Assessment of functional outcomes of temporalis muscle transfers for patients with longstanding facial paralysis

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ABSTRACT: *Background.* Usually, clinical evaluation of facial reanimation provides accurate information about contraction of the mimetic muscles and phonation but fails to identify smile recovery and to quantify the motility of the lower third of the face during a smile. The purpose of this study was to verify that, in longstanding facial palsy, the modified temporalis muscle transfer (MTMT) can result in the ability to smile, not only voluntarily with chewing, but also spontaneously with a sudden emotional stimulus, and to confirm that a symmetric smile can be obtained.

Methods. Ten patients of the treated group (group T; 4 women and 6 men) were randomly selected from a population of 24 patients with longstanding facial palsy treated by MTMT. Five normal subjects of the control group (group C; 3 women and 2 men) were enrolled as the control population. Functional outcomes after transposed temporalis muscle were examined and measured through clinical assessment by using a scored smile symmetry grading system, video recording, and surface electromyography (sEMG). In addition, the voluntary smile test (VST) and the not-voluntary smile test (NVST) were performed to study voluntary and spontaneous smiling.

Results. Subjects in the VST group (group T) were able to smile voluntarily and the expression was characterized by symmetry. In the NVST group, they were able to smile spontaneously and the symmetry of the smile was maintained for 8 subjects and only partially for 2 subjects. During both tests, the temporalis muscle of the treated side and the orbicularis oris muscle of the not-treated side were activated during smiling, indicating spontaneous activity of the transposed temporalis muscle with an emotional stimulus. For the control group, smiles during VST and NVST were symmetric and the temporalis muscles were not activated during smiling, whereas the orbicularis oris muscles were.

Conclusion. Our study shows that the Morrison MTMT is able to restore the voluntary smile ability. Particularly, this technique allows for recovery of the spontaneous smile with symmetry. This assessment would seem to suggest that the transposed temporalis muscle might adapt from a chewing to a mimetic muscle. © 2016 Wiley Periodicals, Inc. *Head Neck* **38**: E1535–E1543, 2016

KEY WORDS: **facial reanimation, longstanding facial paralysis, temporalis muscle transfer**

INTRODUCTION

Facial paralysis is a significant functional and aesthetic handicap. The main functional stigmata of facial palsy are lowering of the eyebrow, impaired eye closure causing dry eye and excessive tearing, facial weakness with drooping of the corner of the mouth, and drooling in this area, as well as spontaneous twitching.[1,2]

The purpose of facial palsy treatment consists of the recovery of important dynamic functions, including the ability to fully close the eyelids, to speak fluently, and to eat and drink without drooling from the mouth. Equally important for patients is the recovery of a harmonious expression and to be able to smile spontaneously.[3–6]

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Additional Supporting Information may be found in the online version of this article.

The gold standard for the treatment of longstanding facial palsy remains the functional microvascular muscle transfer, usually using the gracilis muscle flap or the latissimus dorsi muscle flap in a 1- or 2-stage procedure.[7–12]

However, facial reanimation may also be performed by 1-stage regional pedicle muscle flaps.[13,14]

In 1996, Breidahl et al,[15] modifying the technique initially described by McLaughin,[16,17] used the temporalis muscle for the "reanimation of the lips," demonstrating the possibility of using this technique to recover the dynamic functions of the mouth.

Labbé,[18–20] in 1997, and other authors[21,22] had modified the temporalis muscle pedicle transfer flap for facial reanimation describing the lengthening temporalis myoplasty procedure.

This myoplasty technique has proven capable of producing a coordinated and symmetrical smile of the paralyzed side of the face, especially when intraoperative muscle electrical stimulation is used for accurate positioning of the temporalis muscle tendon to the nasolabial fold.[14]

TABLE 1. The treated group (group T) population.

Patient no.	Age, y	Sex	Primary pathology	Follow-up, y
Patient 1	52	F	Parotid carcinoma excision	6
Patient 2	45	F	Neuroma (VIII cranial nerve): iatrogenic injury	6
Patient 3	69	M	Neuroma (VIII cranial nerve): iatrogenic injury	4
Patient 4	68	M	Neuroma (VIII cranial nerve): iatrogenic injury	5
Patient 5	73	M	Bell's palsy	4
Patient 6	65	M	Parotid carcinoma excision	5
Patient 7	52	M	Neuroma (VIII cranial nerve): iatrogenic injury	6
Patient 8	47	F	Neuroma (VIII cranial nerve): iatrogenic injury	4
Patient 9	60	F	Neuroma (VIII cranial nerve): iatrogenic injury	5
Patient 10	58	M	Neuroma (VIII cranial nerve): iatrogenic injury	6

The previously modified temporalis muscle transfer (MTMT) techniques have demonstrated the ability to recover a smile, but no tests have evaluated an objective quantification of that. Moreover, no research could distinguish the voluntary from the spontaneous smile and evaluate the symmetry of the spontaneous smile after an MTMT in order to assess the actual adaptability of the temporal muscle from the chewing muscle to the mimetic muscle. Clinical evaluation provides information about contraction and phonation but fails to identify smile recovery and to quantify the movement of the lower third of the face.

