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Comparison of Objective Outcomes in Dynamic Lower Facial Reanimation With Temporalis Tendon and Gracilis Free Muscle Transfer

Samuel L. Oyer, MD; Jason Nellis, MD; Lisa E. Ishii, MD; Kofi D. Boahene, MD; Patrick J. Byrne, MD

IMPORTANCE Facial paralysis affects patients' physical, social, and psychological function. Dynamic smile reanimation can mitigate these effects, but there are limited data to guide the surgeon in selecting the best reanimation procedure for each patient.

OBJECTIVE To compare quantitative changes in oral commissure symmetry and smile excursion following temporalis tendon transfer (T3) and gracilis free muscle transfer.

DESIGN, SETTING, AND PARTICIPANTS Retrospective case series of 28 adults with unilateral facial paralysis seeking dynamic lower facial reanimation at a tertiary academic medical center between July 1, 2010, and July 30, 2014. Data were analyzed from May 1, 2016, to June 30, 2016.

INTERVENTIONS Minimally invasive T3 (n = 14) compared with gracilis free muscle transfer (n = 14).

MAIN OUTCOMES AND MEASURES Measured symmetry of the oral commissure between the healthy and paralyzed sides in the horizontal, vertical, and angular dimension and excursion of the paralyzed commissure following reanimation compared with the healthy commissure.

RESULTS Of the 28 patients, 19 (68%) were women; mean (SD) age was 51.7 (17) years. Commissure symmetry during smile improved significantly for the T3 patients in the vertical and angular dimensions, and the gracilis free muscle transfer patients had significant improvement in the vertical and horizontal dimensions. Commissure excursion significantly improved in both groups following surgery, with a larger improvement seen in the gracilis free muscle transfer group (11.3 mm; 95% CI, 7.0 to 15.5 mm) compared with the T3 group (4.8 mm; 95% CI, 0.2 to 9.3 mm), with a mean difference of 6.5 mm (95% CI, 0.7 to 12.4 mm; Cohen *d*, 0.86). Postoperative smile excursion of the paralyzed side was within 1.0 mm of the healthy side in the gracilis free muscle transfer group (95% CI, −2.1 to 4.0 mm).

CONCLUSIONS AND RELEVANCE Temporalis tendon transfer and gracilis free muscle transfer both improve oral commissure symmetry and excursion in facial paralysis. The improvement in smile excursion appears to be larger in patients treated with gracilis free muscle transfer and, on average, the excursion approximates the contralateral healthy side.

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Author Affiliations: Facial Plastic & Reconstructive Surgery, Department of Otolaryngology, Medical University of South Carolina, Charleston (Oyer); Facial Plastic & Reconstructive Surgery, Department of Otolaryngology, Johns Hopkins Hospital, Baltimore, Maryland (Nellis, Ishii, Boahene, Byrne).

Corresponding Author: Samuel L. Oyer, MD, Medical University of South Carolina, 135 Rutledge Ave, MSC 550, Charleston, SC 29425 (oyer@musc.edu).

Facial paralysis can arise from a variety of causes and carries with it a host of functional, psychological, and social impairments. The ultimate goal of facial reanimation is to restore resting facial symmetry and dynamic facial motion that mirrors the opposite side as closely as possible. Much focus is directed at restoring the ability to smile given the documented effects of a smile on emotional expression,[1] facial attractiveness,[2] and psychosocial function.[3] For patients with longstanding facial paralysis who are not candidates for reinnervation or nerve transfer procedures, the 2 primary surgical options to restore a dynamic smile are temporalis tendon transfer (T3) and gracilis free muscle transfer.[4,5]

Both procedures have been used for many years in the treatment of facial paralysis, with each technique yielding successful results. