Comparison of Functional Results After Cross-Face Nerve Graft-, Spinal Accessory Nerve-, and Masseter Nerve-Innervated Gracilis for Facial Paralysis Reconstruction

The Chang Gung Experience

David Chwei-Chin Chuang, MD, Johnny Chuieng-Yi Lu, MD, Tommy Nai-Jen Chang, MD, and Vincent G. Laurence, MD

Background: Using functioning free muscle transplantation (FFMT) for facial paralysis and postparalysis facial synkinesis reconstruction is our preferred technique. Gracilis was the first choice of muscle. Three motor neurotizers: cross-face nerve graft (CFNG), spinal accessory nerve (XI) and masseter nerve (V3) have been used as neurotizers for different indications.

Methods: A total of 362 cases of facial reanimation with FFMT were performed between 1986 and 2015. Of these, 350 patients with 361 FFMT were enrolled: 272 (78%) patients were treated by CFNG-gracilis, 56 (15%) by XI-gracilis, and 22 (6%) by V3-gracilis. Smile excursion score, cortical adaptation stage with tickle test for spontaneous smile, facial synkinesis, satisfaction score by questionnaire, and functional facial grading were used for outcome assessment.

Results: The CFNG-gracilis in a 2-stage procedure achieved most natural and spontaneous smile when longer observation (≥2 years) was followed. The single-stage procedure using the XI-gracilis has proven a good alternative. V3-gracilis provided high smile excursion score in the shortest rehabilitation period, but never obtained spontaneous smile.

Conclusions: The CFNG-gracilis remains our first choice for facial paralysis reconstruction which can achieve natural and spontaneous smile. XI- or V3-gracilis can be selected as a save procedure when CFNG-gracilis fails. The V3-gracilis is indicated in some specific conditions, such as bilateral Möbius syndrome, older patients (age, >70 years), or patients with malignant disease.

Key Words: facial paralysis, CFNG-gracilis, XI-gracilis, V3-gracilis

(*Ann Plast Surg* 2018;00: 00–00)

The cranial facial nerve, originating from pons, contains 2 roots: the facial root contains efferent fibers for facial expression, lacrimation and salivation, and the nervus intermedius root contains afferent fibers for tongue taste and external ear cutaneous sensibility.[1] Facial nerve is composed of 6000 to 7000 myelinated motor fibers[2] that innervate 22 (19–24) mimic muscles for simultaneously and delicately controlling synergistic and antagonistic muscles for complex facial expression. There are 2 major dysfunctions of the facial nerve injury: facial palsy (incomplete or complete) and postparalysis facial synkinesis.[3] Both will cause serious affliction and devastation on the patient's quality of life.

Etiologies of facial paralysis include Bell's palsy (or idiopathic facial palsy), infection (herpes simplex, herpes zoster, or suppurative ostitis media), after tumor resection (cholesteatoma, vestibular schwannoma, acoustic schwannoma, facial schwannoma, or parotic gland tumor), trauma (animal bite, iatrogenic injury, penetrating injury, birth trauma, temporal bone fracture), and congenital (Möbius syndrome, hemifacial microsomia), and others.[4]

For chronic facial palsy (more than 1 year), reconstruction requires the use of alternative muscles for reanimation. Local muscle transfers include frontalis (for forehead rising), temporalis (for eye closure or smile), masseter (for mouth angle smiling), or digastric (for lower lip pull-down) muscle transfer.[5–8] Distal muscle transfers include nonvascularized muscle graft and vascularized functioning free muscle transplantation (FFMT). With advanced microsurgical technique, FFMT has become the standard option for long-standing facial paralysis.[9–17]

Gracilis is the preferred muscle for FFMT by most reconstructive surgeons. Cross-face nerve graft (CFNG), spinal accessory nerve (XI), and masseter nerve (V3) are used most commonly as motor neurotizers.[9–17] The purpose of this study was to comparatively evaluate CFNG-, XI- and V3-gracilis for facial reanimation, their advantages and disadvantages, from our series.

MATERIALS AND METHODS

Between 1986 and 2015, 362 patients were reconstructed with FFMT for facial paralysis or postparalysis facial synkinesis at the Linkou Chang Gung Memorial Hospital. They all were performed by the same surgeon (DCC Chuang). Eight patients with bilateral facial paralysis because of Möbius syndrome underwent bilateral gracilis muscles for reconstruction simultaneously: 6 by bilateral XI and 2 by bilateral V3 for muscle innervation. There were 4 failed gracilis (4/362, 1%) and 3 underwent successful second FFMT. Seven patients treated by facial nerve repair (directly or indirectly) or local muscle transfer were excluded. Functioning free muscle transplantation innervated by ipsilateral facial nerve (8 patients), contralateral facial nerve in a 1-stage procedure (4 patients) were also excluded. Totally, 350 patients with 361 FFMTs were enrolled in this study.

The etiology of the palsies was most commonly because of postoperative complications, then Bell's palsy, congenital, and trauma.

There were 272 patients (272/350, 78%) reconstructed by CFNG-FFMT, 56 (56/350, 15%) by XI-FFMT, and 22 patients (22/350, 6%) by V3-FFMT. Functioning free muscle transplantation came most from gracilis (98%). The facial artery and vein were the preferred vessels for anastomoses.

Surgical Techniques

(A) CFNG-gracilis: The classic 2-Stage Procedure

Stage 1, Short CFNG

Since November 2001, we have started to use a short leg sural nerve (10–15 cm) for CFNG, which was placed subcutaneously from the contralateral cheek of the healthy face to the nasolabial fold of the paralyzed face (Fig. 1A–B), to decrease leg incision wounds and shorten the waiting period (from 1 year to 6 months). The procedure was done under general anesthesia with orotracheal intubation. A preauricular incision about 10 cm in length was made on the healthy

Received April 24, 2017, and accepted for publication, after revision October 26, 2017.
From the Department of Plastic Surgery, Chang Gung Memorial Hospital, Chang Gung University, Taipei-Linkou, Taiwan.
Conflicts of interest and sources of funding: none declared.
Clinical question/level of evidence: therapeutic, IV.
Reprints: David Chwei-Chin Chuang, MD, Department of Plastic Surgery, Chang Gung Memorial Hospital, 5, Fu-Hsing St, Kuei-Shan, Taoyuan 33305, Taiwan. E-mail: dccchuang@gmail.com; micro.cgmh@gmail.com.
Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.
ISSN: 0148-7043/18/0000–0000
DOI: 10.1097/SAP.0000000000001327