The literature agrees with the fact that a voluntary smile can be achieved with the MTMT procedure after facial paralysis.[13,18–22] Nevertheless, no accurate and repeatable measure was performed to identify the ability to produce a spontaneous smile and quantify the range of motion and the symmetry of the smile after this kind of treatment.[23–26] This study evaluated the facial mimetic recovery after MTMT in patients with longstanding facial paralysis and is aimed to verify that a symmetric and spontaneous smile can be attained. The temporalis muscle is usually not activated during a smile.[27] This study would like to investigate the behavior of the transferred temporalis muscle during smiling. For this purpose, the activity of the orbicularis oris, which is activated during a smile, on the not-treated side is also recorded to compare its activation timing in relation to the timing of activation of the transferred temporalis muscle.

MATERIALS AND METHODS

This study was approved by the University Politecnica delle Marche's institutional review board.

Population

The treatment group was composed of 10 patients (group T; 4 women and 6 men; average age, 58.9 years; range, 45–73 years old) randomly selected from a population of 24 patients with longstanding facial palsy treated by MTMT, as described by Breidahl et al,[15] and 5 healthy subjects (group C; 3 women and 2 men; average age 50 years; range, 48–65 years old).

Postoperative follow-up after surgery was from 4 to 6 years. The diagnosis was acoustic neuroma for 7 patients, parotid gland cancer for 2 patients, and Bell's palsy for 1 patient (Table 1). Each subject participated voluntarily to the test after signing the informed consent and was tested with the same evaluation method: clinical assessment, video recording, and surface electromyography (sEMG).

Clinical assessment

For the clinical assessment, patients were examined and scored using the "facial nerve grading system."[23]

Video recordings and surface electromyography. During each experimental session, the subject was seated on an adjustable and comfortable armchair. The height of the chair was adjusted to allow the subject to see the video screen with the head position in neutral. A web camera was positioned in front of the subject just above the viewing screen of the personal computer. The video camera adopted for this study was a webcam (ELMO, model PTC-450C, resolution: 795 × 596).

In the treatment group, sensors for sEMG were placed on the temporalis muscles of the treated and not-treated side and the orbicularis oris muscle of the not-treated side, placing the sensor at the point of insertion of the zygomatic major muscle. The activity of the orbicularis oris muscle of the not-treated side at the insertion of the zygomatic major muscle was recorded because these muscles are usually activated during smiling. We wanted to verify that treated activation during smiling, if present, was simultaneous with the orbicularis oris muscle of the activation of the not-treated side, and correlated temporally with the presence of a smile. To understand the role of the temporalis muscle during smiling after surgical treatment, the authors decided to also record the activity of the temporalis muscle on the contralateral unaffected side. In the control group, sensors were placed on the temporalis and orbicularis oris muscle bilaterally. The recording system was a Pocket EMG (BTSengineering, Milano, Italy). The acquisition frequency was 1000 Hz. The sEMG sensor positions for the temporalis muscle were as described by Michelotti et al[28]: the first sensor was placed on a line between the upper orbital margin to the upper point of the outer ear 2 cm behind the anterior border of the muscle (border determined from palpation). The second sensor was located 15 mm superiorly to the first, along the muscle fibers. For the orbicularis oris muscle, the sensor locations were as described by Vaiman[29]: 1 electrode was located above the upper lip and the other below the lower lip of the not-treated angle of the mouth. Interelectrode distance was lower than 15 mm.

FIGURE 1. The electromyography sensors placed on the orbicularis oris muscle of the treated and not treated.

A third electrode, the reference, was positioned on the wrist (Figure 1).

Test description

Subjects were analyzed while undergoing 2 different tests: one to measure voluntary smile (voluntary smile test [VST]) and one to detect and quantify the spontaneous smile (non-voluntary smile [NVST]).

Voluntary maintained and maximum smile tests. During the first part of this test, subjects were asked to smile and to maintain the smile for 7 seconds. Subjects were alerted to the start of the smile by an acoustic and visual stimulus. The acoustic stimulus consisted of a drum roll lasting 7 seconds. Simultaneously with the acoustic stimulus, a visual stimulus, the notice "smile!" appeared on the computer screen. The evoked smiles were repeated a total of 3 times. Before and after the 7 second recordings, a rest period of 15 seconds was introduced. The total session duration was 81 seconds.

After a rest period of about 5 minutes, the second part of the test commenced. For the second part, subjects were asked to produce the most animated smile possible after being prompted by an acoustic stimulus. In this case, the stimulus was very short. The evoked smiles were repeated 3 times. The rest period and total session duration was as described in the previous test.

Spontaneous funny and emotional smile test. The first part of the NVST was designed to elicit the subject's emotional conversational smile during a one-on-one encounter; the subject's video recordings and sEMG signals were recorded while an examiner explained the VST to the subject. The test duration was variable depending on the examiner's explanation and on the subject's need to pose questions. The experimental situation was casual and the patient's reaction could be variable. The second part consisted of the subject watching a selection of comic videos. Subjects were asked to watch a video (5 minutes) while the examiner was out of the room. During this part, the subjects were unaware that their smile in response to the on-screen humor (funny smile) was being recorded.

