One-Stage Procedure Using Spinal Accessory Nerve (XI)–Innervated Free Muscle for Facial Paralysis Reconstruction

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Background: For the treatment of facial paralysis, functioning free muscle transplantation has become accepted standard treatment. Choice of donor nerve and number of surgery stages, however, are still matters of great debate.
Methods: Between 2000 and 2011, 36 patients (out of 329; 11 percent) with 42 functioning free muscle transplantations were treated using spinal accessory nerve (XI)–innervated muscle for facial reanimation as a one-stage procedure. Indications included bilateral or unilateral Möbius syndrome, severe postparetic facial synkinesis, and patient preference. Postoperative smile training was required to achieve spontaneous smile. For outcome assessment, patients were evaluated using multidisciplinary methods, including objective smile excursion score (range, 0 to 4), cortical adaptation stage (range, I to V), tickle test, and subjective patient questionnaire and satisfaction score (range, 1 to 5).
Results: Mean smile excursion score improved from 0.5 preoperatively to 3.4 postoperatively. Eighty-three percent of patients were able to perform independent and even spontaneous smile after 1 year of follow-up. Ninety percent of patients had a mean satisfaction score of 3.4 out of 5. However, 50 percent expressed more concern with aesthetic appearance than functional status. There was no functional morbidity of the donor shoulder in daily life.
Conclusions: The classic two-stage procedure is still the first choice for facial paralysis reconstruction. However, the effectiveness of XI-innervated free muscle for facial reanimation in a one-stage procedure has proven it to be a good alternative treatment. It has become second in popularity for facial paralysis reconstruction in the authors' center. (*Plast. Reconstr. Surg.* 132: 117e, 2013.)
CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

Facial paralysis is a disaster for the patient. Functioning muscle transplantation has become the accepted standard of surgical treatment for facial paralysis. However, procedures with one,[1–4] two,[5–8] or more stages[9] and choice of the motor nerve for innervation[1–11] have always been discussed and debated.[12,13]

An ideal motor nerve to innervate a functioning muscle transplantation for facial reanimation should (1) be a nearby nerve to avoid the requirement of a nerve graft, (2) be a strong nerve to provide an adequate innervation, (3) provide a quicker recovery with a short rehabilitation time, (4) have minimal donor-site morbidities, (5) have the potential to create a spontaneous smile, and (6) provide universal application in different situations. A cross-face nerve graft remains a popular choice in providing

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Fig. 1. (*Above*) A 20-year-old man presented with Bell's palsy of 4 years' duration. He received XI-innervated gracilis transfer for facial reanimation. Patient is shown 1 year postoperatively (*center*) at rest and (*below*) while smiling. His smile excursion score improved from 0 to 4, and his cortical adaptation stage improved from stage I to V (see Video, Supplemental Digital Content 2). His satisfaction score was 5 (completely satisfied). The patient had no inconvenience to his daily activities and social interaction, although he still had mild arm-to-face synkinesis. The patient has been asked continue to practice before a mirror (mirror therapy) for smile training.

a symmetric and spontaneous smile.[5–8,13] A two-stage procedure and comparably weak power with a slow recovery have been its main disadvantages. The masseter motor nerve has gained widespread popularity in the past decade.[2,14,15] It is a one-stage procedure, and the nerve is strong, providing adequate muscle excursion and quick recovery of smile in 3 to 6 months. The C7 spinal nerve,[9] the hypoglossal nerve,[10] and the phrenic nerve[11] have also been introduced in the literature, but not popularly due to their disadvantages, such as multiple stages, associated morbidities, and required nerve grafting.

The spinal accessory (XI) nerve has been a common choice in brachial plexus reconstruction.[16,17] Terzis et al.[18] applied the XI nerve elongated with a nerve graft in 11 functioning muscles for Möbius syndrome patients with facial paralysis. However, XI-innervated free muscle for facial paralysis reconstruction has never been considered a popular choice due to its difficult dissection, possible use with a nerve graft, and donor-site complication.[19,20] In this article, we present our experience using XI-innervated free muscle without a nerve graft as a one-stage procedure for unilateral and bilateral facial palsy.

PATIENTS AND METHODS

From 1987 to 2011 (a 25-year period), a total of 329 facial palsy patients were treated with 335 functioning muscle transplantations for smile reconstruction. Six patients with bilateral facial paralysis due to bilateral Möbius syndrome were

Video 1. Supplemental Digital Content 1 shows a 20-year-old man who received XI-innervated gracilis transfer for facial reanimation, ***http://links.lww.com/PRS/A751***. His result at 1 year postoperatively showed a good smile excursion score and a good cortical adaptation stage. He passed the tickle test.

