Outcomes of Microneurovascular Facial Reanimation Using Masseteric Innervation in Patients With Long-Standing Facial Palsy Resulting From Cured Brainstem Lesions

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BACKGROUND: The functions of the human face are not only of esthetic significance but also extend into metaphoric nuances of psychology. The loss of function of one or both facial nerves has a remarkable impact on patients' lives.

OBJECTIVE: To retrospectively analyze the functional outcomes of microneurovascular facial reanimation using masseteric innervation.

METHODS: Seventeen patients with irreparable facial paralysis resulting from benign lesions involving the facial nuclei (n = 14) or Möbius syndrome (n = 3) were treated with free muscle flaps for oral commissural reanimation using ipsilateral masseteric innervation and using temporalis muscle transfer for eyelid reanimation. Results were analyzed by the absolute commissural excursion and commissural excursion index and by a patient self-evaluation score. Presence of synkinesis was documented. Follow-up ranged from 8 to 48 months (mean, 26.4 months).

RESULTS: Normalization of the commissural excursion index was observed in 8 of 17 patients (47%), an improvement was seen in 7 of 17 (41%), and failure was observed in 2 of 17 (12%). The individual dynamics of absolute commissural excursion and commissural excursion index changes are presented. A natural smiling response was observed in 10 of 17 patients (59%) but not in the remaining 7 (41%). This response reflected the patient's ability to relay the natural emotion of smiling through the masseteric nerve. Patients' self-evaluation scores were a level higher than objective indices.

CONCLUSIONS: Innervation of free muscle flaps with the masseteric nerve for oral commissure reanimation might play an important role in patients with lesions of the facial nuclei (as in Möbius syndrome). Synkinesis persists for long periods after surgery. However, most of the patients learned to express their emotions by overcoming this phenomenon. Despite hypercorrection or inadequate correction, patients evaluated themselves favorably.

KEY WORDS: Facial nerve, Facial paralysis, Free functional muscle flaps, Masseteric nerve

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The functions of the human face not only are of esthetic significance but also extend into metaphoric nuances of psychology.[1-3] The human face has been so exhaustively treated in literature sources of different times and cultures that the meaning of the word "face" ventures into abstraction.[2-4] Approximately 70% of the function of the face can be traced to the intactness of the facial nerves. Thus, the loss of function of one or both facial nerves has a remarkable impact on patients' lives. The treatment of facial paralysis is based on several factors such as the level of neural (nerve or centers) lesion, latency between the time of lesion and the time of treatment, age, concomitant conditions of the patient, and consequently the general prognosis.[5,6] Whereas acute lesions of the facial nerve, eg, lacerations or iatro-

ABBREVIATIONS: CEI, commissural excursion index; **FFMT**, free functional muscle transfer

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genic injury during removal of tumors, may be surgically treated by nerve repair or nerve transfer,[7-9] in chronic lesions, the target mimic muscles undergo atrophic changes and are not receptive to a regenerating nerve.[6,10-12]

Long-standing nerve lesions may be defined as irreparable when the palsy is persistent for > 1 year, the target muscles show complete atrophy and connective tissue transformation, and/or primary nerve reconstruction has failed to reinnervate the muscles at a follow-up of > 1 year. Such a lesion is irreparable, however, not in the surgical sense of the word but rather from the perspective of possible outcomes after primary nerve repair. Atrophy with complete loss of neuromuscular synapses and connective tissue transformation of a muscle occurs approximately 1 year after denervation. These cases can be reanimated only by means of secondary procedures such as tendon and muscle transfers or transplantation.

Although a very complex and combined movement pattern involved in the expression of emotions is lost with an irreparable facial nerve lesion, the 2 most important functions that debilitate the patients are lack of eyelid closure, which leads to chronic inflammation, and slackness of the oral commissure, which imparts a cosmetically unacceptable appearance and causes a functional inability to withhold food particles being chewed. Thus, these 2 anatomic regions are the main targets of surgical reanimation of the paralyzed face.[13-15] Various static and dynamic procedures have been described.[16,17] The microsurgical reanimation of the paralyzed face is by means of autotransplantation of a free vascularized and innervated muscle flap (also known as free functional muscle transfer [FFMT]) either to the oral commissure alone or to both the oral commissure and the eyelids.[18-20] The most commonly applied microsurgical facial reanimation consists of addressing the oral commissure with an FFMT and the eyelid closure through the transfer of a strip of the temporalis muscle.[14,16,18] The mode of innervation of the FFMT is the crux of the issue leading to success. In unilateral paralysis, the contralateral facial nerve is used to reinnervate the FFMT in either a 2-stage or a 1-stage approach.[20-23] In bilateral facial paralysis, eg Möbius syndrome, the masseteric nerve (a motor branch of the trigeminal nerve) is used to reinnervate the FFMT.[13,24,25] There is considerable debate as to the reinnervation of the FFMT with nerves other than the facial nerve because it is allegedly the only pathway leading to proper facial expressions.[14,16,23,26] Our observations challenge this hypothesis.

From our initial results of quick and wholesome reinnervation of the FFMT using the masseteric nerve in patients with bilateral or nearly bilateral facial paralysis (as an aftermath of benign lesions of the brainstem that were successfully healed) as opposed to those receiving a 2- or 1-stage reinnervation using the contralateral facial nerve, we extended our practice of exclusively using the masseteric nerve as the motor donor of the FFMT to patients with long-standing unilateral facial palsies. The long-term functional outcomes of the former group are presented in this article. A hypothesis on neuronal plasticity of facial expressions is proposed and discussed.

PATIENTS AND METHODS

Patients

Seventeen patients were included in this analysis (14 female and 3 male patients; age range, 18-62 years; mean age, 43.5 years; Table 1). Fourteen patients had established long-standing unilateral facial nerve palsy as an aftermath of lesions of the brainstem involving the facial nuclei (the primary disease had been cured). Three other patients were adults with neglected Möbius syndrome. The patients were operated on between February 2001 and November 2008 and followed up until May 2009. Follow-up ranged from 8 to 48 months (mean, 26.4 months). For ease of understanding the dynamics, the patients were divided into 3 categories according to the available follow-up data: 8 to 18, 22 to 36, and 48 months.

The prerequisites for surgery included the following: (1) unilateral or bilateral irreparable (for definition, see above) flaccid facial palsy of any genesis persistent for > 1 year despite initial attempts of primary nerve reconstruction through repair or transfer, (2) absence of a consuming concomitant disease (patients should have been cured of their benign brainstem lesions), (3) presence of a powerful masseteric nerve function verified by clinical examination before planning, and (4) a physiologically young and otherwise healthy patient.

Surgical Technique

A pretragal straight-line incision is made on the affected side of the face. The superficial temporal vessels are dissected and kept ready for revascularization of the muscle flap (see Figures 1 and 2 and Video 1, Supplemental Digital Content 1, http://links.lww.com/NEU/A320, which shows the surgical technique of microneurovascular facial reanimation using masseteric innervation).

Identification of the Masseteric Nerve

The deep fascia and the masseteric insertion from the lower border of the zygomatic arch are incised. Microsurgical dissection is carried out in the depth in the matter of the masseter with bipolar nerve stimulation forceps (Aesculap, Tuttlingen, Germany). The masseteric nerve is visualized coursing the inner aspect of the masseter (positive nerve stimulation response can be observed from the masseter muscle). This nerve is followed distally, and a branch containing 2 fascicles is separated and kept ready for reinnervating the free microneurovascular muscle flap (Figure 1D and 1E).

