Comparison of Lengthening Temporalis Myoplasty and Free-Gracilis Muscle Transfer for Facial Reanimation in Children

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Background: Lengthening temporalis myoplasty (LTM) and cross-face nerve graft with free gracilis muscle transfer (CFNG-FGMT) are the 2 most common procedures used to restore dynamic facial animation and improve facial symmetry. There has not been direct comparison or consensus. Here, the authors compare our experience with respect to muscle activity, symmetry, and excursion.

Methods: A retrospective review was performed of patients with facial palsy who had CFNG-FGMT or LTM from 2008 to 2016 at a single institution. Postoperative surface EMG was recorded at maximum open smile. Normal and paralyzed sides of the face were analyzed with Facial Assessment by Computer Evaluation software. Commissure excursion and symmetry was assessed.

Results: Six patients with LTM and 10 with CFNG-FGMT met inclusion criteria. Muscle activity was 1st identified in LTM patients after 3 months (47.42 mV, $P < 0.001$) and CFNG-FGMT patients after 3 months (28.30 mV, $P < 0.001$) compared to immediate postoperative period. Relative to preoperative excursion, there was significant increase of 3.33 mm in commissure excursion seen at the 0 to 3 month period for LTM patients ($P = 0.04$). Commisure excursion for CFNG-FGMT was seen later, in the 3- to 6-month postoperative period (4.01, $P = 0.024$). During smile, CFNG-FGMT patients had better symmetry than unilateral LTM patients. In bilateral LTM patients, there was no significant change in symmetry.

Conclusion: Dynamic facial animation improved in both surgical groups. The LTM demonstrates a faster rate of muscle recruitment compared to CFNG-FGMT. After 3 months, both LTM and CFNG-FGMT groups had comparable excursions. A decision-making algorithm is presented.

Key Words: Facial palsy, facial reanimation, gracilis muscle, lengthening temporalis myoplasty, pediatric facial paralysis

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Facial palsy can be debilitating, with a wide range of clinical presentations. Longstanding facial palsy may cause pronounced psychosocial and functional effects. Patients may have varying degrees of eyelid dysfunction, corneal de-sensitization, and vision impairment. The mouth may be affected resulting in deficits in communication, ability to eat, control of saliva, pronunciation of words, and communication of emotions such as with spontaneous smile.[1] In addition, several reports have demonstrated decreased quality of life, depression, and perceived lack of attractiveness.[2,3]

Management of disease can vary based on the patient's age, onset of symptoms, severity, and surgeon experience. The spectrum of disease may range from complete bilateral facial palsy to a partial unilateral facial weakness. Intervention strategies and operative options are based on physiology of muscle de-innervation over time. Patients with acute onset facial palsy who have de-innervated facial musculature of <1 year may be amenable to nerve-based reconstruction using direct nerve repair, nerve grafts, or nerve transfers.[4] However, longstanding facial palsy presents a different problem, as after 1 year, motor-end plates lose viability, and function thus losing suitability for re-innervation. In this setting, treatment requires providing an alternative viable muscle transfer along with a new neural stimulus.[5] This muscle replacement can be provided using a regional or free muscle flap.

First described by Harii et al in 1976, the free gracilis muscle flap has long been accepted as treatment of long-standing facial palsy.[6] This procedure is classically performed in 2 stages. The 1st entails harvest of the sural nerve to create a cross-face nerve graft (CFNG) from a branch of the contralateral, unaffected facial nerve, which provides a true facial nerve donor motor input for the 2nd stage, the free gracilis muscle flap.[4] The use of the contralateral facial nerve allows for a spontaneous, emotional smile. However, if there is congenital agenesis of the facial nerve or bilateral disease, this precludes use of this specific procedure.[7] In this scenario, the free gracilis muscle flap may be powered by the motor nerve to the masseter as a single-stage procedure, though this does entail the use of a nonfacial nerve motor source.[8]