Table 1. Patient Demographics

Characteristic	Value
Total no. of patients	36
Total no. of FFMTs	42
Mean age, yr (range)	22 (4–63)
Male:female, no.	19:17
Paralysis	
Unilateral	30
Bilateral	6
Side	
Left	13
Right	17
Bilateral	6
Cause of facial paralysis	
Bell's palsy	11
Tumor	11
Congenital	9
Infection	3
Trauma	2
Nerve grafts used	0
Indications	
Congenital	9
Facial synkinesis	9
Patient preference	18

FFMT, functioning free muscle transplantation.

reconstructed with bilateral gracilis muscles. They all were operated on by the same surgeon (D.C.-C.C.). Ninety-nine percent (331 of 335) of functioning muscle transplantations utilized gracilis muscles. Different motor nerves were utilized. A classic two-stage procedure, with a cross-face nerve graft as the first stage followed by functioning muscle transplantation as the second stage, was performed in most patients (282 of 329 patients; 85.7 percent). The XI nerve was the second most popular (36 of 329 patients; 10.9 percent). The rest were ipsilateral facial nerve–innervated free muscle (six cases; 1.8 percent), masseter-innervated free muscle (four cases; 1.2 percent), and contralateral facial nerve–innervated muscle as one-stage procedure (one case; 0.3 percent).

We started using XI-innervated free muscle for facial paralysis in 2000 for bilateral Möbius syndrome with bilateral facial palsy.[4] Because of its effectiveness, we adapted this technique and continue to use it for unilateral facial paralysis (Fig. 1). (**See Video, Supplemental Digital Content 1**, which shows a 20-year-old man who received XI-innervated gracilis transfer for facial reanimation, ***http://links.lww.com/PRS/A751***. At 1 year postoperatively, he had a good smile excursion score and a good cortical adaptation stage. He passed the tickle test.)

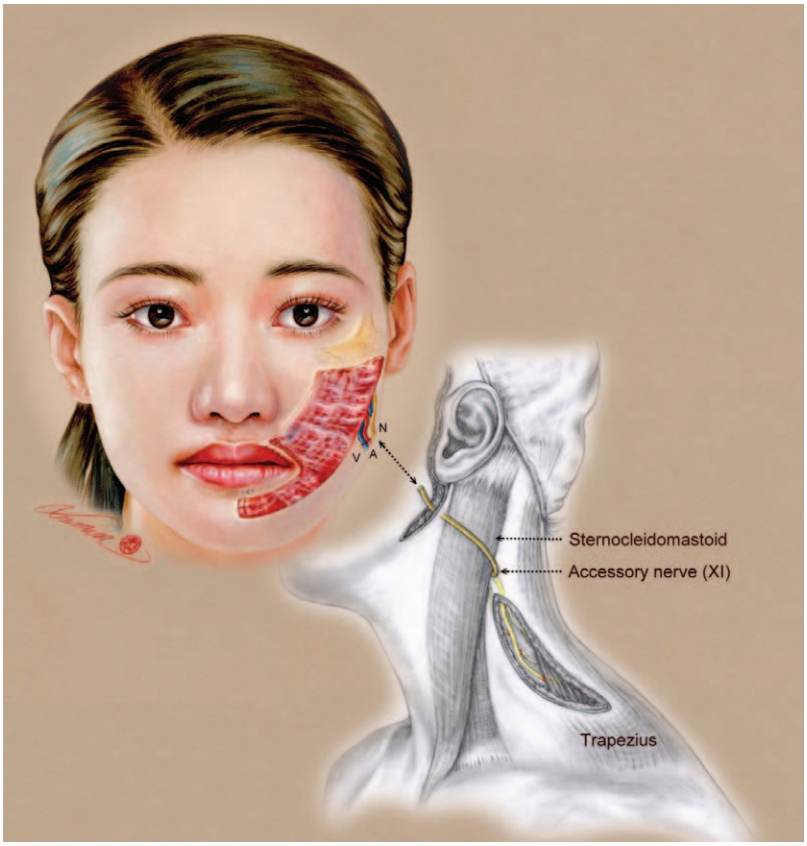


Fig. 2. Drawing shows the anatomic relationship of the transferred muscle and the spinal accessory nerve (see text).

Table 2. Smile Excursion (Tooth Exposure) Scoring System*

Teeth Visible	Score	Contracture	Synkinesis
No or full first incisor not visible	0	–0.5	–0.5
Full or nearly full first incisor visible	1	–0.5	–0.5
First incisor and part of second incisor visible	2	–0.5	–0.5
First incisor and part of second and third teeth visible	3	–0.5	–0.5
Premolar or more teeth visible	4	–0.5	–0.5

*A score of 2 or higher indicated an acceptable smile.