Next, a straight incision is made along the nasolabial fold of the affected side, and the modiolus is grasped with two 2-0 nonabsorbable, braided sutures (Mersilene). A subcutaneous tunnel is made between the pretragal incision and the nasolabial incision with a retractor-integrated endoscope, meticulously coagulating bleeders (Figure 1C). This pocket will lodge the muscle flap. A portion of the gracilis muscle (12 flaps), latissimus dorsi (2 flaps), or serratus anterior (3 flaps) is raised as 1 functioning motor unit on the basis of their respective microvessels and nerves[27](Figure 1A and 1B). This flap is brought to the face and spanned between the modiolus and the zygomatic arch with 2-0 nonabsorbable, braided sutures (Mersilene; Figure 2). Then, the microvessels of the flap are anastomosed to the superficial temporal vessels, and the motor nerve is anastomosed to the 2 separated fascicles of the masseteric nerve (Figure 1D through 1G). One Jackson-Pratt drain is inserted into the face, and 1 Redon drain is inserted into the donor area. The wounds are closed in layers after meticulous hemostasis is established (Figure 1I).

TABLE 1. Results of Microneurovascular Facial Reanimation Using Masseteric Innervation: Part 1[a]

Patient/Sex	Side	Cause of Palsy	Latency, y[b]	Age, y	Follow-up, mo	Excursion of the Oral Commissure, cm								Commissural Excursion Indices				Patient Self-Evaluation Score
						Preoperative		8-18 mo		22-36 mo		48 mo		Preoperative	8-18 mo	22-36 mo	48 mo	
						H	P	H	P	H	P	H	P					
1/F	R	Möb-ngl		18	8	4.0	−3.5	3.5	3.0	—	—	—	—	−1.14	1.17	—	—	A
2/F	R	Idio	2	35	9	4.2	−2.8	3.3	2.2	—	—	—	—	1.50	1.50	—	—	B
3/F	L	VS	5	38	10	3.8	−2.4	1.4	1.4	—	—	—	—	−1.58	1.00	—	—	A
4/F	R	Men	2	48	10	3.8	−3.1	3.0	2.5	—	—	—	—	−1.22	1.20	—	—	B
5/M[c]	L > R	Möb-ngl		22	15	2.3	−4.7	2.1	0.9	—	—	—	—	−0.49	2.33	—	—	D
6/F[c]	L	VS	4	49	17	4.2	−3.0	3.6	1.8	—	—	—	—	−1.40	2.00	—	—	C
7/M	L	Men	> 10	60	18	4.8	−3.4	1.8	1.5	—	—	—	—	−1.41	1.2	—	—	B
8/F	R	Hem	3	58	22	3.6	−5.2	3.1	3.7	3.1	2.9	—	—	−0.69	0.88	1.07	—	A
9/F	R	BSG	> 10	62	24	3.6	−3.0	3.9	0.0	3.0	2.1	—	—	−1.20	0.00	1.43	—	A
10/M	R	Möb-ngl		29	27	4.0	−3.4	2.8	1.6	2.8	2.0	—	—	−1.18	1.75	1.40	—	A
11/F	R	Epi	1	37	36	4.1	−4.4	1.9	0.9	1.9	1.1	—	—	−0.93	2.11	1.73	—	B
12/M[d]	L	VS	> 10	48	36	4.5	−2.4	3.7	−0.8	3.7	−0.3	—	—	−1.88	−4.63	−12.3	—	E
13/F	R	VS	5	53	36	4.8	−2.1	2.8	1.9	2.8	1.9	—	—	−2.29	1.47	1.47	—	B
14/F	L	Men	8	53	36	3.8	−2.1	1.6	0.3	1.6	1.2	—	—	−1.81	5.33	1.33	—	A
15/F	R > L	Hem	6	39	48	4.1	−2.2	1.9	2.0	2.0	1.2	1.8	3.5	−1.86	0.95	1.67	0.51	A
16/F	L	Idio	6	44	48	5.9	−3.0	2.4	0.9	2.5	1.7	2.5	1.7	−1.97	2.67	1.47	1.47	A
17/F[d]	L	Hem	4	46	48	3.5	−5.5	2.3	−0.2	2.4	−0.2	2.7	−0.7	−0.64	−11.5	−12.0	−3.86	E
Mean			43.5		26.4	4.1	−3.3	2.7	1.4	2.6	1.4	2.3	1.5	−1.36	1.89	1.45	0.99	
SD						0.7	1.1	0.8	1.2	0.6	1.0	0.5	2.1	0.50	1.37	0.20	0.68	

[a] BSG, brainstem glioma; Epi, epidermoid; H, healthy side; Hem, hemangioblastoma; Idio, idiopathic; L > R, uneven bilateral paresis, left side treated; Men, meningioma; Möb-ngl, neglected Möbius syndrome; R > L, uneven bilateral paresis, right side treated; P, paretic side; VS, vestibular schwannoma.
[b] Rounded.
[c] Improvement and muscle activity were noticeable but not to expected level.
[d] Failed cases; negative excursion improved owing to scarred muscle (static effect).

Eyelid Reanimation Using the Split Temporalis Muscle

Soon after the pretragal incision and isolation of the superficial temporal vessels, a frontal strip of the temporalis muscle is raised and extended using the above-lying fascia. This fascial strip is split into 2. Subcutaneous tunnels are dissected toward the upper and lower eyelids (Figure 1C and 1H). The facial strips of the temporalis muscle are brought to the eyelids and sutured to the wasted orbicularis oculi muscle at the upper and lower eyelids. This procedure was performed in the same sitting as the oral commissure reanimation in 16 of 17 patients.

Postoperative Care

For the first 5 days after surgery, the patients received liquid and semisolid nutrition only and were discouraged from chewing. Face and neck massage was performed to enhance lymphatic drainage (caveat: the face is devoid of lymph nodes and contains only lymph vessels). After facial swelling subsided, transcutaneous exponential current therapy was applied to the transplanted muscle until volitional reinnervation occurred (approximately 2 months postoperatively). Patients were then advised to chew gum to augment the reinnervation of the flap. Once this was done (approximately 3-6 months), specific smile training before the mirror was begun to differentiate the smiling movement from chewing.

Evaluation of Results

Objective Evaluation

Standardized anterior photographs were used for the analysis. Commissural excursion indices (CEIs) were calculated using stationary (laterally the tragus and the nasion and mentum for the midline) and mobile (the oral commissures and the midpoint of the philtrum) landmarks (see Figure 3).

The CEI was calculated as follows: CEI = $(\alpha - \alpha') / (\beta - \beta')$, where α is the distance between the oral commissure and the tragus of