Historically, regional muscle flaps have preceded use of free muscle transfer, in particular the temporalis muscle flap.[9] These procedures have been refined and modified over time, and a frequently used contemporary procedure for treatment of

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longstanding facial palsy is the lengthening temporalis myoplasty (LTM). This procedure was described by Daniel Labbé as a modification of the originally described temporalis myoplasty.[10] In Labbé's technique, the use of a tendon graft is avoided, precluding late postoperative stretching of the tendon. This technique is especially useful in certain clinical situations, such as the unavailability of a functional contralateral facial nerve, or in bilateral disease such as in congenital Moebius syndrome. Furthermore, the LTM can provide dynamic function in a single-stage procedure. Some studies have shown inadequate development of spontaneous smile, while Labbé has reported automatic spontaneous smile in up to 94% of patients.[11]

While the LTM procedure is not as common as the free gracilis muscle flap, it has become an increasingly popular alternative for treatment of facial palsy. Though the LTM is designed to leave the oral commissure in a neutral position, it may also provide a static sling in the short term. There has been speculation that there is earlier muscle activity due to the preclusion of nerve coaptation, and a native vascular and neural supply. There still remains a lack of consensus on easily adopted objective measurements of facial animation, function, and symmetry though several recent studies have offered new tools.[12,13]

Despite these being the 2 most common procedures of dynamic reanimation in facial palsy, there has not been a direct objective comparison between the 2 in the pediatric population. One review has examined the literature comparing these procedures between studies; however, demonstrating no example of a self-contained study comparing experience with both procedures within the same institution.[14] The purpose of this study is to directly compare outcomes in our institution of the most common procedures for dynamic facial reanimation in children: free gracilis muscle flap innervated by the CFNG (CFNG-FGMT) and the regional muscle flap, LTM. Specifically, we wish to examine the objective differences in reconstructive efforts for dynamic reanimation, as measured by commissure excursion and muscle activity.

METHODS

Facial Palsy Subjects

A retrospective chart review was performed of patients with facial palsy who received either CFNG-FGMT or LTM from 2008 to 2016 at a single pediatric institution. Patients who underwent an FGMT to motor nerve to masseter were excluded in this study. Demographic and perioperative data were prospectively collected and reviewed retrospectively.

Surgical Technique

The LTM was performed as classically described by Labbé.[10] Briefly, a bicoronal incision is used and the temporalis muscle dissected off the temporal bone to the sphenotemporal crest. The zygomatic arch is exposed in a subperiosteal manner, and osteotomized at its anterior and posterior articulations. The arch is temporarily removed, and the overlying masseteric fibers are divided. The tendinous insertion of the temporalis muscle is dissected and the coronoid process exposed. A coronoidectomy is performed. Next, a nasolabial fold incision is made and a tunnel is bluntly made connecting this incision to the bicoronal exposure. The coronoid process is grasped with a Kocher clamp through the nasolabial fold incision, and all interfering pterygoid and masseteric fibers are bluntly dissected off the distal temporalis with a periosteal elevator. These maneuvers are critical to extend the temporalis tendon to the nasolabial fold. The coronoid bone is excised and the distal tendon is spread and sewn to the subdermis of the nasolabial fold. The zygomatic arch is replaced and fixated with hardware or sutures, and the temporalis muscle is resuspended directly to the temporal crest anteriorly and with spanning sutures posteriorly. The coronal flap is closed over a drain. Therapy is initiated at 3 weeks postoperatively.