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

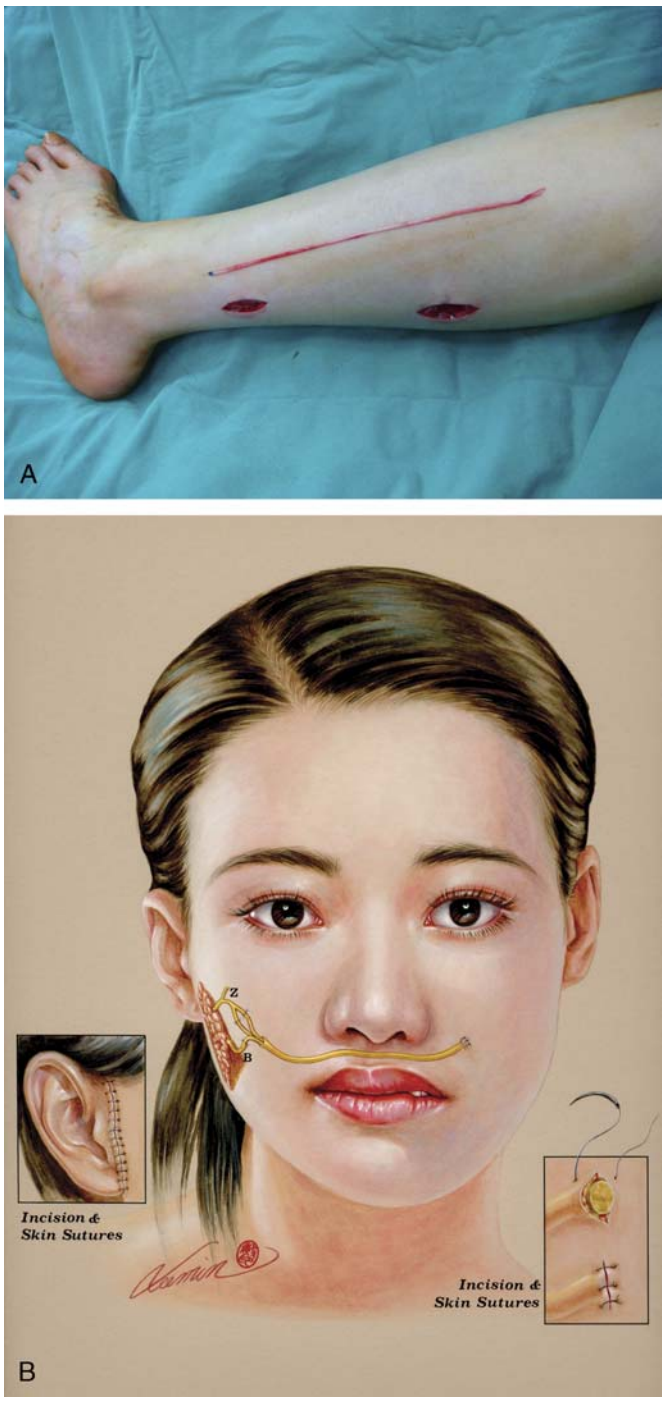

FIGURE 1. A, Using 2 small incisions to harvest a leg sural nerve graft. B, The graft is placed subcutaneously from the cheek of the healthy face to the nasolabial fold of the paralyzed face. Reproduced with permission from *Facial Plastic Surgery* 2008; 24(2):194–203, New York: Thieme.

side. Subcutaneous dissection to lift the face between preauricular and pupil lines was performed. The facial skin flap was elevated. In front of the parotid gland, the zygomatic and buccal branches of the facial nerve can be found through careful dissection with the help of a nerve stimulator. One small branch of the zygomatic and the whole buccal branch were cut and transferred. The sural nerve was placed in reverse fashion subcutaneously with the help of a nerve passer. Another small hole incision over the nasolabial fold of the paralyzed face was made. The nerve passer was used to pass the sural nerve subcutaneously from the elevated skin flap wound to the contralateral nasolabial fold wound. The sural nerve graft was coapted to the transferred zygomatic and buccal branches under the microscope (Fig. 2). The other end of the sural nerve stump was sutured to the dermis of the nasolabial fold wound on the paralyzed face. The total operative time was about 3 hours or less.

Stage 2: Gracilis FFMT

The second stage procedure was performed under general anesthesia with nasotracheal intubation, instead of orotracheal intubation, to minimize the interference of the upper lip manipulation. The operation consisted of simultaneous dissection of the donor (the contralateral gracilis) and recipient (the paralytic face) sites by 2 teams. On the paralyzed side of the face, an incision about 2 cm in length on the white line of the upper lip between philtrum-lip junction point and mouth angle (but not including these 2 points) was made first. The previous stump neuroma of the CFNG was identified and dissected proximally as long as possible. The stump neuroma was cut from its fixed point and placed deep inside the lip wound for protection.

Another preauricular incision extending to the mandibular body was made on the paralyzed side of the face. Subcutaneous dissection was performed from the infraorbital rim superiorly, the mandibular margin inferiorly and to the upper lip wound. Under the facelift skin flap, a 4-cm transverse incision was made along the inferior zygomatic arch (behind the zygomatic body) down to the periosteum which was mildly elevated. Anchoring 3-0 Vicryl stitches (usually 4 stitches) were placed on the elevated periosteum for fixation of the transferred muscle. The soft tissue from the infrazygomatic margin down to the upper lip was removed to create a pocket for the muscle fill-in. The buccal fat pad was also removed to make the surface of the pocket smooth. The Stenson duct was identified and protected to avoid injury.

To determine the length and shape of the harvested gracilis, we made an in-site face measurement. The distance between the most inner stitch over the zygomatic arch and medial edge of the upper lip wound (AA', Fig. 3 A), and the distance between the most outer stitch over the zygomatic arch and the lateral edge of the upper lip wound (BB') were measured. The measurement should be done loosely. From experience, we have learned to add about 2 cm to the medial edge (AD) and 3 cm to the lateral (BC) to avoid consequent lip contracture deformity. The width of the gracilis was determined by the infrazygomatic stitches

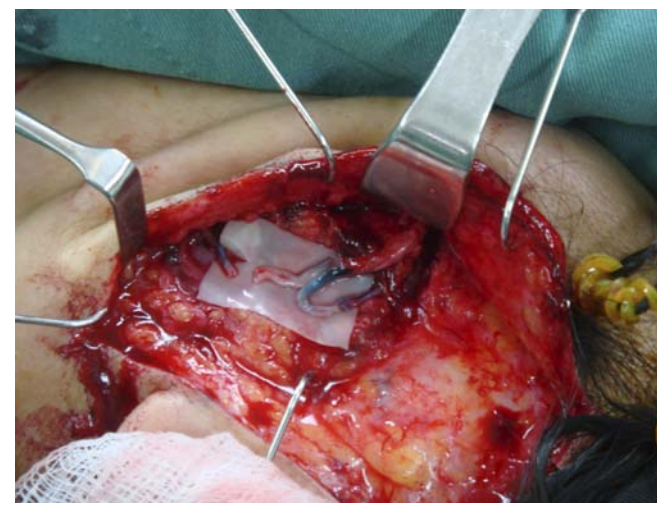

FIGURE 2. The short CFNG is split into 2 parts to coapt the transected facial nerve branches: a small zygomatic and a big buccal branches.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