Thirty-six patients with 42 XI-innervated free muscles were enrolled in this study (Table 1). Their mean age at time of functioning muscle transplantation was 22 years (range, 4 to 63 years). The causes of facial paralysis were Bell's palsy (11 patients), congenital (nine patients), tumor resection (11 patients), cholesteatoma with chronic otitis media (three cases), and traffic accident (two patients). In the congenital group, eight patients had Möbius syndrome (six bilateral and two unilateral). A 10-year-old girl born with bilateral deafness, left vision defect, a congenital heart defect (patent ductus arteriosus and atrium septum defect), left facial paralysis (complete), and right facial paresis (incomplete) was recognized as one of the congenital group. Nine patients had severe postparetic facial synkinesis[21,22] following facial palsy sequelae. The remaining 18 patients (50 percent) preferred a quick recovery and selected the one-stage procedure.

Preoperative Evaluation

Patients' history and examination were completed preoperatively. Every patient was required to have an accompanying person(s) (couple or parents) listen to the explanation. Advantages and disadvantages of different options (such as one-stage versus two-stage procedure) and choice of neurotizer were explained and illustrated with photographs and/or videos of previous patients' results. Potential complications and donor-site morbidity were described. Decisions were made in the next visit. Photographs and videos were taken preoperatively for later comparison.

Table 3. Cortical Adaptation Stage System for a Functioning Muscle Transplantation*

Stage	Muscle Function
Stage I	No or little movement (or smile)
Stage II	Dependent movement (or smile)
Stage III	Independent movement (or smile)
Stage IV	Spontaneous movement (or smile), with presence of involuntary movement
Stage V	Spontaneous movement (or smile), with no or mild involuntary movement

*Stage III or higher was considered an acceptable smile.

Table 4. Questionnaire

For facial smile
1. Primary complaint
   a. What are you most unsatisfied about the results after the surgery?
   b. Is it a functionally or aesthetically based complaint?
2. Do you think you have a symmetric smile?
3. Do you use your smile in daily activities?
   a. Do you use it in front of family and friends?
   b. Do you use it in front of strangers or public situations?

For shoulder function
Shoulder discomfort
   a. Is there shoulder pain or soreness on the side of the affected shoulder?
   b. Do you feel tightness of the shoulder?
   c. Do any of these discomforts or dysfunctions of the shoulder disturb you?
   If yes, please describe it:

Satisfaction score
1. Regrets the surgery
2. Not acceptable, but does not regret surgery
3. Acceptable, but needs major improvement
4. Satisfied, but needs only minor improvement
5. Completely satisfied

Operative Method

The operation consisted of simultaneous dissection of the donor site (the contralateral gracilis) and recipient site (the paralytic face and neck) by two teams. The procedure was performed as described before.[4,8,23] On the donor thigh, the upper gracilis muscle, including its neurovascular pedicles, was dissected and trimmed into a trapezoid shape based on the inside face measurement. The one-side trimmed gracilis muscle was elongated either with its tendinous aponeurosis or a tendon graft for lower lip up and lateral pulling. On the neck, the XI dissection had to be long enough to reach the mandibular angle through a tunnel beneath the platysma muscle, usually at least 10 cm (Fig. 2). On the paralyzed side of the face, a subcutaneous face lift was performed from the infraorbital rim superiorly to the mandibular margin inferiorly, and to the upper and lower lip wounds. The facial artery and vein were identified below the platysma muscle. The trimmed gracilis was fixed at the posterior wall of the orbicularis oris muscle distally and at the infrazygomatic periosteum proximally. One artery and one vein anastomoses were made. The XI nerve was coapted to the motor nerve of the gracilis.

After wound closure and dressing, the neck was immobilized with a prefixed neck splint. The

Table 5. Results and *p* Values

	Preoperative	Postoperative	*p*	Data Enrolled
Smile excursion score (out of 42)	Average, 0.50 ± 0.552 (range, 0–2)	Average, 3.45 ± 0.739 (range, 0–4)	<0.001 (paired *t* test)	36 patients, 42 XI-innervated FMTs
Cortical adaptation stage		Stage I, 1; stage II, 4; stage III, 16; stage IV, 14; stage V, 5; total, 42 FMTs		
Satisfaction score (out of 5)		Score 1, 1; score 2, 2; score 3, 15*; score 4 , 9†; score 5, 3; total, 30 patients‡		
Correlation between smile excursion score (postop) and satisfaction score			Spearman correlation coefficient +0.160 ($p = 0.325$)	

*Satisfaction score of 3 meant acceptable but in need of major improvement (for deep nasolabial fold or upper lip contracture correction).
†Satisfaction score of 4 meant satisfied but in need of minor improvement (blepharoplasty, fat injection, lip revision, or debulking).
‡Six patients could not be reached for a telephone interview.

patient was transferred to the Microsurgery Intensive Care Unit for close monitoring and postoperative care. The neck was immobilized with a neck splint for 3 weeks to avoid interruption of the coapted nerves.