The CFNG-FGMT was performed as described by Zuker.[5] Briefly, at stage I, 20 to 25 cm of sural nerve is harvested using minimally invasive techniques. Following this, a facelift incision with neck extension is performed on the nonparalyzed side of the face. A supra-SMAS dissection is made until the anterior border of the parotid at which point exploration is performed for several branches of the buccal and zygomatic facial nerves. Once identified, these are then stimulated with a Checkpoint stimulator (Checkpoint Surgical, Cleveland, OH) and smile vector and force are assessed. A buccal branch with a superolateral vector of smile is chosen, once confirmed that another distinct branch performs the same function. This is then divided, and the sural nerve is reversed in orientation and is bluntly tunneled to the contralateral upper lip via a gingivobuccal incision. It is sutured to the periosteum above the contralateral canine. Nerve coaptation is then performed between the buccal branch and the sural nerve using interrupted epineural 9-0 nylon sutures. The patient is followed in clinic and once Tinel's sign is elicited above the contralateral upper lip, they are ready for stage II, usually 9 to 12 months. At this time, a 2-team approach provides greater efficiency and decreased operative time. The contralateral thigh is utilized for gracilis muscle harvest. The medial femoral circumflex pedicle and obturator nerve are identified and dissected to their greatest length. Approximately half of the width of the gracilis muscle is harvested to decrease facial bulkiness. Meanwhile, the paralyzed side of the face is dissected via a matching face lift incision. Recipient vessels, usually the facial artery and vein, are dissected as is the end of the sural nerve graft in the upper lip. The gracilis muscle is then inset into preplaced sutures at the nasolabial fold (3–4 sutures). Vascular flow is then reconstituted using microvascular anastomoses with the aid of an operating microscope and 8-0 or 9-0 nylon sutures. The obturator nerve is then co-apted to the sural nerve also using interrupted epineural sutures. The gracilis muscle is inset in a vector that mimics the zygomaticus major and anchored to the temporalis fascia at resting tension. The cheek flap is then closed over a drain. Muscle function is usually observed at approximately 6 months.

Excursion

Facial Assessment by Computer Evaluation (FACE) software (available at: http://www.sircharlesbell.org/facial_nerve_programs.html; FaceGram, Massachusetts Eye and Ear Infirmary) demonstrates strong inter- and intraobserver agreement.[15] This software was used by a single author (KSF) to obtain objective measure of commissure location, as described previously.[13,15] Analysis of the normal and affected sides of the face, in repose and while smiling, in pre- and postoperative photographs was performed. Commissure excursion was calculated as the difference between rest and open mouth smile positions of the oral commissure. Measurement of the position of oral commissure was taken in the three vectors: horizontal axis, vertical axis, and hypotenuse (C). The hypotenuse (C) is measured from the lower lip midline vermillion to the commissure. The hypotenuse was used as the primary end point for commissure excursion. The commissure excursion was calculated as the difference in millimeters between the resting C value and the smiling C value. This was measured in preoperative photographs and subsequent postoperative photographs (Fig. 1).

Muscle Activity

Postoperative surface EMG (sEMG) measurements were used to calculate muscle activity for patients who underwent LTM and CFNG-FGMT. Surface electrodes were placed on the cheek skin

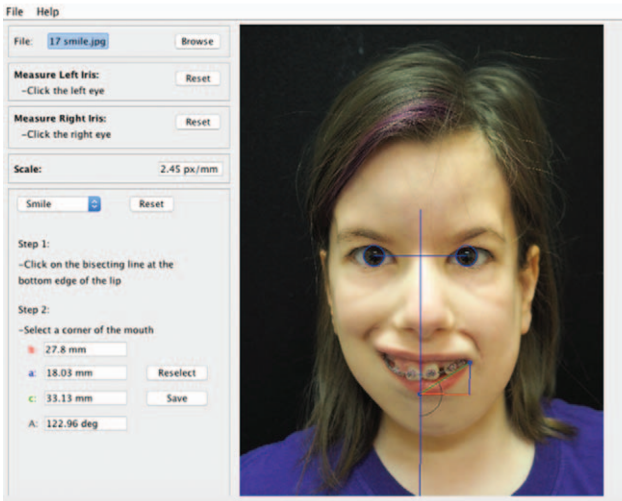

FIGURE 1. Image demonstrating example of Facial Assessment by Computer Evaluation-gram software interface, measuring commissure position in a patient with bilateral facial palsy.

directly overlying the muscle flap. To ascertain the prefatigued muscle activity, these measurements were only recorded for the preworkout reading before each physical therapy session.