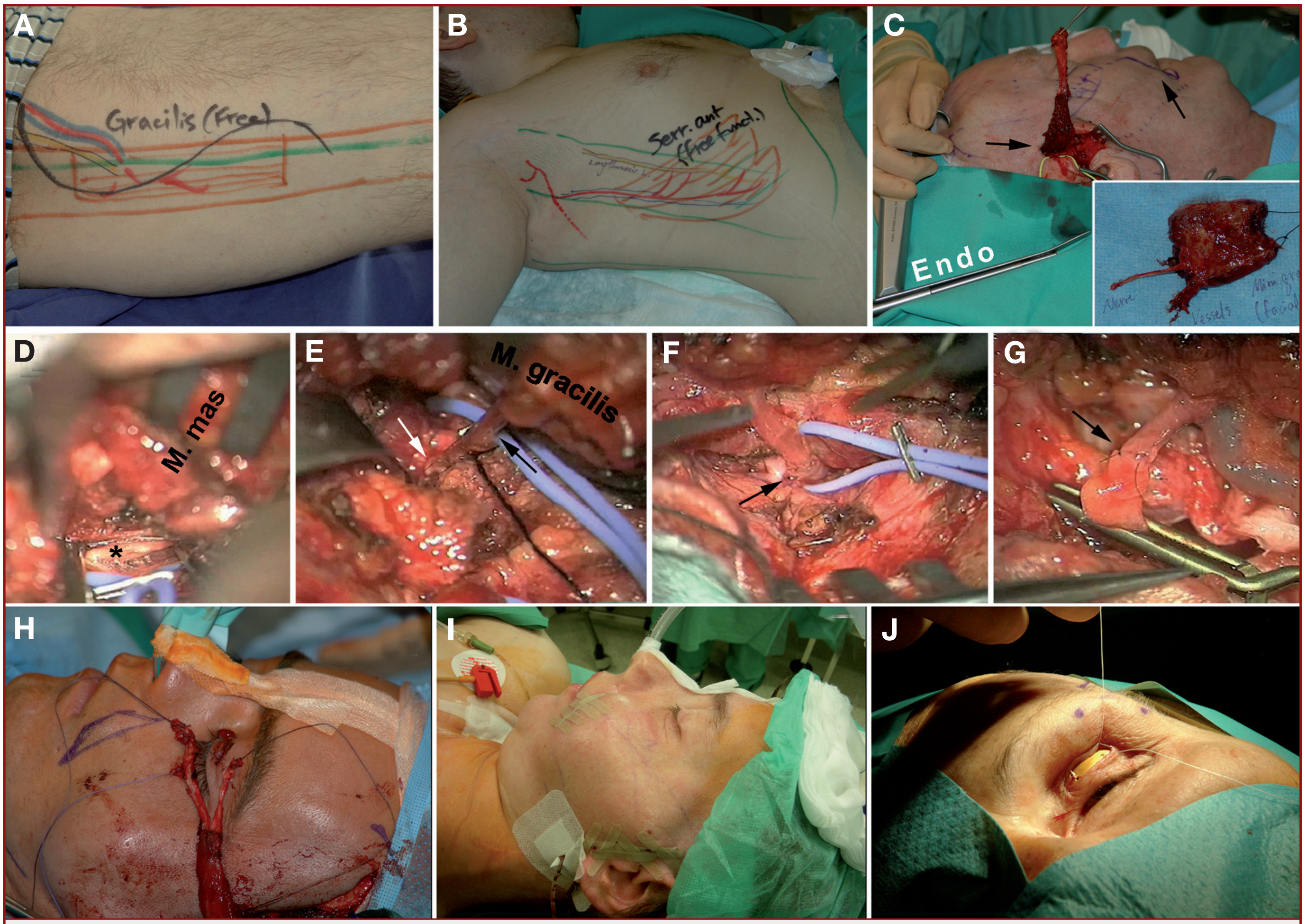

FIGURE 1. *The surgical technique.* **A**, *planning the harvest of the free vascularized and innervated split gracilis muscle flap.* **B**, *planning the serratus anterior flap.* **C,** *the temporalis muscle has been mobilized and awaits subcutaneous transposition. Black arrows show the skin incisions placed in the pretragal area and the nasolabial fold. The retractor-integrated endoscope is used to dissect between the 2 skin incisions. This technique helps prevent postoperative lymphedema of the face and thus surpass complications related to edema (as opposed to long skin incisions). Inset, The harvested muscle flap with its microvessels and nerve.* **D**, *the masseteric nerve (black star) is being prepared for nerve suture with the nerve to the muscle flap.* **E**, *nerve suture has been completed (black arrow, nerve to gracilis; white arrow, 2 fascicles of the masseteric nerve).* **F** *and* **G**, *venous and arterial microanastomoses (black arrows) between the superficial temporal vessels and the vessels to the free muscle flap.* **H**, *temporal muscle transposition for eyelid reanimation.* **I**, *immediate postoperative view after flap insertion (Note that there are only 2 relatively small skin incisions hidden in the nasolabial fold and the pretragal area).* **J**, *insertion of a gold weight in the upper eyelid when temporalis transfer failed. Endo, retractor-integrated endoscope; M. gracilis, gracilis muscle; M. mas, masseter muscle; Serr ant, serratus anterior muscle; .*

the resting healthy side, α' is the distance between the oral commissure and the tragus of the smiling healthy side, β is the distance between the oral commissure and the tragus of the resting affected side, and β' is the distance between the oral commissure and the tragus of the smiling affected side. Absolute values of commissural excursion were documented and the CEIs were calculated.

Interpreting the CEI

The ideal normal CEI value is 1, although values ranging from 1.3 to 0.7 may be accepted as variations of the norm (dotted area in the graph in Figure 5). Negative values always represent severe unilateral facial palsy (diagonally checkered area in Figure 5). Values between 1.5 and 2 denote a certain hypercorrection, whereas values > 2 or < 0.5 mean inadequate correction. Eyelid closure was assessed in a "yes or no" fashion.

Subjective Evaluation

The natural smiling reaction of the patient during a casual conversation with the investigator was documented as muscle activation or nonactivation. A patient self-evaluation questionnaire integrated a column containing the following scores: A = normal function, B = almost-normal function, C = good mobility possible, D = mobility with difficulty, E = minimal or trace movements possible, and F = poor outcome (failure). Persistence of synkinesis with chewing movements was marked as yes or no.

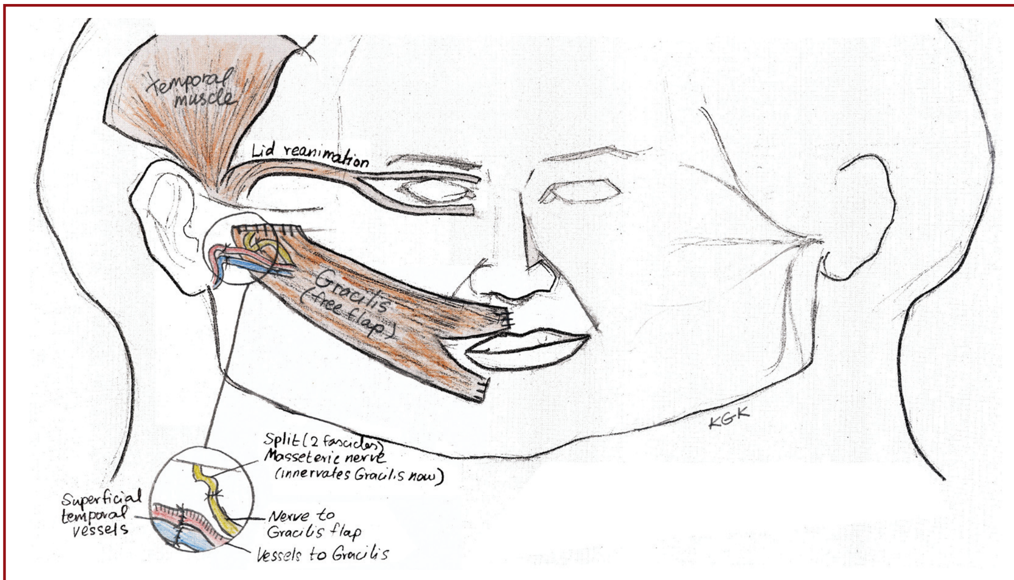

FIGURE 2. *A schematic 2-dimensional representation of the described procedure. As opposed to how it is represented here, both comitant veins are anastomosed. This technique reduces postoperative edema and thus prevents associated complications.*

