPS

Of 50 patients with flaps, 10 were evaluated within 3 months of surgery, and 1 patient (10%) perceived light touch (Figure 1). Of 17 patients with flaps evaluated 3 months to 1 year after surgery, 7 (41%) perceived light touch. Of 11 patients with flaps evaluated 1 to 2 years after surgery, 3 (27%) perceived light touch. For flaps evaluated after 2 years, 9 (75%) of 12 patients perceived light touch. In total, 40% of patients with flaps perceived light touch at the time of evaluation.

Three (30%) of 10 patients with flaps evaluated within 3 months of surgery could differentiate warm from cold. At 3 to 12 months, 10 (59%) of 17 patients could differentiate warm from cold. Between 12 and 24 months, 6 (55%) of 11 patients could differentiate warm from cold. After 24 months, 10 (83%) of 12 patients could distinguish between warm and cold. In total, 58% of patients with flaps were able to differentiate warm from cold.

In differentiating dullness from sharpness, 3 (30%) of 10 patients succeeded within 3 months. In the group evaluated between 3 and 12 months, 8 (47%) of 17 patients could distinguish between sharp and dull sensations. Five (45%) of 11 patients evaluated at 12 to 24 months could differentiate these 2 sensations. In the group evaluated more than 24 months after surgery, 8 (67%) of 12 patients could distinguish between sharp and dull. In total, 48% of patients with flaps could distinguish between sharp and dull at the time of evaluation.

Twenty-one (42%) of 50 patients with flaps reported subjective sensory loss at the site of surgery at the time of evaluation. Of these, 6 patients were evaluated within 3 months of surgery, 6 were evaluated at 3 to 12 months, 6 were evaluated at 12 to 24 months, and 3 were evaluated after 24 months. Of 50 patients, 30 (60%) reported sensory distortion at the site of the operation.

Table 2. Site of Tumor in Flap and Graft Groups

Site	Patients, No. (%)	
	Flap	Graft
Forehead	8 (16)	1 (5)
Cheek	1 (2)	0
Nose	22 (44)	14 (70)
Ear	2 (4)	1 (5)
Preauricular	4 (8)	0
Upper lip	1 (2)	0
Other	12 (24)	4 (20)
Total	50	20

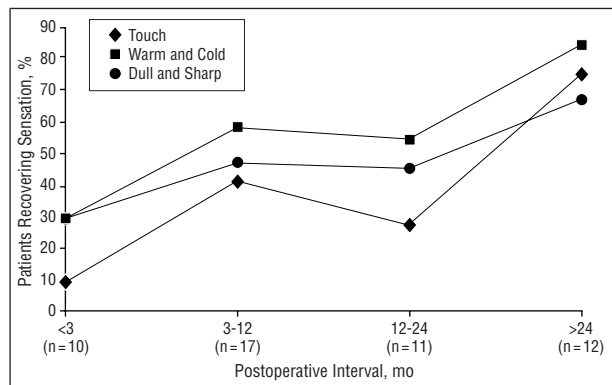


Figure 1. Sensation recovery in patients with flaps. The number of patients evaluated in each interval is shown in parentheses.

GRAFTS

All 13 patients with grafts evaluated less than 24 months after surgery were unable to perceive light touch (**Figure 2**). Of 7 patients evaluated more than 24 months after surgery, 2 patients (29%) could perceive light touch. In total, 10% of patients with grafts were able to perceive light touch at the time of evaluation.

Three (23%) of 13 patients evaluated less than 24 months after surgery could differentiate warm from cold. Three (43%) of 7 patients evaluated after 24 months could differentiate warm from cold. In total, 30% of patients with grafts could distinguish between warm and cold at the time of evaluation.

None of 13 patients evaluated less than 24 months after surgery could distinguish between sharp and dull. Three (43%) of 7 patients evaluated after 24 months could differentiate sharp from dull. In total, 15% of patients with grafts could detect the difference between sharp and dull sensations.

Seven (35%) of 20 patients with grafts reported sensory loss, and 8 (40%) of 20 patients reported sensory distortion.