Image processing

Video recordings were examined and, for each of them, frames with the patient at rest (reference frame with the patient not smiling) and smiling, were extracted and processed. The presence of a smile in each subject's video recording was manually identified and the related instant in time was noted to examine the corresponding electromyographic activity. For each session of the VST, 6 frames were extracted: 1 frame at rest, 1 frame before the smile, and 3 frames. For each session of the NVST, 1 frame at rest and 1 frame, if any, every time the subject smiled was processed.

The selected frames for each test were then processed following these steps: (1) gray scale transformation of the image; (2) image enhancement of the contour of the mouth was selected and black colored through image processing software (Photoshop); moreover, a pixel on the left corner of the tip of the nose was selected as reference point; (3) edge detection of the binary version of the image was obtained and a threshold of 0.1 was applied in such a manner that intensity equal to 1 (white color) was assigned to the pixel with intensity higher than 0.1 (the image was white with the exception of the mouth and the reference point that appeared black), then a Sobel filter was applied to finally extract the edge; and (4) the mouth corners and reference point localization was determined.

As a point of interest, both the corners of the mouth were selected. The coordinates of the corners of the mouth and the reference point (detected as described in point 2) were obtained after the Sobel application. They were expressed with respect to the image reference system that is the reference system centered on the top of the image at the right (Figure 2). The x-axis is oriented

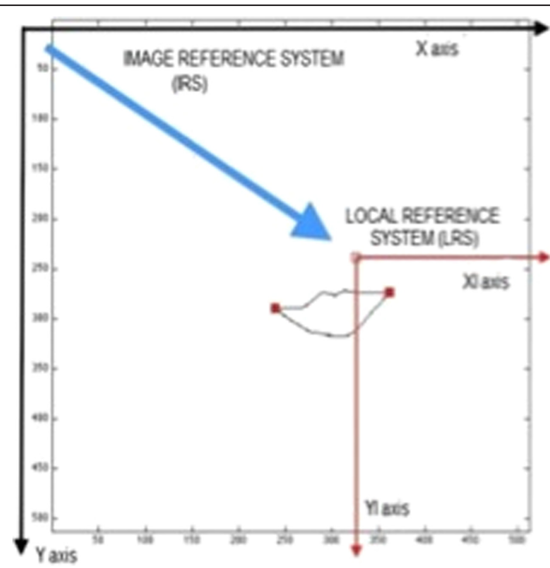

FIGURE 2. Local and image reference system. Red squares show the mouth corners (point of interest).

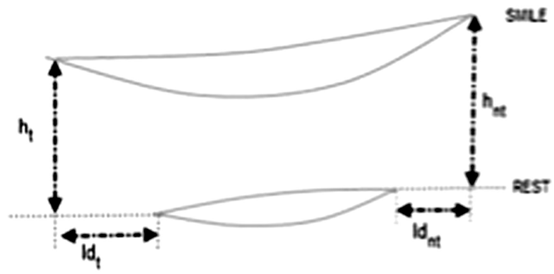

FIGURE 3. Parameters examined to measure a smile with respect to rest. ht and hnt: vertical displacement of the treated (t) and not-treated (nt) corner of the mouth. ldt and ldnt: lateral displacement of the treated (t) and not-treated (nt) corner of the mouth.

from the left to the right, and the y-axis is oriented from the top to the bottom.

The reference point was chosen as the origin of the local anatomic reference system (LARS) with respect to which of the coordinates of points of interest were expressed. The x-axis and the y-axis of the LARS were parallel, respectively, to the horizontal and the vertical axis of the image reference system. To extract the relative movements of the mouth corners and to guarantee their invariance with respect to the shot, coordinates of the mouth corners were expressed with respect to the LARS.

To measure the movement of mouth corners the following parameters were calculated: (1) vertical displacement of the mouth corners from rest to the smile position (ht = treated side; hnt = not-treated side; Figure 3); (2) lateral displacement of the mouth corners from rest to the smile position (ldt = treated side; ldnt = not-treated side; Figure 3); (3) inclination angle of the mouth (α_r = at rest; α_s = smile). Small values showed symmetry of the mouth expression (Figure 4).

The frames of the patients' video recordings characterized by smiles were examined and correlated with the sEMG activity at the same instant in time.

Symmetry was not easily evaluated because of the absence of reference data in the literature. We decided to consider a result asymmetric when the asymmetry index ($AI_{\%}$ = R [or affected side]-L [or unaffected side]/R [or affected side] + L [or unaffected side] $\times$ 100), calculated for the vertical displacement, was over 60%.[30]

In addition, the mouth inclination was considered as a parameter able to reveal symmetry during rest or smile.