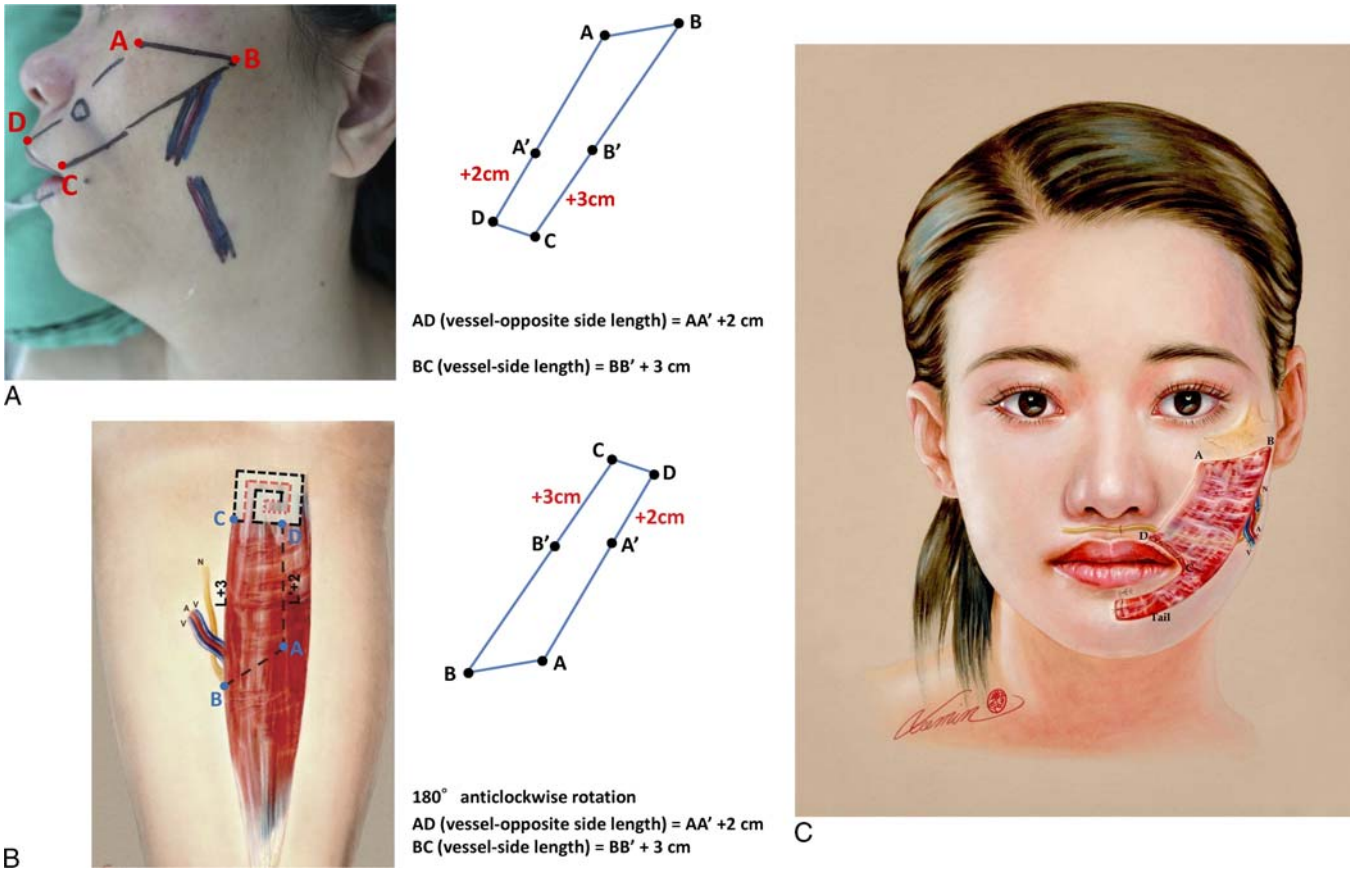

FIGURE 3. A, In the recipient site, the draw depicts the position of the inside face measurement, including vessel-opposite side (AA'), vessel side (BB'), and 2 attachment sides: infrazygomatic arch (AB) and upper lip wound (A'B'). B, In the donor thigh (always contralateral to the paralyzed face), infrazygomatic attached side (AB) will be placed on the caudal muscle, and upper lip attached side (CD) on the lower margin of the aponeurosis (BC vessel side length = BB' + 3 cm; and AD vessel-opposite side length = AA'' + 2 cm). The upper aponeurosis was harvested as long as possible; (C) the trimmed gracilis has been in place inside the face (reproduced with permission from *Facial Plastic Surgery* 2008; 24(2):194-203, New York: Thieme).

placement superiorly (AB) and the length of the incision along the upper lip inferiorly (CD). The trapezoid shape of the potential implanted muscle was drawn down (ABCD, Fig. 3A).

The contralateral gracilis was always used as donor to take advantage of pedicle orientation. A 10-cm incision along the medial thigh posterior to the adductor longus was performed to expose the proximal gracilis muscle with its aponeurosis at its origin, and its neurovascular pedicle, which were mobilized from the surrounding tissues. The trapezoid shape (ABCD) measured on the face was then transferred onto the gracilis, but in an inverted fashion, anticlockwise 180° rotation (Fig. 3B). The distal end of the gracilis (AB) should be marked 2 finger widths beyond the neurovascular pedicle. The proximal aponeurosis should be dissected as far as possible to its bony origin. Distance BC (lateral edge on face) was on the pedicle side, and AD was on the nonpedicle side. The proximal end of the gracilis (CD) was located at the lower aponeurosis. The trapezoid shape of the gracilis was marked. The muscle was then cut with cautery. The distal gracilis (AB) was sutured with interrupted 3-0 nylon stitches, and the nonpedicle side (AD) with running, locked 3-0 catgut sutures for hemostasis. The part of the most proximal thin fascial aponeurosis, with 1-cm width of continuity with the muscle, was harvested as the drawing shown (Fig. 3B), in a series of concentric right angles, to provide the longest tail for eventual insertion on the lower lip.

The motor nerve (anterior branch of the obturator nerve) should be dissected as long as possible, under and beyond the adductor longus muscle, up to the obturator foramen where the posterior branch was further separated from the anterior branch, and transected. The vessel pedicles usually 1 artery and 2 accompanied veins were dissected up to the bifurcation of the femoral profunda artery and vein. The pedicle vessels were ligated and transected before the bifurcation.