COMPARING FLAPS AND GRAFTS

Patients with flaps were more likely than those with grafts to have touch sensation at the time of testing (adjusted odds ratio, 8.91; 95% confidence interval, 1.06-74.62; $P = .04$), the ability to distinguish between warm and cold (adjusted odds ratio, 3.99; 95% confidence interval, 1.05-

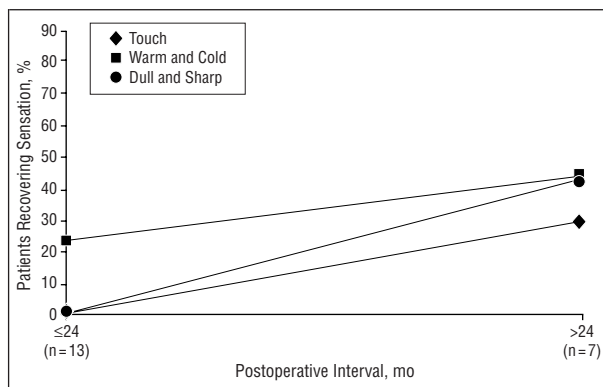


Figure 2. Sensation recovery in patients with grafts. The number of patients evaluated in each interval is shown in parentheses.

15.16; $P = .04$), and the ability to distinguish between sharp and dull (adjusted odds ratio, 27.31; 95% confidence interval, 2.20-339.71; $P = .01$) after controlling for postoperative size and number of months after surgery.

SUBJECTIVE VS OBJECTIVE TESTING

In the total population of 70 patients, 28 (40%) reported a subjective sensory loss. Of these, 21 patients (75%) were unable to perceive light touch with monofilament testing, 15 patients (54%) were unable to differentiate warm from cold, and 17 patients (61%) were unable to differentiate sharp from dull. Of 70 patients, 38 (54%) had a subjective perception of sensory distortion at the surgical site. Of these, 27 patients (71%) were unable to perceive light touch, 17 patients (45%) were unable to differentiate warm from cold, and 22 patients (58%) were unable to differentiate sharp from dull.

Of patients with flaps, 42% reported sensory loss (defined in the questionnaire as numbness) and 60% reported sensory distortion. In comparison, 60% of patients with flaps were unable to perceive light touch and 26% were unable to perceive any of the sensations tested. Of patients with grafts, 35% reported sensory loss and 40% reported sensory distortion. Of all patients with grafts, 90% were unable to perceive light touch and 60% were unable to perceive any of the sensations tested.

COMMENT

The reinnervation after surgery of a flap or graft depends on the regrowth of cutaneous nerves along with proper vascular support. Previous studies using histochemical staining determined the mechanisms of cutaneous reinnervation.⁶ In grafted sites, nerves regenerate from the wound edges and the graft bed. The regeneration occurs randomly except in the epidermis and upper dermis, where the nerves tend to migrate toward the follicular and appendageal structures. Reinnervation depends on an intact neural network in the recipient bed of the flap or graft.

Results of related studies demonstrate sensory reinnervation after cutaneous surgery. In the evaluation of flaps in the oral cavity, Close et al⁷ found spontaneous reinnervation in 83% of patients who underwent recon-

struction with noninnervated flaps. Results of studies by Lahteenmaki et al⁸ and Chang et al⁹ investigating flaps on the extremities demonstrate sensory recovery. In graft sites, results of studies show the return of sensation as well as autonomic function.¹⁰ Several investigators^{11,12} described the correlation between return of sweating and return of sensation in transplanted skin.

In this study, we characterized the degree to which cutaneous reconstructed flaps and grafts of the face undergo reinnervation. Results of our study demonstrate that sensory recovery for light touch, temperature, and pinprick steadily improve with increasing time after the operation. Most patients could distinguish between warm and cold. The reasons for this are unclear. However, the object used to test for warm and cold differentiation had a large surface area that may have impinged on adjacent nonoperative tissue. Although every attempt was made to avoid this error, small flap and graft sites may have been susceptible, and a higher than true value for warm and cold differentiation may have resulted. Our results thus differ from those in previous studies^{7,13-15} of noninnervated extremity flaps and oral cavity or oropharyngeal flaps, which showed that sensation recovered in a predictable manner, with pinprick or pain first, touch and 2-point discrimination next, and temperature last.

Intuitively, one would expect flaps to regain the ability for sensation more quickly than grafts because an undivided tissue pedicle is maintained. In 1966, Santoni-Rugiu¹⁶ confirmed this supposition, reporting in a histological study that nervous structures reappeared earlier in patients with flaps than in those with free skin grafts. Results of our study support these histological findings with clinical testing. For all 3 methods of sensation testing, flaps fared better than grafts. Patients with flaps were 9 times more likely to recover touch sensation, 4 times more likely to detect temperature differences, and 27 times more likely to distinguish between sharp and dull when size and postoperative interval were controlled. For the categorical and continuous variables, no statistically significant difference was found between the 2 groups (Table 1).

