Comparison of Hemihypoglossal Nerve versus Masseteric Nerve Transpositions in the Rehabilitation of Short-Term Facial Paralysis Using the Facial Clima Evaluating System

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Background: Masseteric and hypoglossal nerve transfers are reliable alternatives for reanimating short-term facial paralysis. To date, few studies exist in the literature comparing these techniques. This work presents a quantitative comparison of masseter-facial transposition versus hemihypoglossal facial transposition with a nerve graft using the Facial Clima system.

Methods: Forty-six patients with complete unilateral facial paralysis underwent reanimation with either hemihypoglossal transposition with a nerve graft (group I, $n = 25$) or direct masseteric-facial coaptation (group II, $n = 21$). Commissural displacement and commissural contraction velocity were measured using the Facial Clima system. Postoperative intragroup commissural displacement and commissural contraction velocity means of the reanimated versus the normal side were first compared using a paired sample t test. Then, mean percentages of recovery of both parameters were compared between the groups using an independent sample t test. Onset of movement was also compared between the groups.

Results: Significant differences of mean commissural displacement and commissural contraction velocity between the reanimated side and the normal side were observed in group I but not in group II. Mean percentage of recovery of both parameters did not differ between the groups. Patients in group II showed a significantly faster onset of movement compared with those in group I (62 ± 4.6 days versus 136 ± 7.4 days, $p = 0.013$).

Conclusions: Reanimation of short-term facial paralysis can be satisfactorily addressed by means of either hemihypoglossal transposition with a nerve graft or direct masseteric-facial coaptation. However, with the latter, better symmetry and a faster onset of movement are observed. In addition, masseteric nerve transfer avoids morbidity from nerve graft harvesting. (*Plast. Reconstr. Surg.* 130: 662e, 2012.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

Facial paralysis represents a challenging topic in reconstructive surgery. In recent decades, different surgical procedures have been described to treat it,[1–3] with various authors reporting very good functional and aesthetic results.[4–7] To address cases with short-standing paralysis (i.e., 6 months to 2 years), all attempts should be made to obtain smile reanimation with the still viable mus-

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culature, avoiding its atrophy during the process. For this purpose, Terzis's group introduced the "baby-sitter" procedure.[8] In addition, for this group of patients, cross-facial nerve grafting and direct neurotization using an ipsilateral nonfacial nerve are also valid and reliable alternatives, with masseteric and hypoglossal nerve transfers being the most widespread techniques used for such purposes. With either of these nerves, adequate symmetry at rest and good commissural contraction is obtained, with minimal donor-site morbidity.[9–12]

If choosing the right and best suited technique in a particular case can sometimes be a complex task, more complex is the comparison of the different procedures described. An individual's smile is practically unique, and thus its standardization cannot be achieved without considerable bias. Moreover, if surgical reanimation has been performed, the picture is further complicated. In an effort to overcome this problem, several qualitative and quantitative measurement systems have been developed to allow, on one hand, classification of the degree of facial paralysis and, on the other hand, measurement of the results obtained with specific reanimation techniques. The traditional measurement system used is the House-Brackmann scale,[13] which has the problems of assessing the degree of facial paralysis in qualitative terms and being an observer-dependent method. To resolve these deficiencies, computerized systems have been developed to provide quantitative measures based on analysis of a photograph or video recording,[14] by counting pixels,[15] and by looking at variation in light reflections.[16] Nevertheless, because of the complexity of the analysis generated by these systems and the fact that they provide dynamic information limited to two dimensions of space, none of them has been accepted for clinical use. Moreover, this type of method makes comparisons between different techniques and surgical centers almost impossible, because every center uses its own measurement system to quantify their results. In 2008,we developed an automatic, easy, fast, quantitative method called Facial Clima, which provides dynamic three-dimensional information that allows comparison of results obtained after reanimation with different surgical techniques.[17] The objective of this study was to compare commissural displacement, velocity of muscle contraction, and onset of movement of two reanimation techniques (i.e., masseteric nerve transfer and hypoglossal nerve transfer) with a nerve graft in patients with short-standing facial paralysis using the Facial Clima system.