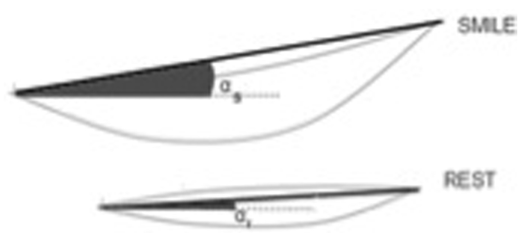

FIGURE 4. Parameters examined to measure a smile with respect to rest. ht and hnt: vertical displacement of the treated (t) and not-treated (nt) corner of the mouth. ldt and ldnt: lateral displacement of the treated (t) and not-treated (nt) corner of the mouth.

TABLE 2. The treated group (group T) clinical assessment of smile symmetry after the facial nerve grading system, version 2.0.

Grade	I	II	III	IV	V	VI
At rest			6 patients	4 patients		
Smile without showing teeth		1 patient	5 patients	4 patients		
Smile with showing teeth			6 patients	4 patients		
Showing teeth			4 patients	6 patients		

Because of the absence of reference data, we considered higher values of angles α_r and α_s as an indicator of asymmetry. In group C, the median values for these angles were <10°. We decided asymmetric of the smile with α_r and α_s >15°.

Surface electromyography processing

The sEMG signal was rectified and low pass filtered (Butterworth, 2°-order, cut of frequency 2 Hz) to calculate the envelope.[31]

RESULTS

Clinical results

Group T demonstrated a good recovery of the smile symmetry during the voluntary smiling (Table 2), and group C demonstrated symmetry during the voluntary smiling.

Image processing results

One patient in group T was not fully cooperative during each session; in particular, he was able to complete the VST, but not the NVST because of a lack of cooperation.

Voluntary smile test

Group C performed the VST with high symmetry (AI% <50, α_s α_r <10°).

All the subjects in group T were able to complete the VST. During the VST, patients were able to smile for 7 seconds. All of them were able to perform the test as required, but, during the test, they needed to correct their expression to avoid sagging of the affected corners of the mouth.

Results for groups T and C related to the inclination angle of the mouth at rest (α_r) and during a smile (α_s), the vertical and lateral displacement were shown through the median, 25°, and 75° percentiles (confidence bound) values (Table 3).

At rest, the mouth inclination angle was <10°. The inclination angle during a smile was <10° for maximum smile and over for the maintained smile, showing that during this last session the mouth expression was slightly asymmetric, while during the maximum smile it was not. The increased asymmetry during the maintained smile is probably because of the correction of the expression to avoid sagging of the affected corners.

The lateral and vertical displacement of the mouth corners for the treated sides were lower than for the not-treated sides, in both the test sessions.

TABLE 3. Table showing median, 25°, and 75° percentiles of the parameters calculated during both the sessions of the voluntary smile test for the treated group (group T) and the control group (group C).

Test	α, degree		h, cm	AI%	ld, cm
	α_r	α_s			
Group T					
Maximum smile	7.6 (3.2–13.7)	10.8 (4.5–13.6)	T: 1.51 (0.75–2.1) NT: 2.92 (1.15–3.26)	31.82	T: 0.82 (0.32–1.8) NT: 0.75 (0.50–1.78)
Maintained smile	8.9 (3.9–12.5)	13.1 (9.2–16.6)	T: 1.15 (0.54–2.15) NT: 1.80 (0.72–2.42)	22.03	T: 0.54 (0.22–1.6) NT: 1.23 (0.8–2.4)
Group C					
Maximum smile	1.8 (0.7–3.8)	2.5 (1.4–3.2)	Right: 0.6 (0.44–1.0) Left: 0.52 (0.24–1.6)	7.14	Right: 0.6 (0.4–1.12) Left: 0.51 (0.32–1.3)
Maintained smile	3.4 (1.8–5.2)	4.6 (2.4–8.5)	Right: 1.12 (0.4–1.52) Left: 1.3 (0.6–1.64)	7.43	Right: 0.4 (0.21–1.12) Left: 0.82 (0.25–1.40)

Abbreviations: T, treated side; NT, not-treated side.
Parameters are related to vertical displacement of the mouth corners from rest to the smile position (ht, treated side; hnt, not-treated side); lateral displacement of the mouth corners from rest to the smile position (ldt, treated side; ldnt, not-treated side); asymmetry index (AI%); inclination angle of the mouth (α_r, at rest; α_s, smile).

All the subjects in group T presented a good recovery of the symmetry during the voluntary smile, confirming clinical results. See video (Supplementary Digital Content S1, online only), which demonstrates symmetric voluntary smile during VST.

Only 1 patient in group T showed a symmetry in VST very close to the threshold value that distinguishes symmetry from asymmetry: the AI% for him was 72% and the α_s was 13°. At rest, the mouth angle was <10° and AI% was 15%.

Not-voluntary smile test

The subjects in group C performed smiles during both the sessions of NVST. Symmetry for the group was high (AI% = 12.56, α_s and α_r <10°; Table 4).