The trimmed gracilis including the neurovascular bundles was then transferred to the cheek flap in an inverted fashion. The distal muscle edge was mattress-sutured to the infrazygomatic periosteum (as the new origin) with the anchoring stitches set earlier. The proximal cut edge of aponeurosis was anchored to the mucosa beneath the orbicularis oris of the upper lip with 4-0 Vicryl (usually 4 stitches). A third incision, approximately 2 cm in length over the white line of the lower lip of the paralytic side was made. The created tail of the fascial aponeurosis passed through the incision wound and sutured to the lower lip orbicularis oris muscle as medially as possible under tension (Fig. 3C).

Once the muscle was well set, vessel anastomoses (1 artery and 1 vein) to the facial vessels were performed. Finally, the obturator nerve of the gracilis muscle, passing under the muscle to the upper lip wound, was coapted to the previous CFNG under operative microscope in the small but adequate upper lip wound.

(B) XI-Gracilis, One Stage Procedure

For the second stage CFNG-gracilis, a 2-team approach was used, with simultaneous dissection of the paralyzed face, neck, and

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

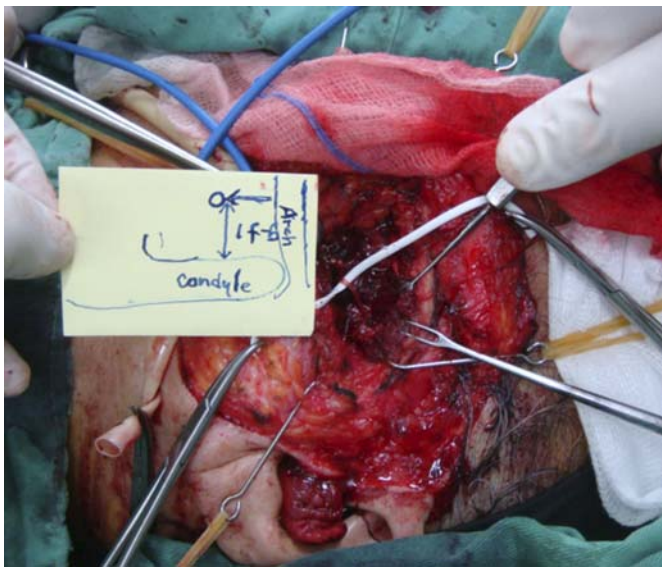

FIGURE 4. The masseter nerve is found at the intersection of 1 finger width inferior to the zygomatic arch and 1 finger width anterior to condyle process of the mandible. The origin of the masseter muscle is transected, removed, and retracted. The masseter nerve is found deep into the masseter muscle with aid of a nerve stimulator.

the contralateral gracilis. On the paralyzed face, facelift, trough creation, vessel preparation, in-side muscle measurement, and so on, the preparations were all the same as the described above. An additional incision on the neck was performed to identify the XI with help of the nerve stimulator. The length of the XI dissection should be long enough to reach the mandibular angle through a tunnel beneath the platysma muscle, usually 10 cm at least. The gracilis dissection, shaping, attachment at the new origin and insertion sites, and vessel anastomoses were

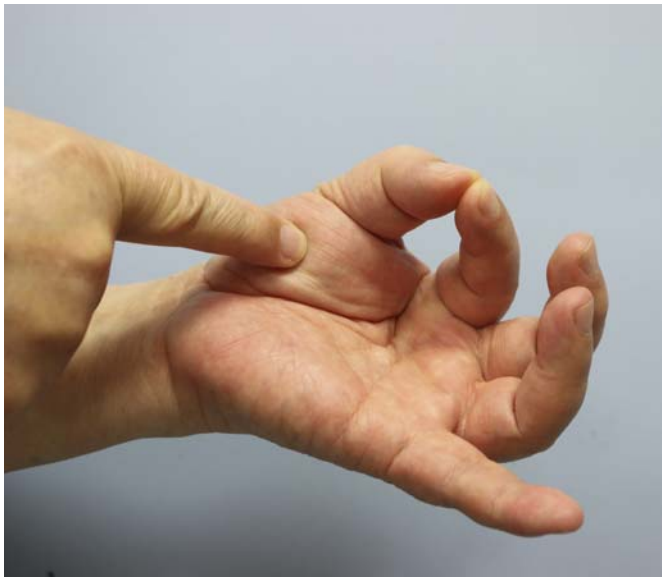

FIGURE 5. Varying firmness of the thenar eminence with different (index to small) finger-to-thumb opposition, which can be used as a reference for severity of facial swelling. The firmness of thumb-index opposition is the 1° swelling.

TABLE 1. Chuang's Smile Excursion Score

Score	Visible Teeth
0	None of minimal central incisor
1	Full or near-full central incisor
2	Full central incisor and part of lateral incisor
3	Full central incisor, lateral incisor, and canine
4	Full central incisor, lateral incisor, canine and premolar or more

the same as described above. The XI nerve was coapted to the motor nerve of the gracilis in the mandibular angle.[16]

After wound closure and dressing, the neck was immobilized with a prefixed neck splint to avoid interruption of the nerve coaptation.

(C) V3-Gracilis, One Stage Procedure

Incision, elevation of the cheek flap, and dissection of the facial vessels were as described above. The V3 nerve was roughly localized to the intersection of lines: one finger-width inferior to the zygomatic arch and one finger-width anterior to the condyle process of the mandible (Fig. 4). The masseter muscle was incised at its origin and partially removed until the V3 was identified with the aid of a nerve stimulator. The V3 nerve was dissected distally to gain enough length, then divided and reflected upward for nerve repair. Gracilis shaping, harvest, and inset were as above. The V3 nerve and gracilis motor nerve were coapted with tension-free.

Postoperative Care and Rehabilitation Protocol

(A) CFNG-Gracilis

In the first stage, patient was usually hospitalized for 3 to 5 days. There was no need for postoperative rehabilitation. In the second stage, patient was usually hospitalized for a week. Patient would be extubated after the operation and spend 3 to 5 days in the microsurgery intensive care unit (ICU) for close monitoring. A simple system to check the swelling was used. Palpation of the nasojugal region to check face swelling was performed every hour in the ICU observation. There are 4 different degrees of swelling which can be compared with the varying firmness of the thenar eminence with different (index to little) finger-to-thumb opposition. If the face firmness is same as thumb-index opposition, it is soft and classified as 1° swelling (Fig. 5). If the firmness is slightly firmer same as thumb-long finger opposition, it is 2° swelling. As thumb-ring finger opposition, it is 3°; and thumb-little finger, 4° swelling. A 1° to 2° swelling is acceptable, 3° swelling is concerning and warrants closer observation. A 4° swelling is critical and requires wound opening to assess the hematoma.