PATIENTS AND METHODS

From 2000 to 2010, 46 patients with complete, short-term (i.e., 6 months to 2 years), unilateral facial paralysis underwent reanimation with either hypoglossal nerve transfer (group I, $n = 25$) or masseteric nerve transfer (group II, $n = 21$). All operations were performed by the senior author (B.H.). For all patients, sex, cause of disease, age at surgery, time of evolution of paralysis, and onset of movement (days between surgery and notice of first contraction reported by the patient) were registered. In all cases, a complete evaluation including physical examination, standard photographs and video, electromyography, and Facial Clima was conducted preoperatively and 3, 6, 12, and 24 months after surgery. Complete paralysis was defined as the absence of clinical movement according to both physical examination and the Facial Clima system and the absence of signs of recovery on needle electromyography at least 6 months after injury. It is important to note that in all cases the objective of both operations was to reanimate the smile in a one-stage procedure.

Operative Technique

Hemihypoglossal Nerve Transposition with a Nerve Graft

Through a preauricular incision on the paralyzed side, a cheek flap was elevated by means of a supra–superficial musculoaponeurotic system dissection until the anterior margin of the parotid gland was identified, where the zygomaticofacial trunk was located. To locate the hypoglossal nerve, a 1- to 2-cm incision parallel to the lower mandibular line was performed. Then, the submandibular gland was retracted and the digastric muscle tendon was displaced, thus visualizing the nerve. The sural nerve was used as the donor nerve graft, with a mean length of 8 cm (range, 6 to 10 cm). It was harvested by means of two small horizontal incisions in the posterolateral leg. The sural nerve graft was interposed between the hypoglossal nerve and zygomatic trunk of the facial nerve using a tendon stripper to introduce the graft through a subcutaneous tunnel. One-third of the diameter of the hypoglossal nerve was opened and anastomosed end to side to the nerve graft. The distal stump of the nerve graft was connected end to end to the zygomatic trunk of the facial nerve.

Masseteric Nerve Transposition

The approach to the zygomaticofacial trunk is performed as described above. To locate the masseteric nerve, the masseter muscle is approached and partially released below the zygomatic arch. The nerve can then be readily seen 4 cm anterior to the tragus and 2 cm below the zygomatic arch.[18] Next, the nerve is partially transected, oriented toward the zygomaticofacial trunk, and coapted.

Rehabilitation Protocol

Patients are asked to start training 1 month after surgery. Smiling in front of a mirror for at least 10 minutes per day is recommended. During this period and until movement is observed, the patients are told to move the reconstructed side by either pressing the tongue against the front teeth or biting. Once motion is restored, training consists of attempting to smile by triggering the donor nerve's original action, but completing smiling independently from it.

Description of the Capture System: Facial Clima

Facial Clima is an automatic optical system to capture facial movements, which involves placing special reflecting dots on the subject's face following a predetermined configuration. A system of video recording with three infrared-light cameras captures the subject performing the following movements: smiling, mouth puckering, eye closure, and forehead elevation. With these four movements, several vectors are obtained and analyzed (Fig. 1). Images from the cameras are processed automatically by computer software that generates customized information such as three-dimensional data on velocities, distances, and areas. The measurement process is accurate to within 0.13 mm and 0.41 degree. This system has been tested in normal patients and found to have a reliability of 99 percent. For more information about intrarrater and interrater accuracy and exact functioning of this system, see Hontanilla and Aubá.[17]