Symmetry

Data collected from FACE software were used, as described above, to determine the difference between the left and right side of the face in pre- and postoperative photographs. Analysis over time was conducted to examine difference of commissure position *C* between the normal and paralyzed side of the face during smile in unilateral LTM and CFNG-FGMT. For unilateral LTM patients and CFNG-FGMT, the *C* value in millimeters was obtained from the paralyzed and normal side via FACE-gram. This difference between the normal and paralyzed side was calculated at various postoperative intervals to determine if and when facial symmetry, defined by a decreased difference between the normal and paralyzed sides, improved. Bilateral LTM symmetry was calculated as the absolute value of the difference between left and right excursions. Videos can be viewed as Supplemental Digital Content, http://links.lww.com/SCS/A891; http://links.lww.com/SCS/A892; http://links.lww.com/SCS/A893; http://links.lww.com/SCS/A894; http://links.lww.com/SCS/A895; and http://links.lww.com/SCS/A896.

Statistical Analysis

Multi-level mixed-effects regression was used for comparison of sEMG and commissure excursion. Time intervals were grouped into 0-3, 3-6, 6-9, 9-12, 12+, and 24+ months postoperatively. *P*-values were 2-sided and considered significant at the <0.05 α-level. All statistical analyses were performed using STATA version 14.2 (StataCorp, College Station, TX).

RESULTS

Subject Demographics

Six patients with LTM and 10 with CFNG-FGMT met inclusion criteria. Three patients had unilateral LTM, and 3 had bilateral LTM, for a total of 9 muscle flaps. Age at time of surgery ranged from 7 to 21 years. There were 4 male patients and 12 female patients. Follow-up ranged from 1 to 25 months for LTM, and 1 month to 5 years for CFNG-FGMT. Race demographics included 11 White, 3 Latino, and 2 Asian. Average length of stay was 4.5 days (range 2–11 days) for LTM and 4.5 days (range 4–7 days) for CFNG-FGMT. Average blood loss was 697 cc for LTM and 172 cc for CFNG-FGMT. All patients underwent postoperative physiotherapy starting at 3 weeks from time of surgery.

Excursion

Relative to preoperative excursion, there was significant increase of 3.33 ± 1.58 mm in commissure excursion seen at the 0 to 3 months period for LTM patients ($P = 0.04$). Excursion continued to steadily rise in subsequent postoperative periods. The LTM patients showed the greatest excursion increase of 7.27 ± 1.96 mm ($P < 0.001$) at the 9 to 12 month period, which was the latest postoperative follow-up period. The CFNG-FGMT patients demonstrated increased postoperative excursion in the 3- to 6-month postoperative period relative to preoperative excursion (4.01 ± 1.77 mm, $P = 0.024$). When compared to CFNG-FGMT patients, LTM patients had greater coefficients of postoperative excursion improvement at an earlier and faster rate than CFNG-FGMT (Supplemental Digital Content, Table 1, http://links.lww.com/SCS/A816). Representative pre- and postoperative photographs are shown for patients undergoing smile reconstruction with unilateral and bilateral LTM (Fig. 2A-B and 2C-D, respectively). Figure 2E-F demonstrates smile reconstruction following 2nd stage CFNG technique with FGMT.

Muscle Activity

Significant sEMG muscle recruitment was 1st identified in LTM patients after 3 months postoperatively (35.00 ± 9.93 mV, $P < 0.001$) and CFNG-FGMT patients after 3 months (23.53 ± 9.88 mV, $P < 0.02$) as compared to immediate postoperative values (Supplemental Digital Content, Table 2, http://links.lww.com/SCS/A816) Beta-coefficient regression demonstrated a steady rate of increasing sEMG millivolts in LTM and

FIGURE 2. (A-B) 15-year-old female undergoing unilateral lengthening temporalis myoplasty (LTM) with preoperative smile (A) and 18-month postoperative smile (B). (C-D) 8-year-old female undergoing bilateral LTM with preoperative smile (C) and 19-month postoperative smile (D). (E-F) 11-year-old male undergoing 2-stage cross-face nerve graft with free gracilis muscle transfer with preoperative smile (E) and 19 months postoperative smile from 2nd stage free gracilis muscle transfer postoperative smile (F).