Postoperative Rehabilitation

Smile training was always introduced at approximately 4 months postoperatively. The patient was instructed to perform induction exercises[16] (shoulder abduction with resistance) to trigger and enhance the movement of the transferred muscle. Once the transferred muscle achieved upper lip movement with the lateral incisor visible, induction exercises were to be reduced and avoided.

Outcome Assessment

All patients had at least 1 year of follow-up. For patient evaluation, multiple photographs and videos were taken at each visit. Subjective and objective methods were used for evaluation. If the patient did not return to the clinic as instructed, telephone calls were made to obtain questionnaire results.

The smile excursion system (with scores ranging from 0 to 4) was introduced (Table 2) to categorize patient smiles based on visibility of teeth. Patients were asked to make a big smile with tooth exposure, and photographs were taken. A score was given to each reconstructed side of the face. If any contracture or synkinesis was present, the score was reduced by 0.5. A postoperative smile excursion score of 2 or higher was considered acceptable; a score of 3 or higher meant a good result. An independent reviewer (J.C.-Y.L.) other than the operating surgeon graded these patients based on their photographs and videos.

To evaluate the functional progress of the transplanted muscle, a cortical adaptation stage system (with stages ranging from I to V) was designed (Table 3). Stage I was defined as no or little movement of the transferred muscle. Stage II was defined as dependent movement, which meant movement of the transferred muscle was dependent upon the trigger movement. Stage III was independent movement, which was defined when the smile movement was obvious with no or little effort of the trigger movement. Stage IV was defined as spontaneous movement with the presence of dominant involuntary movement, and stage V spontaneous movement was defined as little or no involuntary movement. Clinically, when the patient smiled spontaneously at tickling (tickle test), the smile was classified as a spontaneous smile. Postoperative stage III was classified as acceptable, and stage 4 or higher was considered a good result.

Muscle excursion did not always correlate with patient satisfaction. To assess patient satisfaction, a questionnaire (Table 4) was devised that included three concerns: facial smile in daily activity, shoulder function, and patient satisfaction. For patients younger than 10 years of age, their representative guardian completed the questionnaire. The questionnaire was administered by an independent reviewer (J.C.-Y.L.) via a telephone interview, and/or a written document which was mailed to the participant's home for any additional input. All patients who participated in the interviews agreed to the questionnaire and granted permission to use their answers.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 17.0; SPSS, Inc., Chicago, Ill.).

Fig. 3. (*Above*) A 48-year-old worman with left facial palsy caused by acoustic neuroma resection 1 year earlier. The patient is shown 1 year postoperatively (*center*) at rest and (*below*) smiling following XI-innervated gracilis muscle transplantation. Her smile excursion score was improved from 0 to 4, her cortical adaption stage improved to stage IV, and her satisfaction score was 4 out of 5 (satisfied). She had a fat injection, nasolabial fold correction, and some adjuvant cosmetic procedures later.

We used the paired *t* test to determine whether the postoperative smile was significantly different from the preoperative one based on smile excursion score. Patients were divided into two age groups: 22 years of age or younger versus 23 years of age or older. Comparisons were made based on smile excursion score and cortical adaptation stage. The Mann-Whitney test was used for two independent samples, and the Kruskal-Wallis test was used for more than two independent groups.

Spearman rank correlation coefficient was used to analyze the intraclass correlation between the smile excursion score (from the reviewer) and the satisfaction score (from patients). A *p* value of less than 0.05 was considered significant.

RESULTS

Smile Excursion Score

The mean smile excursion score of 0.50 (±0.552) preoperatively improved to 3.45 (±0.739) postoperatively (Table 5). The *p* value was less than 0.001 and significant. Ninety-five percent of patients (38 of 40) showed good muscle movement or smile appearance (Figs. 3 and 4). [**See Video, Supplemental Digital Content 2**, which shows a 20-year-old man who presented with complete right facial Bell's palsy of 2 years' duration, ***http://links.lww.com/PRS/A752***. Two years after XI-innervated gracilis muscle transplantation, his smile excursion score improved from 1 to 4, his cortical adaption stage was stage IV, and his satisfaction score was 5 after some cosmetic procedures (blepharoplasty and fat injection). **See Video, Supplemental Digital Content 3**, which shows a 48-year-old woman with left facial complete palsy due to acoustic neuroma resection 1 year earlier, ***http://links.lww.com/PRS/A753***. Results 1 year postoperatively after XI-innervated gracilis muscle transplantation showed her smile excursion score was improved from 0 to 4, her cortical adaption stage improved to stage IV, and her satisfaction score was 4 out of 5 (satisfied). She had fat injection, deep nasolabial fold correction, and some adjuvant cosmetic procedures later.]