The subjects in group T were able to show complete spontaneous smiles: 4 patients during both the sessions of the NVST (emotional and funny smile), of the others, 5 during funny and 1 during emotional. One patient, less cooperative, was able to show just 1 spontaneous smile, during the funny session. Results for each patient are shown in Tables 4 and 5 (see video, Supplementary Digital Content S2, online only, which demonstrates spontaneous smiles during NVST).

Patients 2, 7, 8, and 10 smiled both during both the test sessions: mouth inclination angle at rest was high, and reduced when subject smiled. Asymmetry was observed during the funny smile when AI% was high.

In group T, during the funny smile, the vertical and the lateral displacement for the treated side were below the value for the not-treated side. The differences between the treated and the not-treated sides, for both the displacements, were lower than those measured during emotional smiles.

All patients in group T showed evidence of movement during spontaneous smile, and 8 of 10 patients have recovered the symmetry of the movement. Patient 2 has reached the symmetry only during the emotional smile; patient 8 has reached symmetry exclusively during the funny smile (Table 5).

Superficial electromyography results

Group C showed muscular activity only for the orbicularis oris muscles during smiling in both tests. The temporalis muscles were not activated.

Group T voluntary smile test. The orbicularis oris muscle of the not-treated and treated sides showed activity during smile in all patients. The treated side's activity was simultaneous to the orbicularis oris muscle of the not-treated sides (Figures 5 and 6). Therefore, it was not a response to the orbicularis oris contraction but an active contribute for smiling. During smiles, the not-treated sides were not activated for 2 patients (patients 1 and 3) and seemed slightly activated for the others.

Not-voluntary smile test. The orbicularis oris muscles of the not-treated and treated sides were activated when patients smiled for all of them. The not-treated side was activated in each spontaneous smile examined except for patients 1 and 4.

The activation of the treated side for a task different to chew suggests a possible adaptation of this muscle toward a mimic task. This behavior, observed only for group T, suggests a possible adaptation of the temporalis muscle from chewing to mimic muscle.

The activation of the not-treated sides during smiles was present for some subjects during both the tests. Temporalis activity of the not-treated side must be investigated.

CASE REPORTS

Case 1

A 68-year-old woman had left complete facial paralysis for 10 years after removal of an acoustic neuroma (Figure 7A). Because of left facial weakness with drooping of the corner of the mouth and drooling, she decided to undergo a facial reanimation procedure. Therefore, we performed the MTMT operation. The postoperative course was uneventful. At 9 months postoperatively, we were able to confirm good temporal muscle movement and symmetric smile, the patient was highly satisfied with the results of the surgery (Figure 7B).

TABLE 4. Parameters calculated during both the sessions of the not-voluntary smile test for the treated group (group T) and the control group (group C).

Group T	α, degree		h, cm	AI%	ld, cm
	α_r	α_s			
Patient 1 (funny smile test)	6.97	12.03	T: 1.76 NT: 1.17	20.13	T: 0.24 NT: 0.39
Patient 2 (funny smile test)	31.70	24.14	T: 0.10 NT: 0.88	79.59	T: 0.60 NT: 1.07
Patient 2 (emotional smile test)	31.17	21.82	T: 1.17 NT: 0.73	23.15	T: 0.54 NT: 0.54
Patient 3 (emotional smile test)	17.37	9.81	T: 0.22 NT: 0.91	61.06	T: 0.34 NT: 0.67
Patient 4 (funny smile test)	18.46	9.92	T: 0.14 NT: 0.99	75.22	T: 0.46 NT: 0.75
Patient 5 (funny smile test)	9.61	7.29	T: 0.83 NT: 1.03	10.75	T: 0.20 NT: 0.73
Patient 6 (funny smile test)	21.32	18.48	T: 1.2 NT: 0.92	13.21	T: 0.12 NT: 0.22
Patient 7 (funny smile test)	13.6	16.82	T: 1.54 NT: 1.23	11.19	T: 0.32 NT: 0.41
Patient 7 (emotional smile test)	13.91	15.86	T: 1.11 NT: 1.59	17.77	T: 0.43 NT: 1.15
Patient 8 (funny smile test)	27.32	22.34	T: 0.69 NT: 1.35	32.35	T: 0.43 NT: 0.54
Patient 8 (emotional smile test)	26.88	20.22	T: 0.32 NT: 1.55	65.77	T: 0.51 NT: 1.2
Patient 9 (funny smile test)	8.50	11.22	T: 1.32 NT: 1.65	11.11	T: 0.13 NT: 0.33
Patient 10 (funny smile test)	30.66	35.42	T: 0.88 NT: 1.69	31.51	T: 0.59 NT: 1.35
Patient 10 (emotional smile test)	29.53	33.32	T: 0.50 NT: 1.52	50.49	T: 0.23 NT: 0.99
Group C	5.43 [3.2–8.63]	7.89 (4.98–11.87)	Right: 1.22 (0.72–1.86) Left: 1.38 (0.9–1.63)	6.15	Right: 0.22 [0.11–0.88] Left: 0.46 [0.32–0.94]

Abbreviations: T, treated side; NT, not-treated side.
Parameters are related to vertical displacement of the mouth corners from rest to the smile position (ht, treated side; hnt, not-treated side); lateral displacement of the mouth corners from rest to the smile position (ldt, treated side; ldnt, not-treated side); asymmetry index (AI%); inclination angle of the mouth (α_r, at rest; α_s, smile). Data of patients are related to each smile shown by each patient, the control group data are median, 25°, and 75° percentile values of the parameters.