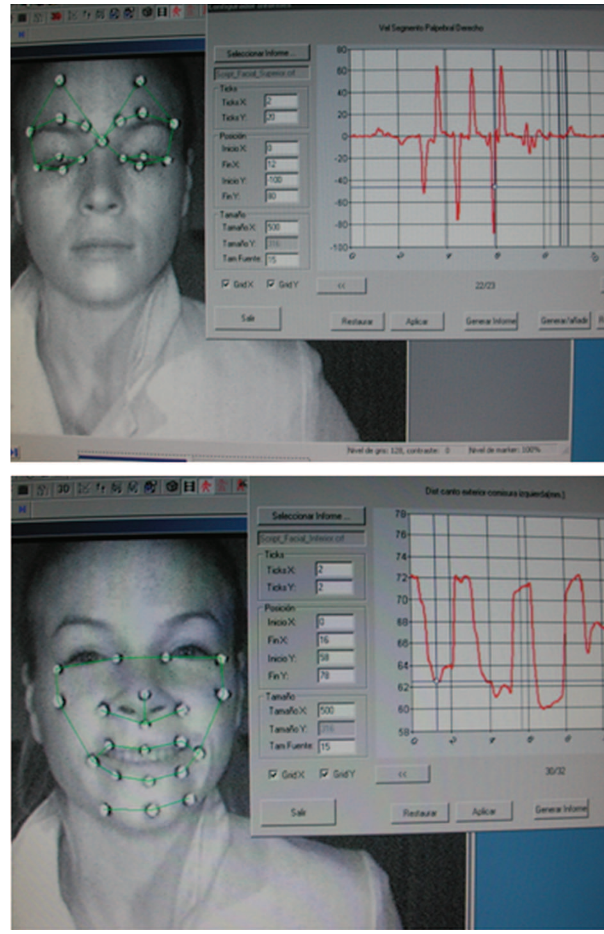


Fig. 1. Main facial plots used for determination of length, angles, and velocity of segment shortening and surface between landmarks. (*Above*) Upper third of the face. (*Below*) Middle and lower thirds of the face.

Statistical Analysis

To compare the effectiveness of the techniques performed, the following parameters were evaluated in each patient by means of the Facial Clima system: commissural contraction velocity (mean of maximum velocity of contraction, in millimeters per second) and oral commissure displacement (mean difference between the minimum and maximum commissural displacement at rest and when contracted, in millimeters). Both parameters were obtained from the normal and reanimated sides. Patients were analyzed 2 years after surgery. Because all patients presented with complete paralysis, both commissural contraction velocity and commissural displacement were 0 in the preoperative situation. First, to evaluate the degree of symmetry obtained with each technique, intragroup comparison of commissural displacement and commissural contraction velocity of the reanimated versus the normal side of each patient was conducted. Next, to assess degree of recovery, after reanimation, the values of commissural displacement and commissural contraction velocity were transformed into a percentage of recovery, with the normal side representing 100 percent. With this, each subject is compared with himself of herself, avoiding biased comparisons between different individuals (i.e., a patient with a strong full smile versus another with a soft lateral smile). Finally, a mean percentage of recovery of commissural displacement and commissural contraction velocity was obtained for each technique.

For intergroup comparisons, first the Levene test for equality of variances was conducted. Next, all quantitative variables (i.e., age, time of evolution, commissural displacement, commissural contraction velocity, percentage of recovery, and onset of movement) were compared using the two-sample t test. For intragroup analysis of commissural displacement and commissural contraction velocity, the paired sample t test was used. SPSS v17.0 (SPSS, Inc., Chicago, Ill.) was used to analyze results and perform all statistical tests, setting significance at $p < 0.05$.

RESULTS

Cause of paralysis included acoustic neurinoma, skull base fracture, brainstem surgery, parotid surgery, facial nerve schwannoma, and varicella zoster infection. Distributions of age, sex, and cause are listed in Table 1. Mean age at surgery was 49.5 ± 8.3 years in group I (hemihypoglossal) and 44.1 ± 7.6 years in group II (masseteric). Evolution of paralysis was a mean of 16.4 ± 5.3 months in patients in group I and 17.1 ± 4.8 months in patients in group II (Table 2). No significant differences were observed for either of these variables. As we have selected patients with complete facial paralysis, preoperative measurements of the paralyzed side in all cases showed neither movement nor electrical activity of the oral commissure.