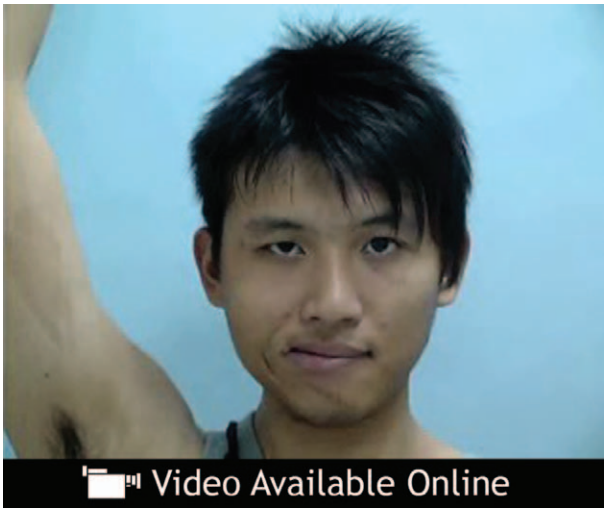
One patient with a congenital facial nerve deficit did not show any improvement in smile excursion for unknown reasons; the procedure was considered to have failed in this patient. One patient (20 years old) with bilateral facial palsy had undergone an additional operation because of one gracilis failure in the first operation. The second operation was performed 1 year later using the segmental rectus femoris muscle innervated by the previous XI nerve. He had a score

Fig. 4. (*Above*) A 51-year-old woman with right facial palsy caused by cholesteatoma resection 2 years earlier. (*Center* and *below*) A good smile was achieved 9 months after XI-innervated gracilis muscle transplantation. Her smile excursion score improved from 1 to 4, her cortical adaptation stage was stage IV, and her satisfaction score was 4.

of 2 for rectus femoris and 3 for gracilis muscle 1 year after the second reconstruction.

Cortical Adaptation Stage

Eighty-three percent (35 of 42) presented with a cortical adaptation stage of at least III (independent smile), where 33 percent (14 of 42) reached stage IV and 12 percent (five of 42) reached stage V. The XI-innervated muscle would regularly start to move at 3 months, and the patient would gain independent smile at 6 months.



Video 2. Supplemental Digital Content 2 shows a 20-year-old man who presented with complete right facial Bell's palsy of 2 years' duration, ***http://links.lww.com/PRS/A752***. Two years after XI-innervated gracilis muscle transplantation, his smile excursion score improved from 1 to 4, his cortical adaption stage was IV, and his satisfaction score was 5 after some cosmetic procedures (blepharoplasty and fat injection).

Video 3. Supplemental Digital Content 3 shows a 48-year-old woman with left facial complete palsy caused by acoustic neuroma resection 1 year earlier, ***http://links.lww.com/PRS/A753***. Results 1 year after XI-innervated gracilis muscle transplantation showed her smile excursion score had improved from 0 to 4, her cortical adaption stage improved to stage IV, and her satisfaction score was 4 out of 5 (satisfied). She had fat injection, deep nasolabial fold correction, and some adjuvant cosmetic procedures later.

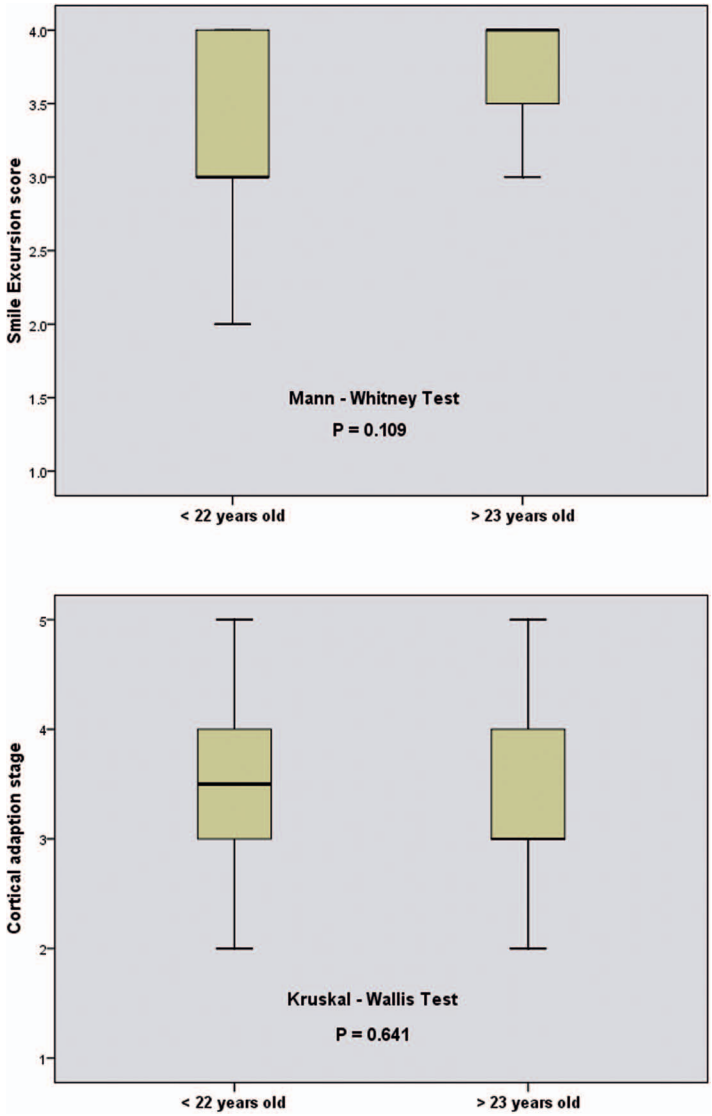


Fig. 5. Comparison of results of two different age groups based on smile excursion score (*above*) and cortical adaptation stage (*below*).