TABLE 2. Chuang's Cortical Adaptation Stage After FFMT Reconstruction

Stage	Description
I	Inability to smile (no movement of the muscle)
II	Dependent smile (movement) with need of inducting movement to initiate the FFMT; failed to pass tickle test
III	Independent smile (movement) of the FFMT; failed to pass tickle test
IV	Spontaneous smile without having to think about it, but still present involuntary movement; tickle test (+) without latency
V	Spontaneous smile with absent involuntary movement; tickle test (+) without latency

Acceptable result, when stage ≥ III postoperatively.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

TABLE 3. Severity of Postoperative Facial Synkinesis

Degree	Description
Mild	Tension face, mild cheek twitching, noticed only on close inspection
Moderate	Tension face, obvious eye-cheek synkinesis, dominant nasolabial fold, chin skin dimples, platysma neck bands
	Hypertrophy of corrugator
Severe	Tension face, contracture with disfiguring : narrow eye, dominant nasolabial fold, dominant platysma bands, dominant lower lip retraction, dominant chin skin dimpling

Rehabilitation, including massage and muscle stimulation, would begin 3 weeks after FFMT. Usually, the muscle may start moving (M1 strength) in 4 to 6 months postoperatively. Induction exercise[18] would start. Patients were encouraged continuous induction exercise for at least 1 year. Surgical treatment of the residual deformity was usually performed a year and half postoperatively.

(B) XI-Gracilis

After surgery, the neck was immobilized with a prefixed neck splint for 3 weeks. The ICU care and postoperative rehabilitation were all the same as the CFNG-gracilis described above. At approximately 4 months postoperatively, M1 muscle movement was found and "induction exercise" was begum. Patient was taught to perform shoulder elevation against resistance, a trigger movement that "jumpstarts" the movement of the transferred muscle. Once the upper lip movement was noted (usually 6–12 months postoperatively) and the lateral incisor was visible (M2 muscle strength), induction exercise should be reduced and stopped. Smile training in front of mirror (mirror therapy) to adjust and control the muscle movement, making symmetric smile to the healthy side, was begun with a goal of achieving a natural smile.

TABLE 4. Satisfaction Score From Patients' Questionnaire

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 complaints?
	2. Do you think you have a symmetric smile?
	3. Do you use your smile in daily activities?
	a. do you use your smile in front of family and friends?
	b. do you use your smile in front of strangers or public areas?
Score	Description
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

(C) V3-Gracilis

After surgery, postoperative ICU care and rehabilitation was the same as the CFNG-gracilis described above without neck immobilization. Upper lip movement could be expected 3 to 4 months postoperatively, or even earlier. "Induction exercise" was begun with biting. Once the transferred muscle achieved upper lip movement with lateral incisor visible (usually 6–12 months postoperatively), induction exercise should be reduced and stopped. Smile training in front of mirror was particularly important for this group of patients.

Patient and Outcome Assessment

In general, the optimal results achieved at different timepoints for each methods: CFNG-gracilis at the second to third year, XI-gracilis the

TABLE 5. Results and *P* Values

	CFNG-FFMT			XI-FFMT			V3-FFMT		
	Preoperative	1 y Postoperative	>2 y Postoperative	Preoperative	1 y Postoperative	>2 y Postoperative	Preoperative	1 y Postoperative	>2 y Postoperative
Smile excursion Score (average)	0.50 ± 0.80	2.74 ± 0.75	3.30 ± 0.70	0.50 ± 0.55	3.30 ± 0.88	3.45 ± 0.74	0.11 ± 0.28	2.59 ± 0.90	3.21 ± 0.77
Cortical adaptation			Most stage IV–V			Most (83%), ≥ stage 3 (33%, stage IV; 12%, stage V)			Most stage II None passes the tickle test
Satisfaction score (average score out of 5)			N = 40			N = 30			N = 15 3.2 (67% pts ≥3)
			3.42			3.40			
						(90% pts ≥3:			
			(83% pts score ≥3:			score 3, 15			
			score 3, 12			score 4, 9			
			score 4, 18			score 5, 3			
			score 5, 3						
Correction between smile excursion score and satisfaction score						+0.160 (P = 0.325)			

Pts, patients.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

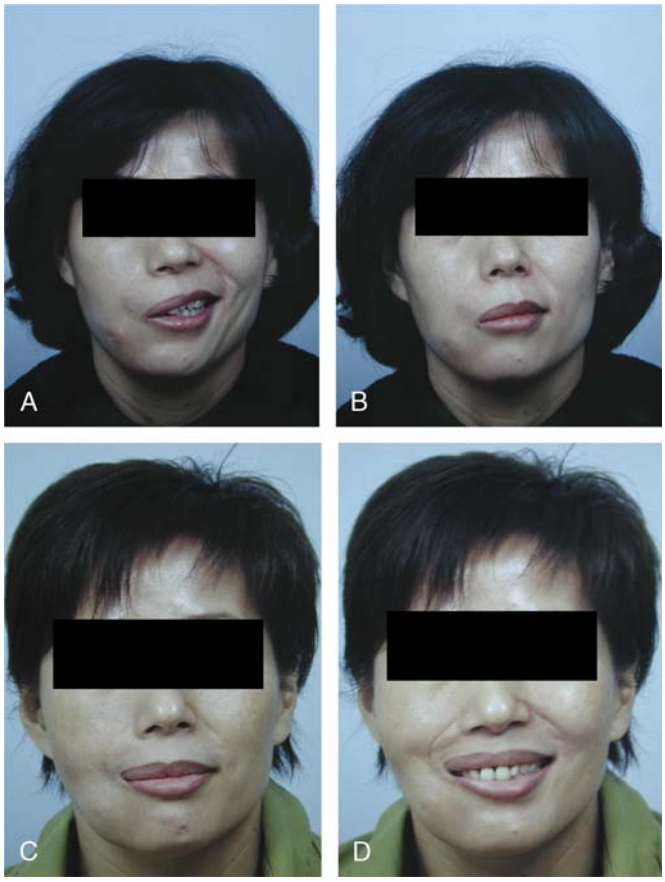

FIGURE 6. A–B, A 43-year-old lady with left Bell's palsy completely since infancy. She received CFNG-innervated gracilis for facial reanimation. C–D, Results of 2 years postoperatively, her smile excursion score was from 0 up to 3.5, cortical adaptation stage from stage 1 up to V, and satisfaction score being 4.

first to second year, and V3-gracilis 6 months to 1 year. Therefore, all patients should be followed at least 2 years. All patients were filmed and videoed routinely at different time points. Five independent observers (the senior author, 2 residents, and 2 research assistants) graded the patients by viewing the photos and videos. Before viewing these materials, all 5 observers met and established a consensus on how to assess the results to maximize interobserver reliability.

For patient assessment preoperatively or postoperatively, Chuang's Smile Excursion Score,[19] Chuang's Cortical Adaptation Stage System,[20] synkinesis severity score,[3] patient satisfaction score from questionnaire, and finally Functional Result Score were used.