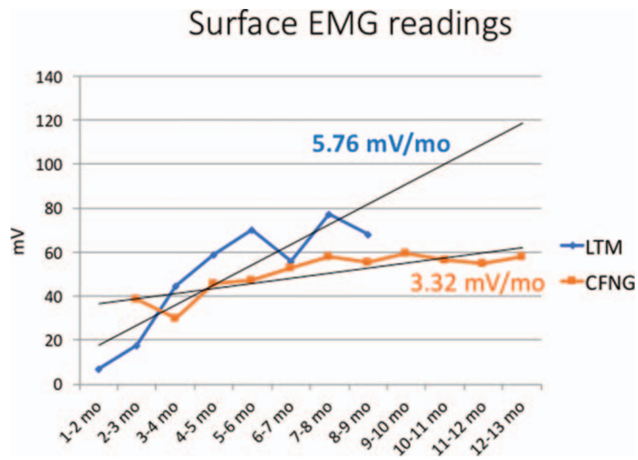

FIGURE 3. Linear regression plot showing muscle recruitment for lengthening temporalis myoplasty (LTM) versus cross-face nerve graft (CFNG) with free gracilis muscle transfer over time in postoperative months.

CFNG-FGMT patients (5.76 mV/month, $P < 0.001$ and 3.32 mV/month, $P < 0.001$; respectively). When comparing LTM versus CFNG-FGMT, LTM demonstrates 2.37 mV more muscle recruitment per month over CFNG-FGMT ($P = 0.039$). Overall, trend for sEMG readings for LTM and CFNG-FGMT is shown in Figure 3.

Symmetry

Patients were divided into 3 groups: unilateral LTM, bilateral LTM, and CFNG-FGMT. In unilateral LTM patients, the paralyzed side after reconstruction demonstrated an initial tightness causing the commissure to be displaced supero-laterally as compared to preoperative position.

This ultimately caused the patients smile to exceed past perfect symmetry and in the opposite direction (Supplemental Digital Content, Table 3, http://links.lww.com/SCS/A816). CFNG-FGMT patients had significant symmetry improvement beginning at the 3 to 6 months time interval and at all subsequent postoperative measurements. The difference in symmetry decreased from an average 9.07 mm preoperatively to an average 0.53 mm postoperatively ($P < 0.001$). In the bilateral LTM patients, as expected due to symmetrical surgeries, there was no significant change in symmetry.

DISCUSSION

The goal of dynamic facial reanimation is to restore a spontaneous, symmetrical smile. Although the free gracilis muscle transfer has long been accepted as the procedure of choice for long standing facial palsy, more recent developments in alternative procedures have generated increasing interest. The LTM according to Labbé has shown to be a reliable alternative for patients.[11,16,17] There are inherent advantages and disadvantages to both procedures. The CFNG-FGMT as classically described, requires 2 stages separated by 6 to 12 months, with inherent morbidity of sural nerve harvest, need for microsurgery, and long operative time. However, the purported advantage is utilizing a true "spontaneous" neural input in the form of the contralateral facial nerve. The LTM can be done in a single stage, including bilateral procedures, with decreased operative time, and no need for microsurgical expertise. However, the neural input for the temporalis muscle is cranial nerve V, which must be retrained by the patient to effect facial movement. Through brain plasticity, there has been some evidence through functional MRI that there are 2 distinct cortical areas of the brain devoted to chewing and smiling, with expansion of the smiling area after LTM.[18] At our institution, all postoperative facial reanimation patients begin physiotherapy at 3 weeks following surgery. The specific exercises are tailored to the muscle group and neural input of the reconstruction.