When comparing the smile excursion score and the cortical adaptation stage among different age groups and etiologies, the differences were all insignificant ($p > 0.05$, Figs. 5 and 6), indicating that the technique was fitting in different situations. Three were older patients (61, 62, and 63 years old). They all were included in the group with age 23 years or greater, since their results were similar to those of the others.

Satisfaction Score

The questionnaire was completed by 30 patients. Six patients were unable to be contacted. The average satisfaction score was 3.4 out of 5. Ninety percent (27 of 30) of patients had a score of at least 3, while 30 percent (nine of 30) had a score of 4 (satisfied) and 10 percent (three 30) had a score of 5 (completely satisfied). The correlation coefficient between the postoperative smile excursion score (from reviewer) and the postoperative satisfaction score (from patients) was +0.160. It was insignificant ($p = 0.325$, Table 5), showing mild agreement between the two groups. This was compatible with our clinical observation of some patients who were unsatisfied despite excellent functional excursion. The most common causes of aesthetic dissatisfaction were asymmetric smile excursion and an unnatural smile, which did not meet their preoperative expectations. This was especially true in bilateral Möbius syndrome patients. Two patients had a score of 2 (not acceptable, but did not regret surgery), although their

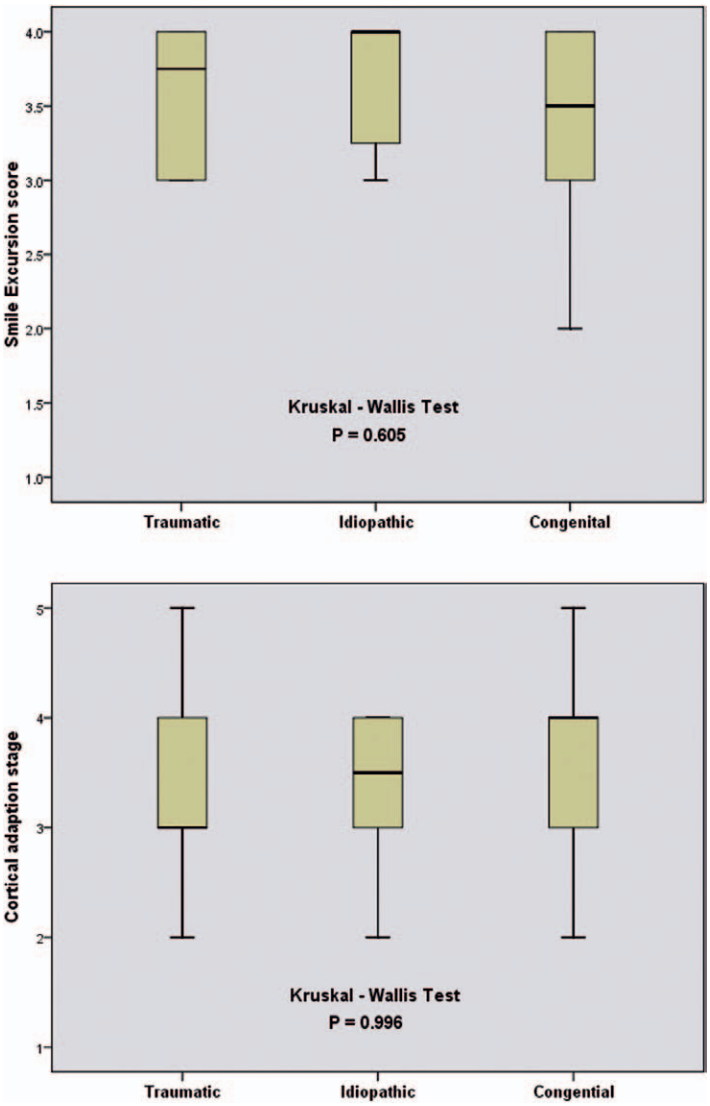


Fig. 6. Comparison of results of different etiology groups based on smile excursion score (*above*) and cortical adaptation stage (*below*). The Bell's palsy patients were included in the idiopathic group. The Möbius syndrome patients were included in the congenital group.

smile excursion score had improved from 2 to 4. Both patients had similar bimaxillary protrusion. When asked what the primary concern was, 50 percent of patients expressed more concerns with aesthetic look rather than functional status. Additional surgical revisions were performed, such as correction of deep nasolabial fold and lip contracture (major procedures) or blepharoplasty, fat injection, lip revision, and brow lift (minor procedures) to improve the results. More than 70 percent (22 of 30) of patients would use their smile in front of familiar audiences.