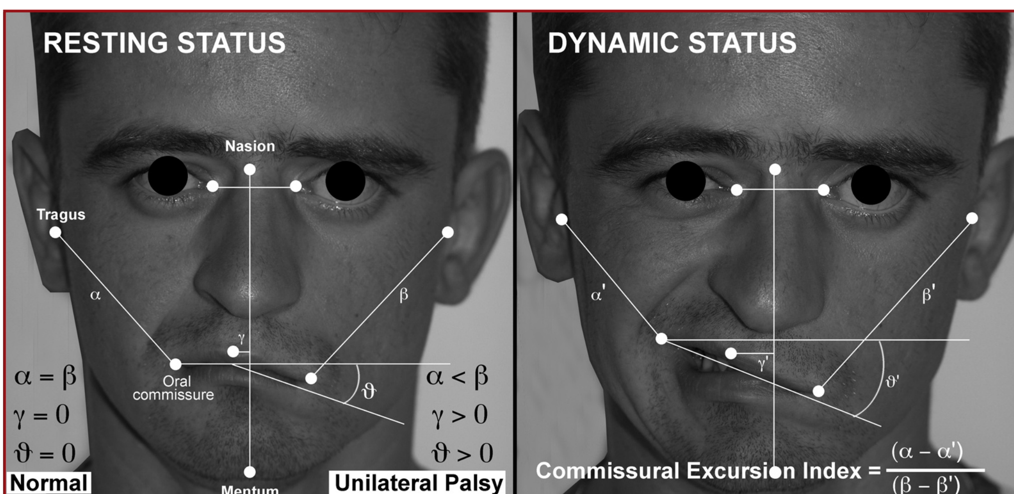

FIGURE 3. *Assessment of frontal-view photographs to calculate the commissural excursion index. The letters are self-descriptive.*

RESULTS

Objective Evaluation

The absolute values of the excursion of the oral commissure, as well as the calculation of the CEIs, which represent the reestablishment of facial symmetry, are provided in Table 1.

Excursion of the Oral Commissure

Patients with unilateral facial paralysis showed an oral commissural excursion of the affected side toward the healthy side. These values were represented as negative integers. As a result of this misbalance, the innervated side showed a higher positive excursion than seen in healthy subjects. The mean commissural excursion of the paretic side accounted to −3.3 ± 1.1 cm (mean ± SD) before surgery, whereas the healthy side showed a mean value of 4.1 ± 0.7 cm. During the follow-up, these values changed to 1.4 ± 1.2 and 2.7 ± 0.8 cm on the affected and healthy sides, respectively. There were no reliable differences in the cumulative mean values found at later stages of the follow-up, although individual patients showed considerable improvement in statuses (see Table 1 and Figure 4).

Commissural Excursion Index

The CEI was calculated to mathematically objectify facial symmetry at rest and smiling. Normalization of the individual CEIs was observed in 8 of 17 patients (47%); an improvement was achieved in 7 of 17 (41%); and surgery failed to improve the outcome in 2 of 17 (12%). Cumulative mean values improved from −1.36 ± 0.5 to 0.99 ± 0.68 at the latest follow-up. The individual values and the dynamics of change are represented in Table 1 and Figure 5.

Subjective Evaluation

The subjective evaluation included 3 paradigms: the presence or absence of activation of the masseteric nerve–innervated FFMT flap on casual conversation with the investigator, the presence or absence of synkinetic movements of the muscle associated with chewing movements, and the patient's self-assessment score (see above).

Muscle Activation

A natural smiling response to casual remarks of the investigator was observed in 10 of 17 patients (59%); in the remaining 7 (41%), this was not the case. The presence or absence of muscle

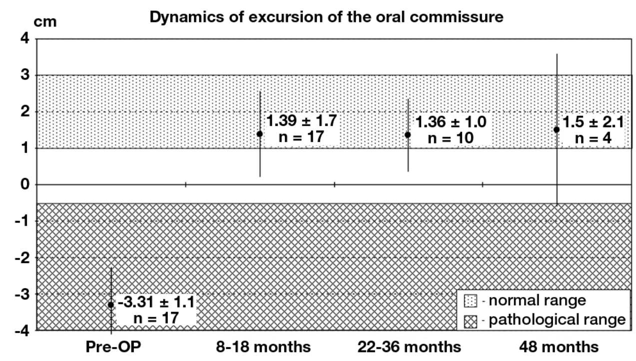

FIGURE 4. *The absolute values of the commissural excursion (in centimeters) in the studied patients plotted against time; x axis shows follow-up times; y axis, excursion in centimeters. Mean ± SD values are shown. Dotted area shows normal range; diagonally checkered area, pathological range.*

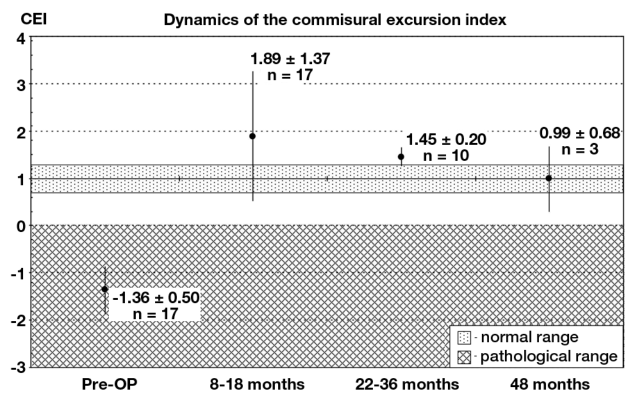

FIGURE 5. *Values of commissural excursion indices obtained in the studied patients plotted against time; x axis shows follow-up times; y axis, values of commissural excursion index. Mean ± SD values are shown. Dotted area shows normal range; diagonally checkered area, pathological range. CEI, commissuaral excursion index*

FIGURE 6. *An example of reinnervation of the free functional muscle transfer flap:* **A**, *preoperative dynamic status.* **B**, *photographs taken approximately 2 months after surgery. Left, Resting status (notice the reestablishment of the "neo"-nasolabial fold). Middle and right, Activation of the inserted free functional muscle transfer flap (reinnervation). Here, the patient was asked to chew (synkinesis).*

activation in a natural smiling response does not reflect the innervation status of the muscle; rather, it reflects the ability of the patient to relay the natural emotion of smiling through a nerve determined to perform the chewing movement (Figure 6).

Synkinesis

Synkinetic movements of the transplanted muscle (see Video 2, Supplemental Digital Content 2, http://links.lww.com/NEU/A321, which shows early and late postoperative masseteric reinnervation of FFMT flap and display of natural emotions at late stages after masseteric innervation) associated with chewing were evident in all patients at their 3-month follow-up, as long as the muscle flap showed innervation (In 4 patients, the muscle was not yet innervated during the first 3 months; in 2 of those patients, the flaps failed to innervate also at later stages of follow-up; Figure 6). Four of 15 innervated muscles transcended synkinesis within the first year after surgery. At and after 1 year, almost all patients in whom the muscle flaps had "taken" and innervated successfully transcended synkinetic movements and were able to provide a normal smiling response (Figure 7). These dynamics can be seen in Table 2.

Patient Self-Evaluation Score

Interestingly, even patients who were considered failed cases according to the objective assessment criteria did not evaluate themselves as failures (2 of 17, score E). Eight of 17 responded with a score of A, 5 with a score of B, and 1 each with a score of C and D. It was evident that patients' self-evaluation scores were a level higher than those of the investigators.

Eyelid Closure

The temporalis muscle was transferred in 16 of 17 patients for eyelid closure (Figure 1H). Only 9 of 16 patients (53%) achieved complete eyelid closure; in 5 of 16 (29%), closure was inadequate, and in 3 of 16 (18%), the temporalis muscle transfer for eyelid closure failed to produce the desired result. In 1 failed case and in 3 cases of inadequate closure, appropriately calibrated gold or platinum weights were implanted in the upper eyelid at later stages (Figure 1J). Two additional patients, to whom we had suggested this ancillary surgery to improve their results, declined the operation.