There were 2 issues to consider in determining LTM versus CFNG-FGMT. As an institution, we had not developed technical familiarity with the LTM until 2015. As such, it was not offered prior to this. However, after having facility with both LTM and the CFNG-FGMT, there were clinical scenarios which steered our collective decision making from one side toward the other. Patients with bilateral facial palsy (ie, Moebius) were preferentially offered LTM. The greatest advantages were a single-stage surgery, shorter recovery time, shorter time to initiation of movement, and symmetric smile vectors. The other procedure offered in these scenarios was an FGMT powered by the motor nerve to masseter, also a cranial nerve V motor source. This procedure necessitates microsurgery and postoperative flap monitoring, and is most commonly staged by doing one side at a time separated by 3 to 6 months. The greatest disadvantages of this technique are 2 surgeries, greater potential for asymmetry of smile vectors, longer operative and recovery times, and time to initiation of movement. A potential advantage is a greater excursion with the FGMT as compared to an LTM. In cases of unilateral palsy, one needed to consider several aspects: etiology of the disease (ie, traumatic/previous surgery/viability and thickness of the temporalis muscle) and patient driven factors (ie, return to work, scar placement, recovery, and ability to access therapy). In these scenarios, patients were given both options, and decision was made jointly. In general, patients who had significant previous surgery and scarred beds, or anatomic preclusion of adequate recipient vessels, we deferred to the LTM. In the patients who had never undergone previous procedures, we would recommend the CFNG-FGMT. See Figure 4 for our treatment algorithm.

There has been one systematic review comparing the 2 procedures objectively, though no study has directly prospectively compared these procedures.[14] In this review of 16 articles in which objective measurements of excursion and symmetry were compared between studies, the authors concluded that patients who had a gracilis flap innervated by the masseteric nerve had greater commissure movement then those innervated by a cross-face nerve, and the LTM achieved less lateral movement of the commissure with controversial evidence of spontaneity.

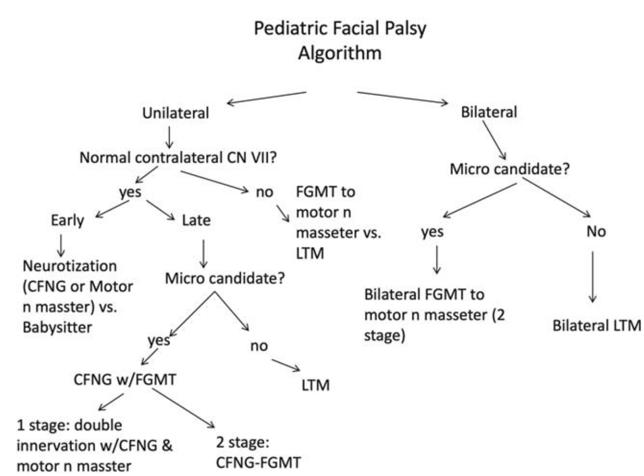

FIGURE 4. Decision-making algorithm for pediatric facial palsy. CFNG, cross-face nerve graft; FGMT, free gracilis muscle transfer; LTM, lengthening temporalis myoplasty.

Our results demonstrate that the CFNG-FGMT has early muscle recruitment, but to a slower degree than LTM. This may be due to the 2 sites of neural coaptation of the cross-face nerve.[19] Though one may anticipate that the LTM would have immediate muscle activity, we did not find this to be the case. This may be in part due to the amount of dissection and stretching of the muscle and tendon in this orthodromic repositioning, with a requisite period of muscle "creep." As the terminal temporalis tendon is repositioned from the coronoid process to its new position at the nasolabial fold, there likely exists a period of relaxation of the muscle before it can begin contracting again.