In group I, the mean oral commissural displacement 2 years after surgery was 7.7 ± 3.9 mm on the reanimated side and 9.3 ± 3.9 mm on the healthy side. The mean recovery of commissural displacement in this group was 83.2 ± 4.5 percent. Mean postoperative commissural contraction velocity was 35.3 ± 16.7 mm/second on the paralyzed side and 48.7 ± 19 mm/second on the normal side, representing a mean recovery of 72.5 ± 17 percent. Mean onset of movement in this group of patients was 136 ± 7.4 days (Table 2). Comparison of commissural displacement and commissural contraction velocity of the reconstructed side versus the normal side showed significant differences 2 years after surgery ($p = 0.017$ for commissural displacement and $p = 0.036$ for commissural contraction velocity) (Table 3).

In group II, the mean oral commissural displacement 2 years after surgery was 7.8 ± 3.1 mm on the reanimated side and 8.5 ± 2.7 mm on the healthy side. The mean recovery of commissural displacement in this group was 91.8 ± 5.1 percent. Mean postoperative commissural contraction velocity was 36.2 ± 10.6 mm/second on the reanimated side and 45.4 ± 12.6 mm/second on the normal side, representing a mean recovery of

Table 1. Distribution of Age Ranges, Sex, and Detail of Causes of Both Groups

Characteristic	Group I	Group II
Age		
<20 years	1	0
20–30 years	0	1
30–40 years	4	7
40–50 years	10	7
50–60 years	8	5
>60 years	2	1
Sex		
Male	9	14
Female	16	7
Cause		
Acoustic neurinoma (>3 cm)	17	15
Skull base fracture	2	3
Brainstem surgery	2	0
Parotid surgery	1	0
Schwannoma	2	1
Varicella zoster	1	2

Table 2. Intergroup Comparisons

			CD (mm)		CCV (mm/sec)		Recovery (%)		
Group	Age (yr)	Time (mo)	Reanimated	Normal	Reanimated	Normal	CD	CCV	Movement Onset (Days)
I	49.5 ± 8.3	16.4 ± 5.3	7.7 ± 3.9	9.3 ± 3.9	35.3 ± 16.7	48.7 ± 19	83.2 ± 4.5	72.5 ± 17	136 ± 7.4
II	44.1 ± 7.6	17.1 ± 4.8	7.8 ± 3.1	8.5 ± 2.7	36.2 ± 10.6	45.4 ± 12.6	91.8 ± 5.1	79.7 ± 15.5	62 ± 4.6
p	0.52	0.61	0.54	0.41	0.5	0.39	0.11	0.19	0.013*

CD, commissure displacement; CCV, commissural contraction velocity.

Table 3. Intragroup Comparisons of Commissural Displacement and Commissural Contraction Velocity*

	CD (mm)			CCV (mm/sec)		
Group	Healthy	Reconstructed	p	Healthy	Reconstructed	p
I	9.3 ± 3.9	7.7 ± 3.9	0.017	48.7 ± 19	35.3 ± 16.7	0.036
II	8.5 ± 2.7	7.8 ± 3.1	0.2	45.4 ± 12.6	36.2 ± 10.6	0.17

CD, commissure displacement; CCV, commissural contraction velocity.
*Significant differences are observed in group I for both parameters.

79.7 ± 15.5 percent. Mean onset of movement in this group of patients was 62 ± 4.6 days (Table 2). Comparison of commissural displacement and commissural contraction velocity of the reconstructed side versus the normal side showed no significant differences 2 years after surgery (Table 3).

For intergroup comparisons, the Levene test for equality of variances showed no statistical significance ($p > 0.05$). Comparison of mean percentage of recovery showed no significant differences between the groups ($p > 0.05$). However, onset of movement was significantly faster in patients reanimated with masseteric nerve transposition ($p = 0.013$) (Table 2). Regarding the functional impact following nerve transfer, because both nerves were partially sacrificed, no clinically relevant deficit was observed in tongue mobility or mastication (Figs. 2 through 4). (**See Video, Supplemental Digital Content 1,** which demonstrates the appearance of the patient in Figure 2 at 24 months after surgery, ***http://links.lww.com/PRS/A580***; **See Video, Supplemental Digital Content 2,** which demonstrates the appearance of the patient

Fig. 2. A 40-year-old man with left facial paralysis secondary to acoustic neurinoma resection. Hemihypoglossal nerve transfer using a sural nerve graft was performed for smile reanimation. Preoperative appearance at rest (*Above*, *left*) and while smiling (*above*, *right*). Postoperative situation after 2 years, at rest (*below*, *left*) and while smiling (*below*, *right*).