Complications

Two patients experienced microvascular complications during the early postoperative phase. Because ultrasound scan showed no bleeding and Doppler study confirmed the patency of the microvas-

FIGURE 7. *An example of conquered synkinesis. Still frames were taken from a video recording of a casual conversation with the patient who underwent the facial reanimation procedure described here 4 years ago. Start observing the still frames from top left and follow the arrows. There is still some dynamic asymmetry visible. However, the patient uses the free functional muscle transfer flap innervated by the masseteric nerve to display emotional response.*

cular anastomoses, surgical revision was not performed. Both patients failed to show muscle innervation at later stages (failed cases). One patient showed profuse bleeding at the muscle donor and another at recipient areas within several hours after surgery. Their wounds were revised, blood clots were removed, and meticulous hemostasis was reestablished. Recuperation was uneventful, and the complications did not affect the final outcome. One other patient presented with an abscess of the cheek owing to a parotid fistula 8 weeks after surgery. The abscess was drained through the mucosal layer of the mouth. Eventually, this complication did not affect the innervation of the transplanted muscle or the final outcome. In 1 female patient, the reinnervation of the muscle flap at long-term follow-up was found to be too powerful, creating an asymmetrical smile favoring the affected side (Figure 8). We suggested debulking the transplanted muscle flap, which the patient declined.

One female patient experienced repeated (twice) migration of the gold weighting in her upper eyelid (Figure 9). She underwent corrective surgery twice to fix or replace the gold weighting.

DISCUSSION

Study of Facial Symmetry

The evolution of microneurovascular facial reanimation procedures has followed a physiological approach. According to classic teachings, it was mandatory to achieve innervation of the free muscle flap via the facial nerve (contralateral in the case of a unilateral irreparable facial palsy).[13,14,16,23] Thus, the 2-stage procedure that used a cross-face nerve graft in the first sitting followed by transfer of the free muscle flap (innervated by the cross-face nerve graft bringing in potentials from the contralateral VII) in the next sit-

TABLE 2. Results of Microneurovascular Facial Reanimation Using Masseteric Innervation: Part 2[a]

Patient/Sex	Associated CN Pathology	Synkinetic Movements Associated With Chewing						Natural Smiling Response	Eye Closure	Complications	Ancillary Procedures
		3 mo	8 mo	12 mo	24 mo	36 mo	48 mo				
1/F	—	Y	Y	—	—	—	—	MnA	Y	—	—
2/F	—	Y	Y	—	—	—	—	MA	Y	—	—
3/F	VI	Y	Y	—	—	—	—	MA	N	—	Lid weighting
4/F	—	Y	Y	—	—	—	—	MA	Y	—	—
5/M	Arn.Ch. + SB	—	Y	Y	—	—	—	MnA	N	Cheek abscess→drainage	Refused weight
6/F	VI	—	Y	Y	—	—	—	MnA	Y/N	—	Lid weighting
7/M	IX-XII	N	Y	Y	—	—	—	MnA	Y/N	Bleeding (recipient site)→revision	Refused weight
8/F	IX-XII, ataxia	Y	N	N	—	—	—	MA	Y	—	—
9/F	IX-XII	—	Y	Y	N	—	—	MA	N	—	Lid weighting
10/M	IX-XII	Y	N	N	N	—	—	MA	Y	Bleeding (donor site)→revision	—
11/F	IX-XII, ataxia	Y	N	N	N	N	—	MnA	Y/N	—	Lid weighting
12/M	VI	—	—	—	—	—	—	MnA	Y/N	Swelling, conservative	—
13/F	VI	Y	Y	N	N	N	—	MA	Y	—	—
14/F	VI	Y	Y	Y	N	N	—	MA	Y/N	—	—
15/F	IX-XII	Y	Y	N	N	N	N	MA	Y	Too powerful muscle[b]	Refused debulking
16/F	—	Y	N	N	N	N	N	MA	Y	—	—
17/F	—	—	—	—	—	—	—	MnA	Y	Swelling, conservative	—
%								59% MA 41% MnA	53% Y 47% N	6/17 Complications	4/17 Repeat surgeries

[a] Arn.Ch., Arnold-Chiari malformation; CN, central nervous; MA, muscle activation; MnA, muscle nonactivation; SB, spina bifida; VI, hypacusis or anacusis; IX-XII, partial lesions of the caudal cranial nerves leading to deglutition problems; Y, positive; N, negative; Y/N, positive but inadequate.
[b] Hypercorrection.

ting was recommended.[6,16,28,29] A modification of the same innervation path was the 1-stage procedure in which an FFMT flap was inserted with a long motor nerve pedicle, which was brought to the nasolabial fold of the healthy side across the philtrum and connected to the end fascicles of the contralateral VII.[16,18,24,30]

According to these teachings, the use of the masseteric nerve, which normally innervates masticatory movements, as opposed to muscles used in expressing emotions for innervation of the FFMT flap follows an abnormal innervation pathway. Thus, it was considered erroneous for the purpose of facial reanimation.[6,11,24,31] However, in patients suffering from bilateral facial palsies, eg, children and adults with Möbius syndrome, the only option is to use nerves destined to perform other functions, eg, the masseteric nerve and accessory nerve, for the innervation of the FFMT flap used to restore smile.[23-25,32] Literature sources point out that these "abnormal" innervation patterns have also succeeded in producing favorable results.[25,32,33]

Another advantage of using the contralateral VII for the innervation of the FFMT flap lies in achieving an early balance between the 2 sides, restoring symmetry by means of partial denervation of the healthy side.[10,16,34,35] However, in patients with complete bilateral palsies or complete unilateral and incomplete contralateral facial palsies, regardless of cause, this paradigm of partial denervation of the healthier side does not apply.[25,32,33] Patients reported in this series fall into the latter category: they had either lesions involving/compressing the facial nuclei at the level of the brainstem of which they had been cured (14 patients) or untreated Möbius syndrome grown into adulthood (3 patients).

Perception of facial symmetry in static and dynamic statuses is a subjective phenomenon based on the impression the appearance creates on the patient himself or herself and the surroundings. Thus, assessment of facial symmetry should include both objective, ie, CEI, and subjective, ie, patient self-evaluation, criteria.[26,34,36-38]

FIGURE 8. *Hypercorrection, a complication at long-term follow-up.* **A**, *dynamic status in the patient with a complete facial palsy on the right side and incomplete palsy on the left before surgery.* **B**, *dynamic status approximately 8 months after surgery. A fair symmetry is observed.* **C**, *however, 3 years after surgery, the patient shows too strong innervation of the free functional muscle transfer flap on the right side. She declined corrective surgery.*

CEI: Its Value and Pitfalls

As mentioned, the impression a reanimated face creates on the interviewer is an aspect that cannot be registered with photography or videography. Nonetheless, it is essential to objectify the results so that the evaluation can be compared with other subjective methods. Many such paradigms have been proposed.[26,37,39-41] Excursion of the FFMT flap and consequentially excursion of the oral commissure on volition offer only a picture of the successful (or failed) innervation of the transplanted muscle alone.

Absolute commissural excursion depends on anthropomorphometric specificities of the individual studied, eg, size of the face, ethnicity of the patient, and breadth of smile. Thus, the normal value of absolute commissural excursion has a broad range, which makes comparison difficult. The CEI, however, compares the 2 sides of the same patient. This index ranges from 0.7 to 1.3 in normal individuals regardless of anthropomorphometry. Thus, CEI values are comparable between individuals with different facial sizes and breadth of smile within a given ethnic group or those of diverse ethnicity. "Normalization" denotes a change in the postoperative CEI value within the dotted area in Figure 5; "improvement" means change in the CEI value nearing the normal (eg, from a negative integer toward 0.7); "failure" means no changes in the CEI value. Hypercorrection, seen in 1 patient, at the long-term follow-up denoted innervation of the transplanted muscle that was too strong and fell into the category of complication. In this case, the CEI changed with the passage of time from negative (preoperative) through "normal" (8-36 months) to hypercorrection (48 months). Hypercorrection is not a failure but is reversible through a muscle debulking surgery, which was declined by the patient. Such objectification notwithstanding, the evaluation cannot be complete without subjective assessment because it is the subjective impression an individual face makes on itself and its surroundings that counts as the final result.