In comparing subjective questionnaire responses with results of objective tests of neurosensation, results of previous studies show a lack of agreement. Coghlan and Irvine¹⁷ reported that patients tended to understate their sensory deficits. In contrast, Cunningham et al¹⁸ found that patients overreported neurosensory problems. In total, our patients tended to understate sensory deficits.

Although the data accrued from our study are statistically relevant, a few limitations should be noted. First, the study design was not longitudinal or prospective and merely tested each patient at a single point in time. The number of patients tested, however, permits extrapolation of clinically useful information. The relevance of detailed extrapolation would be less accurate. The biases inherent in a retrospective study design are present. Second, because our study population had a mean age of 70

years, these data may not apply to younger patients undergoing reconstructive surgery.

In summary, predictable factors are associated with sensory recovery in patients undergoing reconstruction with flaps and grafts on the face. Sensory recovery tends to improve with time and is better in patients with flaps than in those with grafts. Patients with flaps can be reassured that after 2 years, sensation is regained in 75% of patients. Patients with grafts should be informed that touch sensation is regained after 2 years in only 29% of patients. The degree to which sensory dysfunction in flaps and grafts of the face affects quality of life and patient satisfaction needs to be explored for a full understanding of sensory dysfunction after facial reconstructive surgery. In the meantime, we believe that clinicians should routinely consider the potential sensory changes that may result from reconstructive closure.

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REFERENCES

1. Weinstein S. Fifty years of somatosensory research: from the Semmes-Weinstein monofilaments to the Weinstein Enhanced Sensory Test. *J Hand Ther.* 1993;6:11-22.
2. Owen BM, Stratford CJ. Assessment of the methods available for testing sensation in leprosy patients in a rural setting. *Lepr Rev.* 1995;66:55-62.
3. Mueller MJ. Identifying patients with diabetes mellitus who are at risk for lower-extremity complications: use of Semmes-Weinstein monofilaments. *Phys Ther.* 1996;76:68-71.
4. Bell-Krotoski J, Tomancik E. The repeatability of testing with Semmes-Weinstein monofilaments. *J Hand Surg Am.* 1987;12:155-161.
5. Lewis S. Reproducibility of sensory testing and voluntary muscle testing in evaluating the treatment of acute neuritis in leprosy patients. *Lepr Rev.* 1983;54:23-30.
6. Waris T, Rechartd L, Kyosola K. Reinnervation of human skin grafts: a histochemical study. *Plast Reconstr Surg.* 1983;72:439-447.
7. Close LG, Truelson JM, Milledge RA, Schweitzer C. Sensory recovery in noninnervated flaps used for oral cavity and oropharyngeal reconstruction. *Arch Otolaryngol Head Neck Surg.* 1995;121:967-972.
8. Lahteenmaki T, Waris T, Asko-Seljavaara S, Sundell B. Recovery of sensation in free flaps. *Scand J Plast Reconstr Surg Hand Surg.* 1989;23:217-222.
9. Chang KN, DeArmond SJ, Buncke HJ Jr. Sensory reinnervation in microsurgical reconstruction of the heel. *Plast Reconstr Surg.* 1986;78:652-664.
10. Terzis JK. Functional aspects of reinnervation of free skin grafts. *Plast Reconstr Surg.* 1976;58:142-156.
11. Lofgren L. Recovery of nervous functions in skin transplants with special reference to sympathetic functions. *Acta Chir Scand.* 1951;102:229-239.
12. Hurley HJ, Shelley WB. Acquired emotional sweating in transplants. *Arch Dermatol.* 1957;75:815.
13. Kredel FE, Evans JP. Recovery of sensation in denervated pedicle and free skin grafts. *Arch Neurol Psychiatry.* 1933;29:1203-1221.
14. Davis JS, Kitlowski EA. Regeneration of nerves in skin grafts and skin flaps. *Am J Surg.* 1934;24:501-545.
15. Davis L. Return of sensation to transplanted skin. *Surg Gynecol Obstet.* 1934;59:533-543.
16. Santoni-Rugiu P. An experimental study on the reinnervation of free skin grafts and pedicle flaps. *Plast Reconstr Surg.* 1966;38:98-104.
17. Coghlan KM, Irvine GH. Neurological damage after sagittal split osteotomy. *Int J Oral Maxillofac Surg.* 1986;15:369-371.
18. Cunningham LL, Tiner BD, Clark GM, Bays RA, Keeling SD, Rugh JD. A comparison of questionnaire versus monofilament assessment of neurosensory deficit. *J Oral Maxillofac Surg.* 1996;54:454-459.