Fig. 3. A 51-year-old woman with right facial paralysis secondary to varicella zoster infection. Masseteric nerve transfer was performed for smile reanimation. Preoperative appearance at rest (*above*, *left*) and while smiling (*above*, *right*). Postoperative situation after 2 years, at rest (*below*, *left*) and while smiling (*below*, *right*).

in Figure 3 at 24 months after surgery, ***http://links.lww.com/PRS/A581***; **See Video, Supplemental Digital Content 3,** which demonstrates the appearance of the patient in Figure 4 at 24 months after surgery, ***http://links.lww.com/PRS/A582***; **See Video, Supplemental Digital Content 4,** which demonstrates the appearance of a 40-year-old man with right facial paralysis secondary to varicella zoster infection. Masseteric nerve transfer was performed for smile reanimation. Preoperative appearance, ***http://links.lww.com/PRS/A583***; **See Video, Supplemental Digital Content 5,** which demonstrates the appearance of the patient in Supplemental Digital Content 4 at 18 months after surgery, ***http://links.lww.com/PRS/A584***.)

DISCUSSION

Selection of the correct technique with which to reanimate a paralyzed face has been the cornerstone of facial paralysis surgery. Today, con-

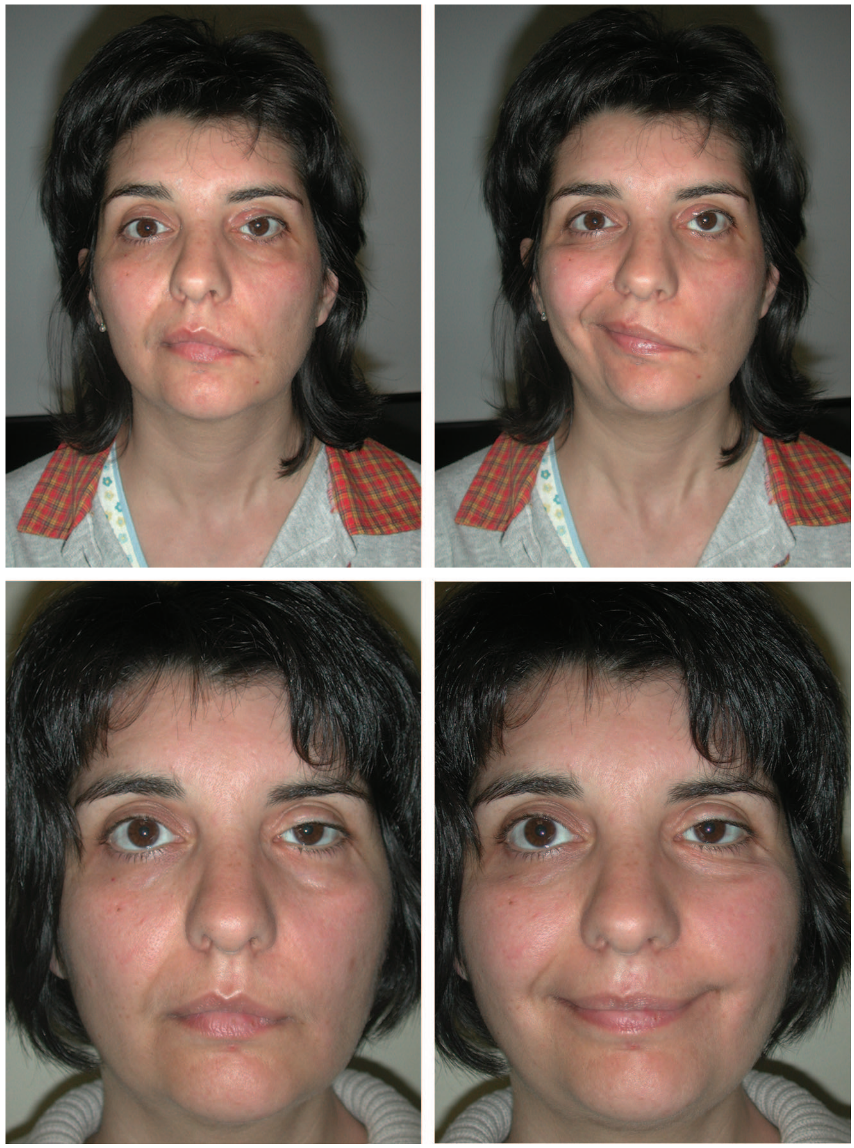
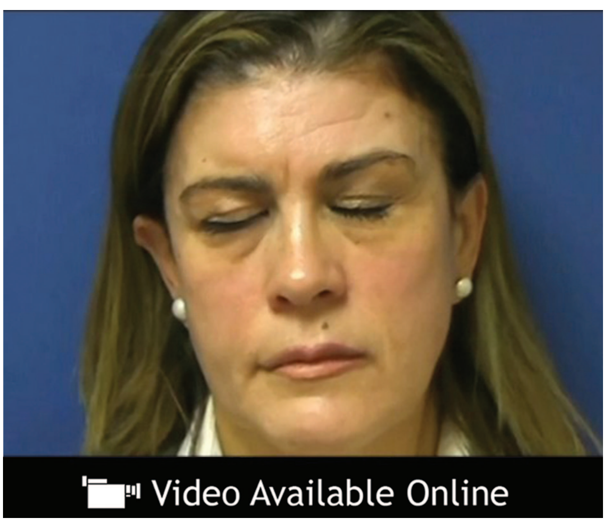