FIGURE 9. *Some complications occurring after weighting of the upper eyelid.* **A**, *black arrows show lateral migration of the gold weight. This happened twice in this patient and was corrected surgically.* **B**, *inadequate closure of the medial epicanthus despite weighting. This is due to a subtle ectropion of the lower eyelid at the medial epicanthal area, which requires correction. The patient refused surgery.*

Timing of Free Microneurovascular Muscle Flap Reanimation of the Paralyzed Face

Nerve transfer surgery (XI to VII, XII to VII, or contralateral VII to VII) is suitable in patients with a short history (≤6 months) of facial palsy. After this period, the mimic muscles undergo rapid atrophy and lose their synapses, and nerve transfer fails to reinnervate the muscles that have undergone connective tissue transformation. Patients with long latency periods benefit from FFMT reanimation or other static and dynamic procedures. In this series, patients with latencies > 1 year (mostly several years; see Table 1) were treated. The surgery described is suitable for patients with such irreparable facial palsy. Secondary procedures such as the one described here will certainly not replace a nerve transfer performed in a timely manner because nerve transfer aims to reinnervate the already available but denervated mimic muscles. On the contrary, this operation may be kept as a backup option and performed several years after failed nerve transfer. However, there is evidence that the masseteric innervation of the free flap (as a 1-stage procedure) might come to replace reinnervation of the free flap using the contralateral VII (as a 1- or 2-stage surgery) owing to rapidity of muscle reinnervation.

The Free Functional Microneurovascular Muscle Flap

Free functional microneurovascular muscle flaps can be raised from different locations of the body.[22,27,29,42,43] Usually, only parts of the donor muscle are used.[15,19,27,44] The most preferred flaps are gracilis, latissimus dorsi, serratus anterior, and rarely thin muscle flaps harvested from the anterior compartment of the forearm. Microsurgical facial reanimation techniques have evolved from a 2-stage to a 1-stage procedure.[5,6,11] The 2-stage approach requires the transfer of a cross-face nerve graft in the first stage. The 1-stage procedure using the contralateral facial nerve as the motor donor requires a muscle flap with a long neural pedicle, which can be brought across the face and sutured directly to a facial nerve branch of the contralateral side. Muscles such as latissimus dorsi and serratus anterior offer long neural pedicles and thus have come to be preferred for this technique.[15,19,27,29] When the masseteric nerve is used as a donor, the length of the neural pedicle of the muscle flap becomes irrelevant because revascularization is achieved via the superficial temporal vessels and the innervation is from the masseteric nerve, which are located in the direct anatomic neighborhood.[5,25,33] Other motor donor nerves of the anatomic vicinity are also described in the literature to innervate the FFMT flaps.[23,24,32,45] In our series, we used the minigracilis muscle in most of the patients (12 of 17 patients). In those patients in whom the split latissimus dorsi (2 patients) or serratus anterior (3 cases) flap was used, the gracilis donor site was scarred or otherwise jeopardized, making the approach to gracilis not free of risks.

The use of free microneurovascular muscle flaps for facial or extremity reanimation is a complex treatment modality and has several hurdles to overcome. To produce fruitful results, (1) the muscle flap has to successfully revascularize and "take" in the recipient area, overcoming possible microvascular compromises such as anastomotic failure, bleeding, and infarction that tend to occur during the first 2 to 5 days after transfer; (2) the lymphatic drainage of both the flap and the recipient site is compromised during the first few days and thus swelling is common until the lymphatic system regenerates; (3) once these hurdles are overcome, the nerve regeneration should occur and the muscle flap should regain its innervation; (4) axonal regeneration from the donor motor nerve into the muscle flap depends on various factors such as the length across which the axonal regeneration occurs (consequently, the nearer the nerve suture line is to the muscle flap, the faster its reinnervation is); and (5) the neuromuscular synapses within the muscle flap must be receptive, which depends on good perfusion. Additionally, general surgical complications such as bleeding, infection, and wound dehiscence should be considered. Thus, experience in microvascular and microneural surgical techniques is mandatory for performing this surgery. Furthermore, using FFMT flaps for facial reanimation specifically has other hurdles; the quantity of the muscle bulk transplanted, mode of inset, vector of pull, and resting tension play important roles in the final outcome. In our series of 17 patients, 2 (patients 12 and 17) failed; both had undergone microvascular failures in the early stages after transplantation. The improvement in the static appearance of the face in these patients could be attributed to the scarred muscle flap, which acts as a static suspender of the oral commissure. In 1 patient (patient 15), the inserted muscle flap was too strong compared with the contralateral side, thus producing too powerful an excursion. This is a typical example of the importance of the muscle bulk and vector of pull provided to the free muscle flap at its recipient site. Although this patient was graded as a poor outcome according to the objective evaluation criteria, she was comfortable with her long-term result (grading herself as A) and refused a debulking surgery.

Advantages and Disadvantages of the Masseteric Nerve as a Motor Donor

The 2 main advantages of using the masseteric nerve as the motor donor for the free functional microneurovascular muscle flap are its consistent availability in the direct anatomic neighborhood, especially when the contralateral facial nerve is weak or absent, and the short distance between the nerve suture line and the muscle flap itself, which makes axonal regeneration straightforward and produces quick results (innervation of the muscle flap within 3 months after transfer). These virtues overweigh the apparent disadvantage, which is the presence of synkinetic activation of the transplanted muscle associated with chewing movements. Our own series and those of others have indicated that the latter disadvantage is overcome by "learning" to use abnormal innervation pathways to express emotions.[25,33,40,46] Eight of 11 patients who were followed up for > 1 year after surgery had overcome synkinesis at their latest interview. Ten of 17 patients (59%) showed activation of the transplanted muscle during a natural smiling response to the remarks of the interviewer. Among the remaining 7 patients (41%), 2 failed—their muscle did not reinnervate at all—and 5 were still in early stages (within a year) of follow-up, certainly a shortcoming of this series. Possible hypotheses on how patients overcome synkinesis and learn to use their new muscle are discussed below.

Eyelid Closure and Ancillary Procedures

This is a tricky aspect of facial reanimation and a prerequisite for a fine result. FFMT flaps used for oral commissure reanimation were split in the upper part further and used for eyelid closure.[17,20,47,48] However, they are quite bulky and are not shown to produce results in symmetry with the contralateral side. The temporalis muscle transfer (a part of the muscle is usually transferred) is a plausible option and has been refined for achieving acceptable results.[14,16,17] However, in our hands, it produced acceptable, complete eyelid closure in only 53% of patients. The simplest surgical option is the implantation of weights fashioned out of gold or platinum.[49-51] The disadvantages of implants are that although they are made of inert metals, they are still foreign bodies and thus are susceptible to infection even years after surgery and tend to migrate and cause corneal irritation.[52-55] The latter complication happened in 1 of our patients twice. Another theoretical option is to weight the upper eyelid with autologous grafts.[56,57] These are inferior to the metal implants because the density of metal is higher than the density of any such autologous graft, mandating the implantation of a bulky cartilage or bone, which is visibly disagreeable for the patient. Furthermore, autologous grafts may get scarred and absorbed with time. The area of eyelid reanimation still requires technological refinement.