Case 2

A 73-year-old man presented to our service in December of 2006, 24 months after the diagnosis of Bell's palsy on the left side (Figure 8A). Three months later, in March 2007, he underwent 1-stage reconstruction that consisted of MTMT to the oral commissure. The postoperative course was uneventful. At 14 months postoperatively, a near-natural cheek motion upon smiling, synchronizing with contralateral cheek motion, was obtained (Figure 8B).

Case 3

A 52-year-old woman presented with complete right facial paralysis, which resulted from excision of high-grade malignancy of the right parotid gland 5 years ago (Figure 9A).

She underwent facial reconstruction consisted of tarsorrhaphy for the eye and MTMT to reconstruct the smile. The postoperative course was uneventful. At 1 year postoperatively, she could close her right eye completely and we were able to confirm good temporal muscle movement with a symmetric smile (Figure 9B).

Case 4

A 45-year-old woman developed an established left complete facial paralysis after ablative surgery of an acoustic neuroma 15 years previously. Because of static and dynamic facial distortion, she decided to undergo a facial reanimation procedure (Figure 10A). A dynamic smile reconstruction with an MTMT and static reconstructive operation for eyelid closure were performed. The

TABLE 5. Evidence of movement and symmetry for spontaneous smile for the treated group (group T).

Spontaneous smile	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Patient 9	Patient 10
Evidence of the movement	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Symmetry of the movement	Yes	Yes (emotional) No (funny)	No	No	Yes	Yes	Yes	No (emotional) Yes (funny)	Yes	Yes

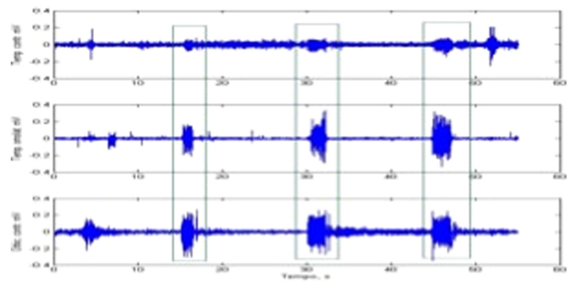

FIGURE 5. Muscle activity of the temporalis (treated and not-treated sides) and the orbicularis oris of the not-treated side during the voluntary smile test (VST) of patient 1.

postoperative course was uneventful. At 9 months follow-up, symmetrical position of the eyebrow, sufficient eyelid closure, and cheek motion synchronized with the contralateral cheek upon smiling were obtained (Figure 10B).

DISCUSSION

The gold standard for the treatment of longstanding facial palsy still remains the functional microvascular muscle transfer, but facial reanimation may also be performed by regional 1-stage muscle pedicle flaps.

Particularly, the Morrison MTMT allows the dynamic reanimation of the paralyzed lip and lower third of the face by transferring the temporalis tendon in a natural orthodromic orientation from coronoid process to the lip, while preserving the muscle fibers innervation because of a minimal surgical manipulation of the muscle.

The aim of the facial palsy surgical treatment not only consists of the recovery of the principal mouth dynamic functions, but also in the recovery of the ability to smile spontaneously.

However, clinical evaluation and instrumental tests used to investigate the postoperative functional recovery provide accurate information about contraction of the mimetic muscles and phonation but fails to identify smile

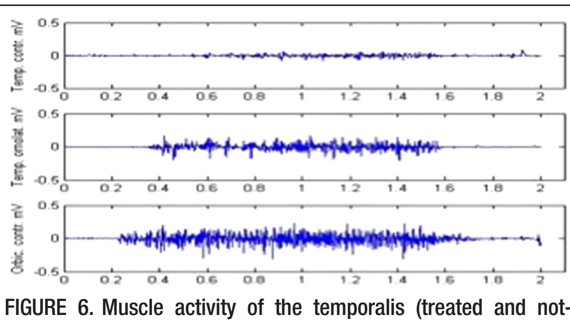

FIGURE 6. Muscle activity of the temporalis (treated and not-treated sides) and the orbicularis oris during the voluntary smile test (VST) of patient 1. During a smile, the temporalis of the treated side and the orbicularis oris of the not-treated side are simultaneously activated, while temporalis at the contralateral side (not-treated) is not activated.