Fig. 4. A 41-year-old woman with a complete left facial paralysis secondary to resection of an acoustic neurinoma. Hemihypoglossal nerve transfer using a sural nerve graft was performed for smile reanimation. Preoperative appearance at rest (*above*, *left*) and while smiling (*above*, *right*). Postoperative situation after 2 years, at rest (*below*, *left*) and while smiling (*below*, *right*).

sidering the variety of procedures available, probably one of the most challenging aspects of facial reanimation is actually indicating the right technique for the right patient. Even though the surgical plan is initially oriented by some basic aspects such as time of evolution and development (or not) of muscle atrophy, surgeons must frequently deal with cases in which more than one technique can be performed. A clear example is the group of patients with paralysis of less than 2 years of evolution in whom the facial musculature is still viable. In this scenario, some valid alternatives include performing a nerve transposition with either hypoglossal or masseteric nerve, a "babysitter" procedure as described by Terzis's group,[8] or even cross-facial nerve grafting alone. It is in these instances when the comparison of techniques has its greater value. Efforts to compare different reanimation techniques have already been conducted by several authors. Temporary transpositions versus free muscle plus cross-facial nerve grafting following the Frey protocol, comparison of three different techniques based on the hypoglossal nerve, and comparison of cross-facial nerve grafting versus mas-

Video 1. Supplemental Digital Content 1 demonstrates the appearance of the patient in Figure 2 at 24 months after surgery, ***http://links.lww.com/PRS/A580.***



Video 2. Supplemental Digital Content 2 demonstrates the appearance of the patient in Figure 3 at 24 months after surgery, ***http://links.lww.com/PRS/A581.***