Neuronal Plasticity and Adaptability

By innervating the FFMT flap used in oral commissure reanimation through the masseteric nerve, we surpass the natural innervation pathway of smiling. One aspect here is to show volitional muscle activation for a still photograph, which was demonstrated by almost all patients in our own series and in those of others.[25,33,46,58,59] A natural display of emotion by smiling is a completely different issue of facial reanimation.[13,58,60] Patients are bound to train themselves to overcome synkinesis associated with chewing and display controlled emotions to achieve a symmetrical smile. In this manner, 59% of the patients were able to display a natural smiling response to the interviewer (Figure 7). The nature of synkinetic response was studied dynamically with the passage of time. At 3 months, only 1 patient had overcome synkinesis; at 8 months, 4; at 12 months, 6; and thenceforth, all studied patients appeared to show a normal smiling response (Table 2). Manktelow et al[25,40] and Chen et al[46] proposed the hypothesis of horizontal cross-connections between the respective cerebral cortical centers. Their hypothesis can be converted into a theory only by functional imaging verification. Furthermore, display of emotions is an issue that has deeper cerebral significance (eg, the limbic system) than cortical areas alone. The mechanism of overcoming facial synkinesis is very subtle, and the best of our contemporary functional imaging technology cannot reveal these subtleties because functional magnetic resonance imaging requires patients to hold their heads still to procure images that are consistently reliable. Although this may function well for studying synkinetic mechanisms in extremities, that of the face cannot be deciphered with contemporary functional magnetic resonance imaging. How do we propose to provoke a natural smiling response in a patient with his or her head completely immobilized? It will be of no more value than a still photograph.

CONCLUSIONS

The salient advantages of masseteric innervation (as opposed to cross-face reinnervation) of FFMT flaps used in facial reanimation are a single-stage, simpler surgery and adequate and rapid reinnervation of the muscle flap. The major disadvantage lies in the persistence of synkinesis. However, our results show that the potential to overcome this phenomenon is present in every patient, although the mechanisms involved in this process are not completely understood. Masseteric innervation for FFMT facial reanimation may come to play a role in the future not only in Möbius and Möbius-like patients but also in long-standing unilateral facial nerve paralysis resulting from other causes.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Bradbury ET, Simons W, Sanders R. Psychological and social factors in reconstructive surgery for hemi-facial palsy. *J Plast Reconstr Aesthet Surg*. 2006;59(3):272-278.
2. Gobbini MI, Haxby JV. Neural systems for recognition of familiar faces. *Neuropsychologia*. 2007;45(1):32-41.
3. Tzou CH, Giovanoli P, Ploner M, Frey M. Are there ethnic differences of facial movements between Europeans and Asians? *Br J Plast Surg*. 2005;58(2):183-195.
4. Parker SW, Nelson CA. The impact of early institutional rearing on the ability to discriminate facial expressions of emotion: an event-related potential study. *Child Dev*. 2005;76(1):54-72.
5. Chuang DC. Free tissue transfer for the treatment of facial paralysis. *Facial Plast Surg*. 2008;24(2):194-203.
6. Guelinckx PJ, Sinsel NK. Muscle transplantation for reconstruction of a smile after facial paralysis past, present, and future. *Microsurgery*. 1996;17(7):391-401.
7. Flores LP. Surgical results of the hypoglossal-facial nerve jump graft technique. *Acta Neurochir (Wien)*. 2007;149(12):1205-1210.
8. Gousheh J, Seyed-Vossoughi M. Analytical study of the treatment of facial paralysis by hypoglossal-facial anastomosis: apropos of 25 cases [in French]. *Ann Chir Plast Esthet*. 1998;43(5):548-553.
9. Kanzaki J, Kunihiro T, O-Uchi T, Ogawa K, Shiobara R, Toya S. Intracranial reconstruction of the facial nerve: clinical observation. *Acta Otolaryngol Suppl*. 1991;487:85-90.
10. Frey M, Koller R, Liegl C, Happak W, Gruber H. Role of a muscle target organ on the regeneration of motor nerve fibres in long nerve grafts: a synopsis of experimental and clinical data. *Microsurgery*. 1996;17(2):80-88.
11. Manktelow RT. Free muscle transplantation for facial paralysis. *Clin Plast Surg*. 1984;11(1):215-220.
12. Manktelow RT. Functioning microsurgical muscle transfer. *Hand Clin*. 1988;4(2):289-296.
13. Bae YC, Zuker RM, Manktelow RT, Wade S. A comparison of commissure excursion following gracilis muscle transplantation for facial paralysis using a cross-face nerve graft versus the motor nerve to the masseter nerve. *Plast Reconstr Surg*. 2006;117(7):2407-2413.
14. Frey M, Giovanoli P, Tzou CH, Kropf N, Friedl S. Dynamic reconstruction of eye closure by muscle transposition or functional muscle transplantation in facial palsy. *Plast Reconstr Surg*. 2004;114(4):865-875.
15. Wei W, Zuoliang Q, Xiaoxi L, et al. Free split and segmental latissimus dorsi muscle transfer in one stage for facial reanimation. *Plast Reconstr Surg*. 1999;103(2):473-480.
16. Frey M, Giovanoli P. The three-stage concept to optimize the results of microsurgical reanimation of the paralyzed face. *Clin Plast Surg*. 2002;29(4):461-482.
17. Michaelidou M, Tzou CH, Gerber H, Stussi E, Mittlbock M, Frey M. The combination of muscle transpositions and static procedures for reconstruction in the paralyzed face of the patient with limited life expectancy or who is not a candidate for free muscle transfer. *Plast Reconstr Surg*. 2009;123(1):121-129.
18. Boahene KD. Dynamic muscle transfer in facial reanimation. *Facial Plast Surg*. 2008;24(2):204-210.
19. Harii K, Asato H, Yoshimura K, Sugawara Y, Nakatsuka T, Ueda K. One-stage transfer of the latissimus dorsi muscle for reanimation of a paralyzed face: a new alternative. *Plast Reconstr Surg*. 1998;102(4):941-951.
20. Watanabe Y, Akizuki T, Ozawa T, Yoshimura K, Agawa K, Ota T. Dual innervation method using one-stage reconstruction with free latissimus dorsi muscle transfer for