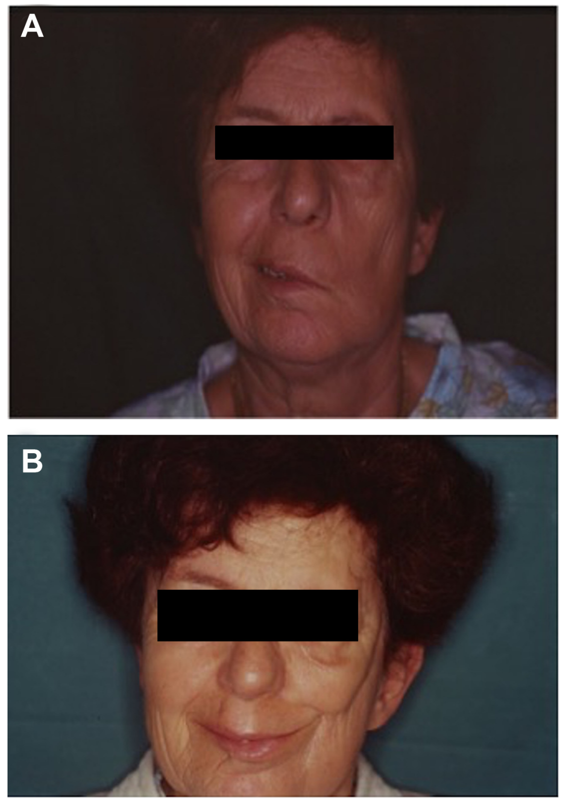

FIGURE 7. A 68-year-old woman with facial paralysis on the left side. (A) Frontal view of the patient preoperatively attempting to smile. There is no excursion of the oral commissure on the patient's paralyzed side. (B) Appearance 9 months after the modified temporalis muscle transfer (MTMT) technique: the patient is smiling, and the smile is symmetric and spontaneous.

recovery and to quantify the motility of the lower third of the face during a smile.

For those reasons, we have developed an accurate and repeatable method of study that can identify the ability to produce both the voluntary and the spontaneous smile and quantify the range of motion and the symmetry of the smile after this kind of treatment.

The subjects in group C were able to smile during VST and NVST showing high symmetry. EMG analysis confirmed the role of the orbicularis muscle as a mimic muscle and of temporalis muscle for healthy subject as a nonmimic muscle.

The subjects in group T were able to smile voluntarily and the expression was characterized by symmetry.

The subjects in group T were able to smile spontaneously and the symmetry of the smiles were completely recovered for 8 of them and partially for 2 (Table 5). Behavior of the treated and orbicularis oris muscle of the not-treated muscles during each experimental session did not reveal a difference between voluntary and spontaneous smile tests. This suggests that the muscular control is an acquired mechanism that acts in the same manner when the patient knows to smile or when the smile happens spontaneously.

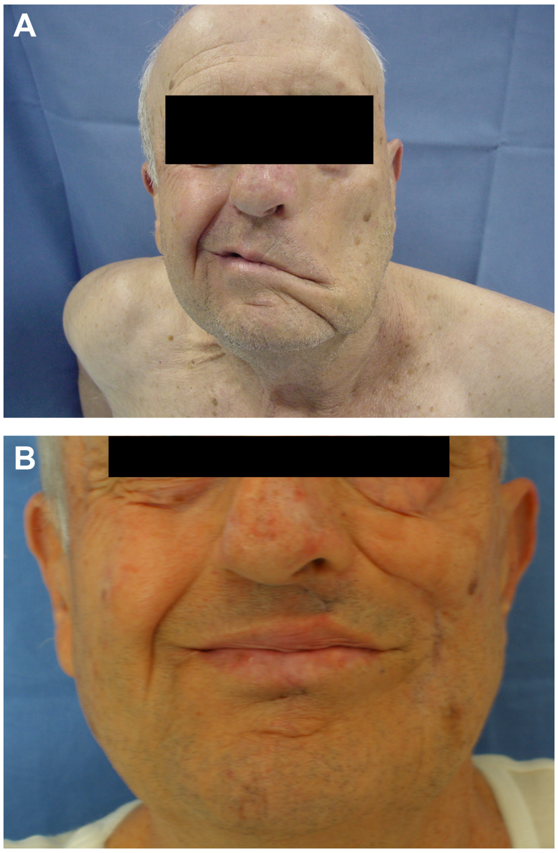

FIGURE 8. A 73-year-old man with facial paralysis on the left side. (A) Frontal view of the patient preoperatively attempting to smile. There is no excursion of the oral commissure on the patient's paralyzed side. (B) Appearance 14 months after the modified temporalis muscle transfer (MTMT) technique: the patient is smiling, and the smile is symmetric with good amplitude.

The contemporary activation of the orbicularis oris muscle of the not-treated and the treated allowed the authors to exclude that the temporalis activity can be a reaction to the traction exerted by the orbicularis oris muscle of the not-treated side. The treated side seems to act to allow the smile of the patient. The presence of treatment when the patient smiles, suggests the possibility that the patient learned to smile using the muscles not smiling-specific, for instance, closing the mandible. Temporalis action is in fact aimed to raise the mandible and to close the jaw.

The results of this study allow us to suppose that, after surgical treatment of facial paralysis, the temporalis muscle acquires a mimic function: patients recur to temporalis muscle action to smile or to strengthen the action of remained mimic muscles.