Chuang's Smile Excursion Score is a score system from 0 to 4[19] to categorize patient's smile based on the visibility of the teeth (Table 1). A postoperative smile excursion score $\geqq 2$ is considered acceptable, $\geqq 3$ meant good, and ≥ 4 as excellent in result.

Chuang's Cortical Adaptation Stage System from I to V is a system to evaluate the functional recovery of progress of the transplanted muscle[20] (Table 2). When the patient can smile spontaneously at tickling (tickle test), it is classified as spontaneous smile. A postoperative stage reaching stage III is classified as acceptable, stage IV as good, stage V as excellent in result.

Postoperatively facial synkinesis was also evaluated. There are three degrees of facial synkinesis[3]: mild, moderate, and severe (Table 3).

Muscle excursion does not always correlate with the patient satisfaction. Therefore, a patient questionnaire was devised, which included 3 concerns: primary complaints, symmetric smile, and facial smile in daily activities (Table 4). For patients younger than 10 years, their representative guardians fill the questionnaire. The questionnaire was performed via a phone interview and/or a written document which is 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. There were 5 scores: regrets the surgery, not acceptable but does not regret surgery, acceptable but needs major improvement, satisfied but needs minor improvement, and completely satisfied (Table 4).

Functional Result Score is finally used to define the results based on the above data. It has 5 categories: excellent, good, fair, poor, and failed.

Statistical Analysis

Data were presented as percentages or means with ranges or SDs. Wilcoxon signed-rank tests were used to compare preoperative and postoperative facial nerve gradings. Fisher exact test was used to compare the ability to smile (tooth visible), working latency, spontaneous movement, and patient's satisfaction. SPSS version 21.0 (SPSS, Inc, Chigaco, Ill) was used for statistical analyses. Two-sided *P* values less than 0.05 were considered statistically significant. The Mann-Whitney

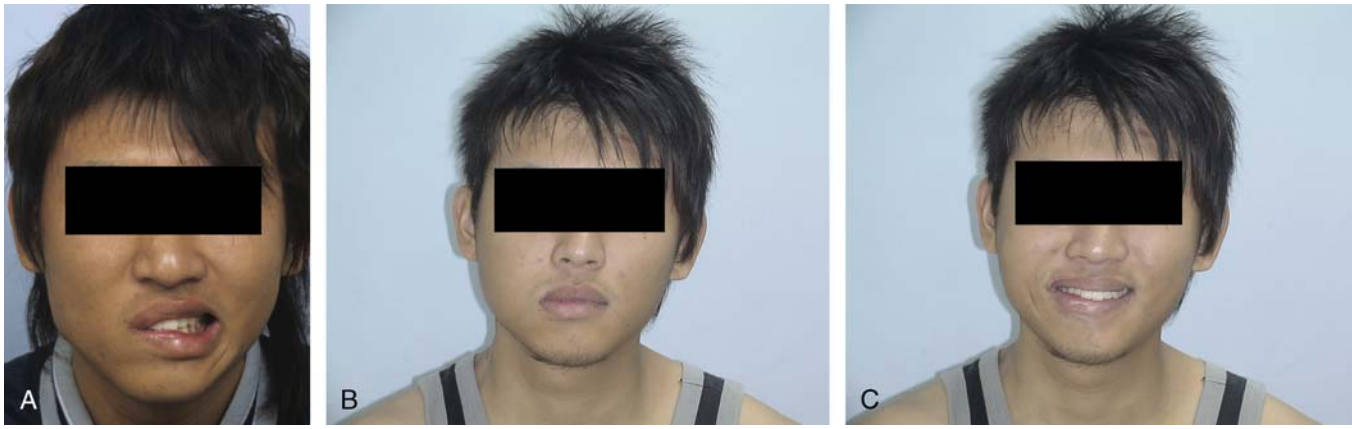

FIGURE 7. A, A 21-year-old young male had right Bell's palsy completely for 6 years. He received XI-innervated gracilis for facial reanimation. B–C, Results of 1 year postoperatively, his smile excursion score was from 0 up to 4, cortical adaptation stage was IV, and satisfaction score was 5.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

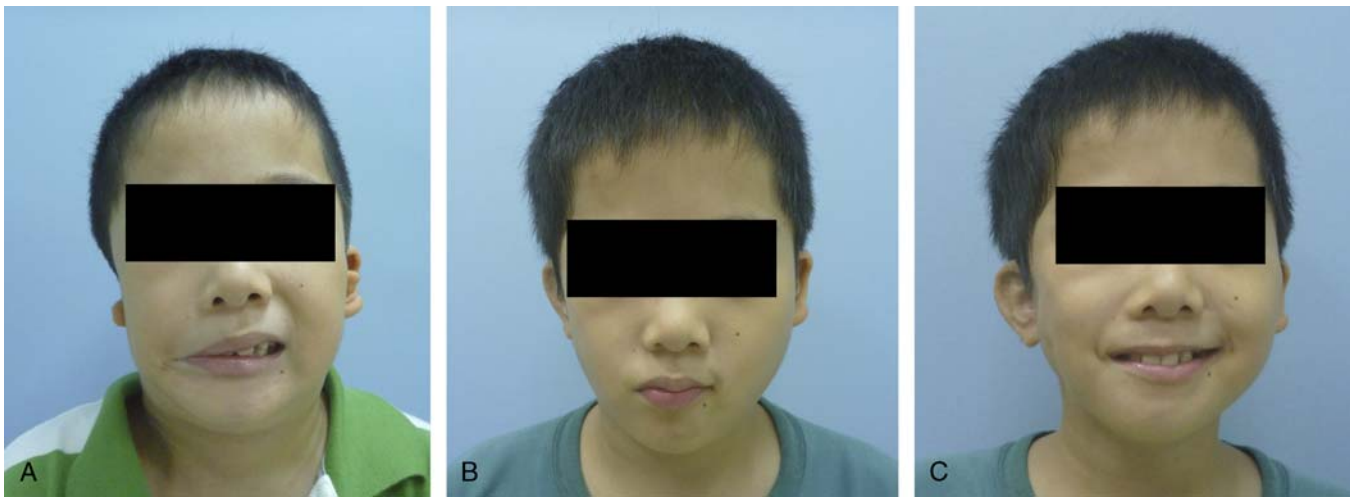

FIGURE 8. A, An 8-year-old boy had right facial palsy due to hemifacial microsomia completely since birth. He received V3-innervated gracilis for facial reanimation. B–C, Results of 9 months postoperatively, his smile excursion score was from 0 up to 4, cortical adaptation stage was III, and satisfaction score was 5.

test was used for 2 independent samples, and the Kruskal-Wallis test was used for more than 2 independent groups.