An additional option for dynamic reanimation in the setting of an unavailable working contralateral facial nerve is coaptation to the motor nerve to the masseter. There now exists a growing body of literature showing the safety and efficacy of this procedure, with increased power and contraction of the muscle given the higher donor axon density.[19–22] Certainly, in patients with Moebius syndrome and congenital bilateral facial palsy, reconstruction must be performed using an alternative motor source, that is, cranial nerve V. Thus, reconstructive options are either free muscle transfer powered by the motor nerve to masseter or a temporalis muscle transfer. Though this procedure is useful in the armamentarium of dynamic facial motion reconstruction, we did not include this group as we wished to specifically examine the efficacy of the traditional 2-stage cross-face nerve powered gracilis muscle versus the regional LTM as these were our most common procedures. Some have advocated for the dual-innervated gracilis muscle flap (from both a CFNG and the motor nerve to the masseter); however, we did not include this group in this study to keep the motor source distinct.[23] Future studies directly comparing free gracilis muscle transfer powered by the motor nerve to masseter and the LTM may offer more insight into perceived spontaneity of smile, as both of these reconstructions are powered through cranial nerve V.

In this study, LTM has greater increase in muscle activity and commissure excursion per month than the CFNG-FGMT. The LTM is a single-stage procedure without the requirement for specialized microsurgery and microsurgical equipment. As a regional flap, there is no inherent axonal loss due to coaptation, which may translate to greater motor power. In this series, the unilateral LTM seems to have such a significant postoperative commissure excursion during smile that the reconstructed side overpowers the normal side. The temporalis muscle is set with care to minimize tension on the nasolabial fold intraoperatively. However, there still is a component of a static sling that relaxes over time. Symmetry may be improved over time with physiotherapy in addition to the natural muscle relaxation.

As a direct input from the facial nerve, CFNG-FGMT has been shown to have a spontaneous, emotional smile in several other studies.[23,24] Criticism of utilizing a muscle that is not powered by the facial nerve is the lack of a true emotional stimulus. Several studies have detailed brain plasticity in facial palsy patients who have been reconstructed with either LTM or motor nerve to masseter, demonstrating an ability to smile "spontaneously" without the need to bite down.[18,22] Labbé describes 3 phases of facial movement with the LTM that progress with physical therapy, beginning with a mandibular smile by biting down, to a temporal smile, and ultimately to a spontaneous smile that does not require a physical trigger, that is, clenching the jaw.[25] In our experience with the LTM, we have found this process to usually occur over the course of the 1st year postoperatively. Here, we have recorded surface EMG data at the beginning of a therapy session, prior to muscle fatigue. It may be useful to record these at both pre- and posttherapy session to assess for muscle resilience and durability.

There are several limitations to consider in this study. One limitation is our limited sample size. Even though we are limited by this sample, enough data accumulated at multiple time intervals postoperatively allowed us to identify significance in excursion and symmetry. However, we may be underpowered to identify if excursion truly improved at an earlier time interval than the identified 3-month postoperative period. Additionally, it is known that continued use and therapy can improve symmetry and comfortability with the reconstructed smile for years after reconstruction. As such, longer term follow-up will be required. Although the FACE software has been validated with strong inter- and intraobserver agreement, it is a 2-dimensional objective measurement of commissure excursion.[13] As there is still no optimal consensus on the most objective method to evaluate outcome, there may be opportunity to incorporate 3-dimensional photography and video. Lastly, perhaps a more telling outcome of surgery using patient reported outcome surveys will need to be included in future studies. Though efforts to restore dynamic facial animation are generally appreciated by patients with facial palsy, the ability and use of the reconstructed smile in day-to-day life is the ultimate barometer of success.

CONCLUSION

Our results show that LTM has increased early muscle activity, with comparable commissure excursion to CFNG-FGMT. Based on these findings, LTM appears to be an excellent alternative for longstanding facial palsy especially in those patients who may not be candidates for microsurgery and desire quicker time to motion. Furthermore, with respect to symmetry and surgical time and burden, it may be the primary option for patients with bilateral disease. Further studies should be tailored to investigate spontaneity of smile in the LTM patients, as well as patient reported outcomes between the 2 procedures.

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