re-animation of established facial paralysis: simultaneous reinnervation of the ipsilateral masseter motor nerve and the contralateral facial nerve to improve the quality of smile and emotional facial expressions. *J Plast Reconstr Aesthet Surg*. 2009;62(12):1589-1597.
21. Fatemi MJ, Forootan SK, Habibi M, Pooli AH, Mansoori MJ. Toward shortening interoperation period in two-stage cross facial nerve graft with muscle transfer. *Ann Plast Surg*. 2008;60(6):639-643.
22. Hayashi A, Maruyama Y. Neurovascularized free short head of the biceps femoris muscle transfer for one-stage reanimation of facial paralysis. *Plast Reconstr Surg*. 2005;115(2):394-405.
23. Rab M, Haslik W, Grunbeck M, et al. Free functional muscle transplantation for facial reanimation: experimental comparison between the one- and two-stage approach. *J Plast Reconstr Aesthet Surg*. 2006;59(8):797-806.
24. Faria JC, Scopel GP, Busnardo FF, Ferreira MC. Nerve sources for facial reanimation with muscle transplant in patients with unilateral facial palsy: clinical analysis of 3 techniques. *Ann Plast Surg*. 2007;59(1):87-91.
25. Manktelow RT, Tomat LR, Zuker RM, Chang M. Smile reconstruction in adults with free muscle transfer innervated by the masseter motor nerve: effectiveness and cerebral adaptation. *Plast Reconstr Surg*. 2006;118(4):885-899.
26. Frey M, Michaelidou M, Tzou CH, et al. Three-dimensional video analysis of the paralyzed face reanimated by cross-face nerve grafting and free gracilis muscle transplantation: quantification of the functional outcome. *Plast Reconstr Surg*. 2008;122(6):1709-1722.
27. Krishnan KG. *An Illustrated Handbook of Flap Raising Techniques*. Stuttgart, Germany: Georg Thieme Verlag AG; 2008.
28. Frey M. Free muscle transplantation for treatment of facial paralysis: first experiences with the International Muscle Transplant Registry. *Plast Reconstr Surg*. 1991;87(1):200-202.
29. Jiang H, Guo ET, Ji ZL, Zhang ML, Lu V. One-stage microneurovascular free abductor hallucis muscle transplantation for reanimation of facial paralysis. *Plast Reconstr Surg*. 1995;96(1):78-85.
30. Forootan SK, Fatemi MJ, Pooli AH, Habibi M, Javidan S. Cross-facial nerve graft: a report of chronically paralyzed facial muscle neurotization by a nerve graft. *Aesthetic Plast Surg*. 2008;32(1):150-152.
31. Manktelow RT, McKee NH, Vettese T. An anatomical study of the pectoralis major muscle as related to functioning free muscle transplantation. *Plast Reconstr Surg*. 1980;65(5):610-615.
32. Chuang DC. Nerve transfer with functioning free muscle transplantation. *Hand Clin*. 2008;24(4):377-388, vi.
33. Zuker RM, Goldberg CS, Manktelow RT. Facial animation in children with Mobius syndrome after segmental gracilis muscle transplant. *Plast Reconstr Surg*. 2000;106(1):1-8.
34. Frey M, Giovanoli P, Gerber H, Slameczka M, Stussi E. Three-dimensional video analysis of facial movements: a new method to assess the quantity and quality of the smile. *Plast Reconstr Surg*. 1999;104(7):2032-2039.
35. Giovanoli P, Kamolz LP, Rab M, Koller R, Mittlbock M, Frey M. Limits of muscle-to-nerve ratio in functional muscle transplantation. *J Reconstr Microsurg*. 2003;19(1):21-28.
36. Frey M, Jenny A, Stussi E, Handschin S, Manktelow R. Development of a new paresis scoring system for pre- and postoperative evaluation of facial paresis. *Eur Arch Otorhinolaryngol*. 1994; Dec S182-S184.
37. Giovanoli P, Tzou CH, Ploner M, Frey M. Three-dimensional video-analysis of facial movements in healthy volunteers. *Br J Plast Surg.* 2003;56(7):644-652.
38. Neely JG, Neufeld PS. Defining functional limitation, disability, and societal limitations in patients with facial paresis: initial pilot questionnaire. *Am J Otol*. 1996;17(2):340-342.
39. Frey M, Jenny A, Giovanoli P, Stussi E. Development of a new documentation system for facial movements as a basis for the international registry for neuromuscular reconstruction in the face. *Plast Reconstr Surg*. 1994;93(7):1334-1349.
40. Manktelow RT, Zuker RM, Tomat LR. Facial paralysis measurement with a handheld ruler. *Plast Reconstr Surg*. 2008;121(2):435-442.
41. Stussi E, Handschin S, Frey M. Quantifying facial asymmetry: a method for objective assessment of impairments of facial motoricity; a pilot study [in German]. *Biomed Tech (Berl)*. 1992;37(1-2):14-19.
42. Sajjadian A, Song AY, Khorsandi CA, et al. One-stage reanimation of the paralyzed face using the rectus abdominis neurovascular free flap. *Plast Reconstr Surg*. 2006;117(5):1553-1559.
43. Takushima A, Harii K, Asato H, Momosawa A, Okazaki M. One-stage reconstruction of facial paralysis associated with skin/soft tissue defects using latissimus dorsi compound flap. *J Plast Reconstr Aesthet Surg*. 2006;59(5):465-473.
44. Lykoudis EG, Spyropoulou GA, Vlastou CC. The conjoint medial circumflex femoral perforator and gracilis muscle free flap: anatomical study and clinical use for complex facial paralysis reconstruction. *Plast Reconstr Surg*. 2005;116(6):1589-1595.
45. Koshima I, Nanba Y, Tsutsui T, Takahashi Y, Itoh S. New one-stage nerve pedicle grafting technique using the great auricular nerve for reconstruction of facial nerve defects. *J Reconstr Microsurg*. 2004;20(5):357-361.
46. Chen R, Anastakis DJ, Haywood CT, Mikulis DJ, Manktelow RT. Plasticity of the human motor system following muscle reconstruction: a magnetic stimulation and functional magnetic resonance imaging study. *Clin Neurophysiol*. 2003;114(12):2434-2446.
47. Rahman I, Sadiq SA. Ophthalmic management of facial nerve palsy: a review. *Surv Ophthalmol*. 2007;52(2):121-144.
48. Seiff SR, Chang JS Jr. The staged management of ophthalmic complications of facial nerve palsy. *Ophthal Plast Reconstr Surg*. 1993;9(4):241-249.
49. Dalkiz M, Gokce HS, Aydin A, Beydemir B. Gold weight implantation for rehabilitation of the paralysed eyelid. *Int J Oral Maxillofac Surg*. 2007;36(6):522-526.
50. Pausch N, Sterker I, Hemprich A, Frerich B. Restoration of lid function in peripheral facial palsy by implanting gold weights [in German]. *Mund Kiefer Gesichtschir*. 2006;10(3):135-140.
51. Tate JR, Kriet JD, Tollefson TT. Paralytic lagophthalmos: gold-weight implantation. *Ear Nose Throat J*. 2006;85(9):580-582.
52. Chepeha DB, Yoo J, Birt C, Gilbert RW, Chen J. Prospective evaluation of eyelid function with gold weight implant and lower eyelid shortening for facial paralysis. *Arch Otolaryngol Head Neck Surg*. 2001;127(3):299-303.
53. Dinces EA, Mauriello JA Jr, Kwartler JA, Franklin M. Complications of gold weight eyelid implants for treatment of fifth and seventh nerve paralysis. *Laryngoscope*. 1997;107(12)(pt 1):1617-1622.
54. Pickford MA, Scamp T, Harrison DH. Morbidity after gold weight insertion into the upper eyelid in facial palsy. *Br J Plast Surg*. 1992;45(6):460-464.
55. Thomas DA, Khalifa YM. Temporalis fascia in the management of gold eyelid weight extrusion. *Ophthal Plast Reconstr Surg*. 2005;21(2):153-155.
56. Caesar RH, Friebel J, McNab AA. Upper lid loading with gold weights in paralytic lagophthalmos: a modified technique to maximize the long-term functional and cosmetic success. *Orbit*. 2004;23(1):27-32.
57. D'Hooghe PJ, Hendrickx EM. Upper lid loading with dermis graft and levator weakening: management of lagophthalmos due to facial palsy. *Ophthalmologica*. 1975;171(6):419-424.
58. Tomat LR, Manktelow RT. Evaluation of a new measurement tool for facial paralysis reconstruction. *Plast Reconstr Surg*. 2005;115(3):696-704.
59. Zuker RM, Manktelow RT. Functioning free muscle transfers. *Hand Clin*. 2007;23(1):57-72.
60. Paletz JL, Manktelow RT, Chaban R. The shape of a normal smile: implications for facial paralysis reconstruction. *Plast Reconstr Surg*. 1994;93(4):784-789.

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COMMENTS

In this paper, the authors describe the use of the motor nerves to the masseter attached to a vascularized muscle flap, as well as the temporalis musculo fascial flap to reinnervate the paralyzed face in patients who cannot undergo most other means of facial reanimation. In conjuction with electrical stimulation , and retraining of the facial muscles, reasonable results were achieved. This is a very promising technique, which will have wide applications in patients who qualify.

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