RESULTS

For 4 failed gracilis, 3 were found at outpatient clinic weeks after discharge. The necrotic muscles were removed at second hospitalization. A second gracilis for further reconstruction 1 year later was performed, and all were successful. The second gracilis was innervated: one from CFNG changed to XI, one from CFNG to V3, and one using the original XI nerve. One additional case who received XI-innervated gracilis for primary reconstruction showed no muscle movement at all after a 2-year follow-up. She did not want to redo reconstruction.

Smile Excursion Score

Photos and video analysis showed that the smile excursion score was improved from mean 0.50 ± 0.80 (no or little medial incisor visible) preoperatively up to mean 3.30 ± 0.70 (at least the canine tooth visible) postoperatively in CFNG-FFMT (Table 5, Fig. 6A–D). In the XI-FFMT group, it was from a mean of 0.50 ± 0.55 preoperatively improved to a mean of 3.45 ± 0.74 postoperatively (Table 5, Fig. 7A–C); and from a mean of 0.11 ± 0.28 preoperatively improved to a mean of 3.21 ± 0.77 postoperatively in V3-FFMT patients (Table 5, Fig. 8A–C). All *P* value were less than 0.001 and significant.

Cortical Adaptation Stage

All patients with CFNG-FFMT achieved at least stage IV (spontaneous smile with some involuntary movement), and many were in stage V (spontaneous smile with no involuntary movement). They all passed tickling test. In the XI-FFMT patients, 83% patients attained at least stage III: 33% reached stage IV and 12% stage V. The XI-FFMT group demonstrated a tendency to reach the stage IV or V gradually over time with continued smile training. For the V3-FFMT, 100% reached stage II (dependent movement), and none passed the tickle test, which meant they often forget to smile and demonstrate a smile latency. All V3-FFMT continued to have involuntary movement when biting.

Satisfaction Score

In the CFNG-gracilis group, the average satisfaction score was 3.42 from 33 patients who were randomly chosen for the study. Eighty-two percent of the patients gave a score of 3 or higher (acceptable or satisfied) out of 5, and many (14/33, 42%) gave a score of 4 (satisfied). In XI-gracilis group, the average score was 3.40 from 30 patients'

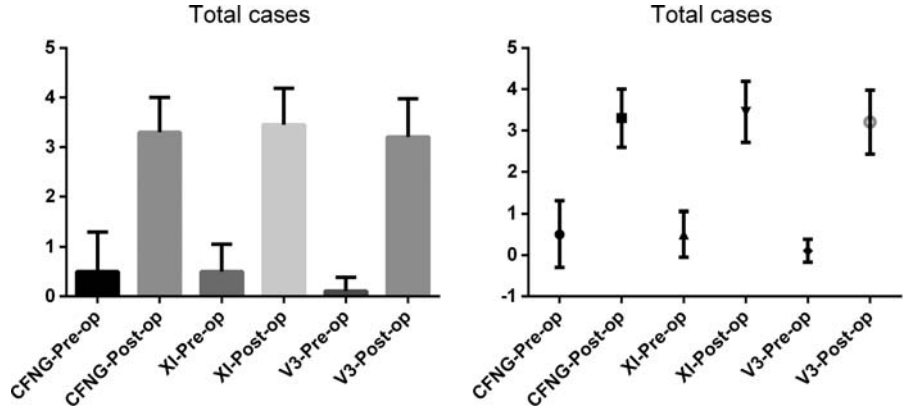

FIGURE 9. These graphs illustrate the Functional Result Score (from 1 to 5) for CFNG-gracilis group (129 patients), XI-gracilis group (43 patients) and V3-gracilis group (16 patients) preoperative and postoperative grading scores. Wilcoxon matched-pairs test, $P < 0.0001$, compared with both the pre- and post-FFMT.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

survey. Ninety percent of the patients gave a score of 3 or higher, and many (15/30, 50%) gave a score of 3. In V3-gracilis group, the average score was 3.2 from 15 patients. Only 67% patients gave a satisfaction score of 3 or higher (Table 5).

Functional Results Score

Three group patients obtained significantly higher scores after FFMT for facial reanimation ($P < 0.0001$), compared with both the pre- and post-FFMT (Fig. 9).

Second Surgery (Revision and/or Aesthetic Surgery)

Nearly half (49%) of the patients requested or required second procedure for secondary deformity correction or aesthetic procedure to enhance the results. The secondary deformities included contracture of upper lip, lower lip or mouth angle, asymmetry of eyelids or lip width (too widening or too thinning), notch of the upper lip, bulkiness or depression on the reconstructed face, dropping eyebrow, and insufficient muscle mobility with inadequate tooth exposure, and asked for correction. Aesthetic procedures included blepharoplasty, rhinnoplasty, fat grafting, botox injection, scar revision, and so on.

DISCUSSION

There is no 1 (or 2) muscle(s) which can totally replace the whole facial animation. Our reconstruction focuses on the upper lip elevation and lower lip suspension only, that is, a reconstruction for smile. The main goal is to achieve a symmetric face at rest and a synchronous (or spontaneous) smile with no latency and no involuntary movement. Upper lip elevation is performed by FFMT, and lower lip suspension on the paralyzed face with an elongated gracilis aponeurosis, or alternatively with a tendon graft, or plantaris tendon graft for the lower lip latero-upward pulling.[21] Forehead elevation and eye narrowing are usually managed conservatively, such as botox injection or lateral tarsorrhaphy.

Most surgeons use the middle third of gracilis belly in either full or split for transfer. There are some disadvantages, including the looser attachment, upper lip bulkiness, and not easy to perform second revision. Using upper third gracilis muscle including proximal attached aponeurosis is the author's preferred method.[16] When secondary revision is required, the aponeurosis has become thick and dense, which is easily identified and revised.

A variety of facial nerve grading scales has been developed over the years with the intended goals of objectively documenting facial nerve function, tracking recovery, and facilitating communication between practitioners.[19,20,22–26] Since 2010, a new evaluation system was developed in this center, which included smile excursion score, cortical adaption stage system, satisfaction score from patient's questionnaire, and finally functional results score for final conclusion of the results.

We have performed CFNG-gracilis, a 2-stage procedure, for facial reanimation since 1985. Though the CFNG neurotizer is theologically the weakest in power, requiring longer rehabilitation before achieving optimal recovery, it offers the greatest chance of restoring a natural-looking spontaneous smile. XI-gracilis, a 1-stage procedure, has been extensively used by the author since 2000.[16] The results, in general, have exceeded expectation. Patients often take 6 to 12 months to reach smile excursion score 3. We actually started V3-gracilis as a one stage procedure at 1995, 5 years earlier than XI-gracilis. We stopped using the procedure for nearly 2 decades because its severe involuntary movement seen in many patients. After 2013, We reused the V3-FFMT technique, because it can remarkably achieve a quick result. V3-FFMT is a good indicative in some conditions, such as bilateral facial palsy, failed primary CFNG- or XI-FFMT cases, aged patients (>70 years), and malignant tumor resection patients.