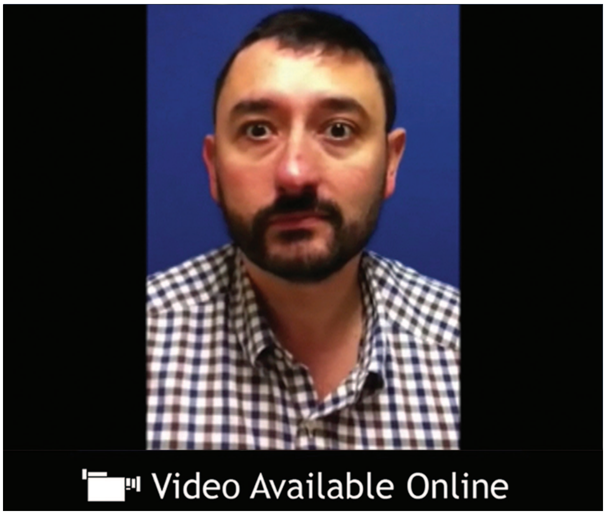
seteric nerve for free muscle neurotization have all been conducted.[19–22]

Regarding nerve transpositions, several authors have reported very good functional and aesthetic results with both the masseter and hypoglossal nerves.[10–12] Furthermore, by partially sacrificing them, morbidity of the donor zone is minimized. Even though both techniques are widely performed by several groups, evidence of objective comparison between them is scarce. Considering this fact, we sought to compare these procedures using a validated, objective, and operator-independent method of evaluation, such as

Video 3. Supplemental Digital Content 3 demonstrates the appearance of the patient in Figure 4 at 24 months after surgery, ***http://links.lww.com/PRS/A582.***

Video 4. Supplemental Digital Content 4 demonstrates the preoperative appearance of a 40-year-old man with right facial paralysis secondary to varicella zoster infection, ***http://links.lww.com/PRS/A583***. Masseteric nerve transfer was performed for smile reanimation.

the Facial Clima system. It is important to mention that, as reported elsewhere, adequate reanimation can be obtained with either of these transpositions in patients with complete paralysis between 6 months and 2 years of evolution, as in the cases presented here. Although cross-face nerve grafting could be an alternative, it is well known that in cases with paralysis beyond 6 months, the results obtained with this procedure are suboptimal.[23] Considering this, we opted for more reliable techniques such as those analyzed here. In addition, it



Video 5. Supplemental Digital Content 5 demonstrates the appearance of the patient in Video, Supplemental Digital Content 4 at 18 months after surgery, ***http://links.lww.com/PRS/A584.***

must be understood that in the present work there has been no randomization of any kind, as this was a retrospective review. At the beginning, we performed hypoglossal transpositions only. However, as different reports on the use of the masseteric nerve as the donor nerve started to appear, we opted for this technique in light of the advantages and good results published, and it soon became our preferred technique of nerve transposition.

On the issue of comparisons, in an initial analysis, to assess the degree of symmetry achieved with each technique, we compared the postoperative intragroup means of commissural displacement and commissural contraction velocity of the reanimated and normal sides. Statistical differences were observed in group I (hemihypoglossal) but not in group II (masseteric), suggesting that greater symmetry is obtained with the latter. In a second analysis, to avoid bias from the heterogeneity of smiles, we compared rates of improvement of each technique, considering the percentage of recovery of the paralyzed side in relation to the normal side in each case. No differences were found between the groups, which is indicative that with both nerves an adequate degree of recovery can be achieved. Considered together, these findings show that both types of nerve transposition achieve good functional results, although the masseteric nerve produces better symmetry, probably because of its greater strength of pull. Notwithstanding the usefulness of both transpositions in the reanimation of the paralyzed face, it is important to emphasize the fact that with both techniques, "triggering," either by pressing the tongue against the front teeth or by biting, is necessary to initiate smiling.