Shoulder functions (abduction and external rotation) were examined and patients' complaints were reviewed postoperatively. No patient had shoulder disability, but shoulder pain was reported in 39 percent (14 of 36) of patients, which was temporary and was relieved without specific medication or rehabilitation.

DISCUSSION

Dynamic reconstruction allows patients to express smile more naturally and is now the procedure of choice, including local[24,25] and free muscle transfer. Local muscle transfer can produce a simulated smile rather than a spontaneous smile. Free muscle transplantation can potentially produce spontaneous smile, and it is now the procedure of choice for smile reconstruction.

Fig. 7. (*Left*) A 5-year-old boy with left Möbius syndrome with left facial palsy received masseter-innervated gracilis muscle for left facial reanimation. Symmetry at rest and (*right*) good muscle excursion were seen 5 months postoperatively. He is now 20 years old (see Video, Supplemental Digital Content 4, ***http://links.lww.com/PRS/A754***).

The masseter-innervated functioning muscle transplantation for facial palsy was actually performed earlier than XI nerve transplantation in our institute since 1995. The pitfall of this procedure is that it does not show complete independent movement. In addition, involuntary movement of the cheek during eating and biting has been shown to persist (Fig. 7). (**See Video, Supplemental Digital Content 4**, which shows a 20-year-old man with left Möbius syndrome and left facial palsy who received masseter-innervated gracilis muscle for left facial reanimation at age 5 years, ***http://links.lww.com/PRS/A754***. He was called back for follow-up study. His smile excursion score improved from 0 to 4, but his cortical adaption stage was still at stage III. He failed to pass the tickle test. Involuntary movement of his left cheek persisted when chewing. His satisfaction score was 3 (acceptable). The patient has been requested to do mirror therapy to improve his involuntary movement and to avoid food-biting in front of people.)

Those disadvantages made us stop using it. The XI-innervated functioning muscle transplantation is a single-stage procedure and has a quick recovery time, as with masseter-innervated functioning muscle transplantation. The patient has the potential ability to obtain spontaneous smile after smile training (**see Video, Supplemental Digital Content 1,** ***http://links.lww.com/PRS/A751***). The XI nerve–innervated muscle is considered more physiologic than the masseter-innervated muscle from our evaluation. Table 6 shows the comparison of functioning muscle transplantation using different motor innervation.

However, two kinds of patients should be cautious in treatment. Bilateral Möbius syndrome patients usually have exceedingly high expectations of a new appearance, not just a new smile. Patients with bimaxillary protrusion will also be unhappy with the functional smile, because the operation does not include adjustment of the bony structure. A full explanation preoperatively is necessary.

Postparetic facial synkinesis is a healing process of facial nerve injury,[21,22] like healed scars with numerous variations. The scars are sometimes ugly and distorted, requiring excision and/or flap resurfacing. The nine patients in this series had severe synkinesis. Radical excision of the synkinetic muscles and nerves and replacement by XI-innervated functioning muscle transplantation were performed for treatment. The results were quite encouraging. (**See Video, Supplemental Digital Content 5**, which shows a 22-year-old woman who developed right postparetic facial synkinesis caused by Bell's palsy of 5 years' duration, ***http://links.lww.com/PRS/A755***. She presented with poor

Video 4. Supplemental Digital Content 4 shows a 20-year-old man with left Möbius syndrome with left facial palsy, ***http://links.lww.com/PRS/A754***. He received masseter-innervated gracilis muscle for left facial reanimation at age 5 years. He was called back for follow-up study. His smile excursion score improved from 0 to 4, but his cortical adaption stage was still at stage III. He failed to pass the tickle test. Involuntary movement of his left cheek persisted when he chewed. His satisfaction score was 3 (acceptable). The patient has been requested to do mirror therapy to improve his involuntary movement and to avoid food-biting in front of people.

smile and dominant oro-ocular and oculo-oral synkinesis.) (**See Video, Supplemental Digital Content 6**, which shows a patient who received radical excision of the right cheek muscles and replacement with an XI-innervated gracilis muscle for reconstruction, ***http://links.lww.com/PRS/A756***. One year later, she had much improved function and aesthetics at rest and when smiling. Her smile excursion score improved from 2 to 4, and her cortical adaption stage was stage V. Her satisfaction score improved to 4 after blepharoplasty.) None of the patients required botulinum toxin type A injection in the follow-up period.