To improve the validity of the study, the sample population has to be increased. Relevance of the results obtained by the sEMG analysis obliges the authors to improve the quality and accuracy of the signal detected. The sensors size of the sEMG should be reduced and interface sensor-skin, especially for the temporalis muscle, should be improved by asking for cutting the air in the sensible area. This choice has been avoided in this preliminary study to reduce the uneasiness to the patients.

CONCLUSIONS

The recovery of the principal dynamic functions of the face, eyelids, and mouth is very important for the patients who have undergone facial palsy surgical treatment, in terms of the quality of life.

For patients suffering from facial palsy, it is crucial to regain control of the lips in order to avoid the embarrassing food pooling from the corner of the mouth, return to speak fluently, but also be able to smile again spontaneously.

Our study shows that Morrison's MTMT technique is able to restore the smiling ability in all the patients treated.

Particularly, this technique allows recovering the spontaneous smile in all the treated patients, with the

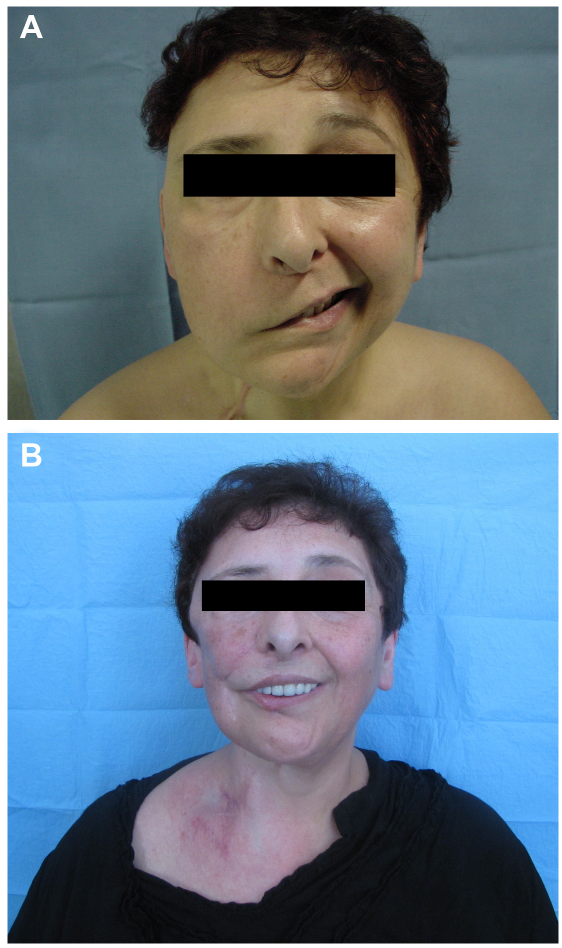

FIGURE 9. A 52-year-old woman with facial paralysis on the right side. (A) Preoperative view with the patient smiling. There is no excursion of the oral commissure on the patient's paralyzed side. (B) Appearance 1 year after the modified temporalis muscle transfer (MTMT) technique: the patient is smiling, and the smile is symmetric and spontaneous. The result is satisfactory.

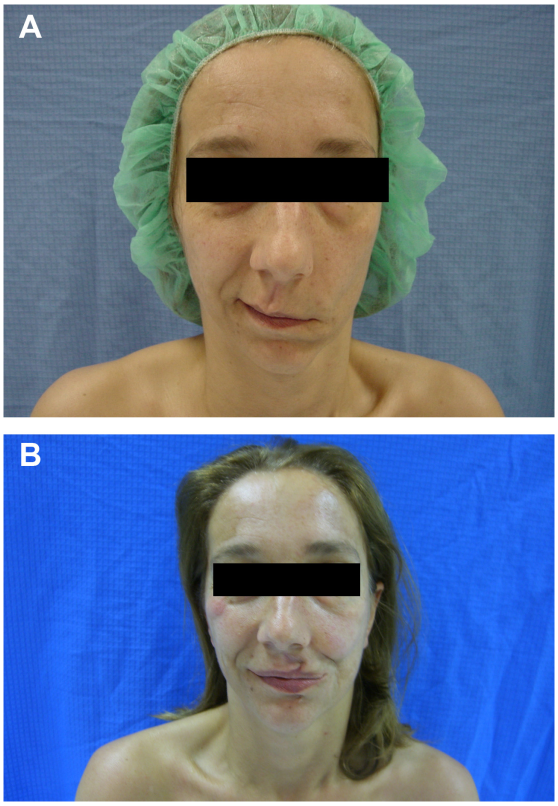

FIGURE 10. A 45-year-old woman with facial paralysis on the left side. (A) Preoperative view with the patient smiling. There is no excursion of the oral commissure on the patient's paralyzed side. (B) Appearance 9 months after the modified temporalis muscle transfer (MTMT) technique: the smile is symmetric, spontaneous, of satisfactory amplitude, and the nasolabial fold is clearly visible.

achievement of a good symmetry. The achievements would seem to suggest that the transposed temporalis muscle might adapt from chewing muscle to mimetic muscle.

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