An important aspect to consider in facial paralysis reanimation is trying to obtain the best possible functional and aesthetic result with minimal morbidity of the donor zone, independent of the technique. As stated above, with masseter and hypoglossal nerve transposition, both of these requirements can be fulfilled because good commissural excursion is obtained and mastication and tongue protrusion or atrophy are not severely affected. Notwithstanding, a major difference between the procedures is the need to harvest a nerve graft (sural or greater auricular) for hypoglossal transposition, with the consequent morbidity that this implies (i.e., anesthesia of the corresponding territories). Furthermore, by interposing a nerve graft, the regenerating fibers must cross two sites of coaptation plus the graft compared with only one anastomosis in cases of masseteric nerve transfer. This fact is clinically translated into significantly faster onset of movement for the latter technique (62 ± 4.6 days versus 136 ± 7.4 days, $p = 0.013$). To overcome the disadvantages of nerve grafting, some groups advocate performing direct end-to-end or end-to-side facial-to-hypoglossal nerve anastomosis by releasing the facial nerve from the geniculate ganglion to the stylomastoid foramen (i.e., modified May technique).[24] Even though good symmetry at rest is obtained, this procedure presents several limitations. First, coapting the hypoglossal nerve to the main trunk of the facial nerve precludes performing selective reanimation of specific branches (i.e., upper zygomaticofacial branches for smile rehabilitation). Second, such gross coaptation will inevitably produce massive movements of the whole hemiface as both the temporofacial and cervicofacial trunks are being commanded by one nerve only. Third, because coaptation is performed in a very proximal segment of the facial nerve, there is a high risk of developing facial synkinesis.[25] Finally, in our opinion, the surgical effort that this technique demands (i.e., mastoid dissection by drilling the facial nerve canal) is overly aggressive considering the fact that other simpler and more effective techniques are available.

The masseter nerve has been used successfully for rehabilitation of the paralyzed face for the past two decades. Several groups have directed their attention to this technique and have achieved very good functional and aesthetic results, and it has thus become an invaluable tool available to facial palsy surgeons. Not surprisingly, a considerable number of studies have been published regarding the anatomy and topographic landmarks of the masseter nerve to aid in its harvest during facial reanimation.[18,26,27] It is used not only for direct coaptation to the facial nerve but also as a babysitter to avoid irreversible atrophy in reanimation with cross-facial nerve grafts and neurotization of free muscle transfers.[10,11,28] In cases of bilateral paralysis, in which the facial and other cranial nerves are affected (i.e., Möbius syndrome), this nerve has shown great reliability for free muscle neurotization.[4,7] One of the main advantages attributed to this nerve is its strength, which makes reanimation of "strong" full smiles possible, a task for which other techniques such as cross-face nerve grafting often fall short. Our results support these previous findings, as we have observed a high degree of symmetry in this group of patients.

An important aspect of our study that deserves thorough discussion is the method used to assess our postoperative results. In 2008, we introduced the Facial Clima system, an automatic, quantitative, operator-independent, objective method that allows dynamic quantification of facial movements. The two most important parameters that are evaluated with this tool are commissural displacement (in millimeters) and commissural contraction velocity (in millimeters per second). By measuring both of these, it is possible to evaluate the degree of symmetry obtained by comparing the reanimated versus the normal side, and to assess the degree of recovery by calculating the percentage of recovery considering the healthy side as the reference. This is an important aspect to consider when comparing different techniques of facial reanimation. Because smiles are different between individuals, comparing only the absolute value of each parameter is not entirely accurate. For example, a patient with a strong smile can have a higher value of commissural displacement than someone with a "weak" smile, without meaning that the latter has some form of paralysis. This is why we sought to compare the percentage of recovery of each individual in relation to his or her normal side. The mean obtained from these percentages is a much more realistic indicator of the actual efficacy of the reanimation technique, making comparisons between procedures possible.

CONCLUSIONS

In light of the results obtained from this study, it is fair to conclude that reanimation of short-standing paralysis can be satisfactorily achieved with both hemihypoglossal nerve transfer with a nerve graft and direct masseteric-facial nerve transposition. Notwithstanding, greater symmetry, faster onset of movement, and absence of nerve grafting morbidity can be obtained with the masseteric nerve. Thus, in our opinion, when both techniques are feasible, the masseteric should be used in patients with short-term facial palsy to optimize outcomes and reduce morbidity from nerve graft harvesting.

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PATIENT CONSENT

Patients provided written consent for use of their images.

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