Outcomes Evaluation

Smile Excursion Score System

Assessment of adequate smile excursion is still not uniform, and there is no consensus. Direction and excursion of smile actually depend more on the placement of transferred muscle (Fig. 8): transversely placed muscle (Fig. 8, *red drawing*) has a more commissure smile; obliquely placed muscle has a more canine smile (Fig. 8, *green drawing*); and vertically placed muscle has a more full-denture smile (Fig. 8, *blue drawing*). The scoring system is simple and easy to follow.

Cortical Adaptation Stage System

There are always five stages of recovery in any nerve transfer technique,[16] ranging from no movement to spontaneous movement. Stepwise recovery with time of smile training has been observed. In our series, 100 percent of patients with bilateral facial paralysis in bilateral Möbius syndrome and 85 percent of patients with other causes of facial paralysis were able to display their smile with at least stage III (independent smile) recovery at 1-year follow-up. This staging system is useful for postoperative evaluation and patient education in order to enhance the importance of smile training.

Tickle Test

All the reported assessments of spontaneous smile were made subjectively by the authors. Telling a joke to induce spontaneous smile is a good way to assess smile, but it is time-consuming and difficult to capture during video recording. Tickling is a more objective and natural way to evoke spontaneous smile, especially in children.

Table 6. Comparison of Functioning Muscle Transplantation with Different Neurotizers

	XI-Innervated FMT	Masseter-Innervated FMT	CFNG-Innervated FMT
No. of stages	1	1	2
Nerve graft required	No	No	Yes
Scar	1 face lift scar, 1 neck scar	1 face lift scar	2 face lift scars, leg scars
Neurotizer power	2	2	1 (as a standard)
Time to M1 (muscle starts to move)	3–6 mo	3–6 mo	6–12 mo
Time to ≥M2 (at least two teeth visible)	6–12 mo	6–12 mo	12–18 mo
Cortical adaptation stage	≥ Stage III (at least independent smile)	Stage II–III	Stage IV–V (spontaneous, sometimes with involuntary movement)
Smile training (mirror therapy) required	Yes	Yes	No

FMT, functioning muscle transplantation; CFNG, cross-face nerve graft.

Video 5. Supplemental Digital Content 5 which shows a 22 year-old woman who had developed right postparetic facial synkinesis due to Bell's palsy of 5 years' duration, ***http://links.lww.com/PRS/A755***. She presented with poor smile and dominant oro-ocular and oculo-oral synkinesis.

Shoulder Function after XI Harvest

Postoperative shoulder pain, based on our evaluation, was not directly related to the XI sacrifice injury, but to partially detached trapezius muscle from the scapula during dissection to obtain more length for the XI nerve. In this series, 39 percent (14 patients) were found to have shoulder pain, which resolved in time for all patients.

Video 6. Supplemental Digital Content 6 shows a patient who received radical excision of the right cheek muscles and replacement with an XI-innervated gracilis muscle for reconstruction, ***http://links.lww.com/PRS/A756***. One year later, she showed much improved function and aesthetics at rest and when smiling. Her smile excursion score improved from 2 to 4, and her cortical adaption stage was stage V. Her satisfaction score improved to 4 after blepharoplasty.

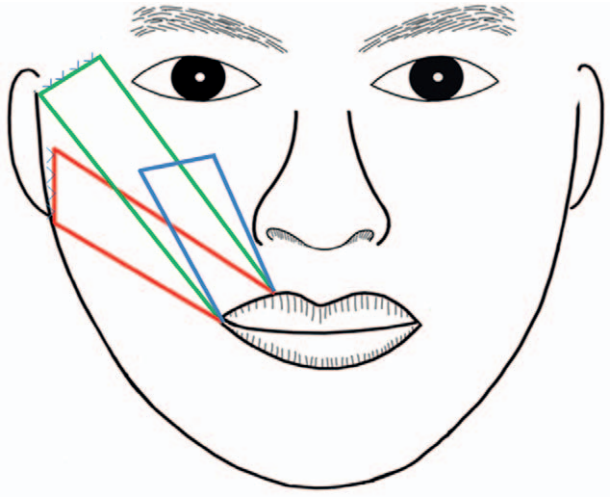


Fig. 8. Placing the transfered muscle in different positions will result in different smile excursions. Transversely placed muscle (*red drawing*) tends to result in a more commissural smile; obliquely placed muscle (*green drawing*) results in a more canine smile; and vertically placed muscle (*blue drawing*) results in a more full-denture smile.

CONCLUSIONS

Cross-face nerve graft–innervated free muscle in a two-stage procedure is still our first choice for facial paralysis reconstruction. However, the effectiveness of using XI-innervated functioning muscle transplantation for facial reanimation in a one-stage procedure has proven it to be a good alternative choice for facial paralysis reconstruction when it is indicated.

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PATIENT CONSENT

Patients or parents or guardians provided written consent for use of patients' images.

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