The advantages and disadvantages of the different neurotizers are shown in Table 6.

To a sugar cane, the sweetest part is at its head portion (at ground part), and least sweet at its tail (in the air) part. The CFNG-FFMT for facial reanimation is something like eating a sugar cane from tail to head, getting more synchronous with time over. The best result of CFNG-FFMT is usually seen in the second to third years postoperatively. On the contrary, V3-FFMT is like eating a sugar cane from its head to tail. The transferred muscle starts to move very early, 3 to 6 months postoperatively. The muscle is getting stronger, not natural. The advantages of XI-FFMT are located between the CFNG- and V3-FFMT.

CONCLUSIONS

The CFNG-FFMT procedure remains our first choice for unilateral facial paralysis reconstruction, especially for children and women patients. However, the effectiveness of using XI-FFMT, a 1-stage procedure, is proven a good alternative. There remain some specific indication for V3-FFMT, such as bilateral facial palsy, failed primary CFNG- or XI-FFMT cases, older patients (>70 years old) and malignant tumor resection patients, but it is generally our third choice.

TABLE 6. Comparison of Functioning Muscle Transplantation With Different Neurotizers

	CFNG-Gracilis	XI-Gracilis	V3-Gracilis
Stage requirement	2	1	1
Nerve graft requirement	yes	No	No
Scars	Face and leg	Face and neck	Face
Neurotizer power	+	++	+++
Time to reach smile excursion score 1 (mo)	6–12	6	2–6
Time to achieve smile excursion score ≥ 2 (mo)	12–24	<12	<6
Cortical adaptation stage	Stage IV–V	Stage III, IV, or V (getting better by time)	Stage II–III (most, stage II)
Tickle test	Spontaneously, no latency	Latency (+)	Latency (++)
Smiling training requirement	+	++	+++
Satisfaction score	4–5	3–4	3

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.

REFERENCES

1. Gray H, Goss CM. *Anatomy of The Human Body*. Twenty-sixth ed. Philadelphia: Lea & Febiger; 1955.
2. Limb CJ, Niparko JK. The acute facial palsies. In: Jackler R, Brackmann DE, eds. Neurotology, Philadelphia, PA: The Curtis Center; 2005:1230–1257.
3. Chuang DC, Chang TN, Lu JC. Postparalysis facial synkinesis: clinical classification and surgical strategies. *Plast Reconstr Surg Glob Open*. 2015;3:e320.
4. Melvin TA, Limb CJ. Overview of facial paralysis: current concepts. *Facial Plast Surg*. 2008;24:155–163.
5. Rubin L. *The Paralyzed Face*. St. Louis, Mosby Year book; 1991.
6. Labbé D, Huault M. Lengthening temporalis myoplasty and lip reanimation. *Plast Reconstr Surg*. 2000;105:1289–1297; discussion 1298.
7. Viterbo F, de Paula Faleiros HR. Orthodromic transposition of the temporal muscle for facial paralysis: made easy and better. *J Craniofac Surg*. 2005;16: 306–309.
8. Boahene KD. Dynamic muscle transfer in facial reanimation. *Facial Plast Surg*. 2008;24:204–210.
9. Manktelow RT. Free muscle transplantation for facial paralysis. *Clin Plast Surg*. 1984;11:215–220.
10. Terzis JK, Noah ME. Analysis of 100 cases of free-muscle transplantation for facial paralysis. *Plast Reconstr Surg*. 1997;99:1905–1921.
11. Guelinckx PJ, Sinsel NK. Muscle transplantation for reconstruction of a smile after facial paralysis past, present, and future. *Microsurgery*. 1996; 17:391–401.
12. Chuang DC. Technique evolution for facial paralysis reconstruction using functioning free muscle transplantation—experience of Chang Gung Memorial Hospital. *Clin Plast Surg*. 2002;29:449–459.
13. Terzis JK, Konofaos P. Novel use of C7 spinal nerve for Moebius. *Plast Reconstr Surg*. 2010;126:106–117.
14. Ueda K, Harii K, Yamada A. Free neurovascular muscle transplantation for the treatment of facial paralysis using the hypoglossal nerve as a recipient motor source. *Plast Reconstr Surg*. 1994;94:808–817.
15. Xu YB, Liu J, Li P, et al. The phrenic nerve as a motor nerve donor for facial reanimation with the free latissimus dorsi muscle. *J Reconstr Microsurg*. 2009;25: 457–463.
16. Chuang DC, Lu JC, Anesti K. One-stage procedure using spinal accessory nerve (XI)-innervated free muscle for facial paralysis reconstruction. *Plast Reconstr Surg*. 2013;132:117e–129e.
17. Bae YC, Zuker RM, Manktelow RT, et al. A comparison of commissure excursion following gracilis muscle transplantation for facial paralysis using a cross-face nerve graft versus the motor nerve to the masseter nerve. *Plast Reconstr Surg*. 2006;117:2407–2413.
18. Chuang DC. Neurotization procedures for brachial plexus injuries. *Hand Clin*. 1995;11:633–645.
19. Tzou CH, Chuang DC, Chen HH. Facial paralysis grading system: a new and simple smile excursion score for evaluating facial reanimation surgery. *Ann Plast Surg*. 2015;74:210–213.
20. Tzou CH, Chuang DC, Chen HY. Cortical adaptation staging system: a new and simple staging for result evaluation of functioning free-muscle transplantation for facial reanimation. *Ann Plast Surg*. 2014;73:50–53.
21. Lin JS, Lu JC, Chuang DC. Simultaneous reconstruction of the lower lip during functioning free muscle transplantation for smile reanimation in facial paralysis: objective and subjective evaluation comparing different surgical methods. Presented at 2017 ASRM meeting, Waikoloa, Hawaii 2017.
22. House JW, Brackmann DE. Facial nerve grading system. *Otolaryngol Head Neck Surg*. 1985;93:146–147.
23. Coulson SE, Croxson GR, Adams RD, et al. Reliability of the "Sydney," "Sunnybrook," and "House Brackmann" facial grading systems to assess voluntary movement and synkinesis after facial nerve paralysis. *Otolaryngol Head Neck Surg*. 2005;132:543–549.
24. Evans RA, Harries ML, Baguley DM, et al. Reliability of the House and Brackmann grading system for facial palsy. *J Laryngol Otol*. 1989;103:1045–1046.
25. Reitzen SD, Babb JS, Lalwani AK. Significance and reliability of the House-Brackmann grading system for regional facial nerve function. *Otolaryngol Head Neck Surg*. 2009;140:154–158.
26. Kim L, Byrne PJ. Controversies in contemporary facial reanimation. *Facial Plast Surg Clin North Am*. 2016;24:275–297.

© 2018 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2018 Wolters Kluwer Health, Inc. Unauthorized reproduction of this article is prohibited.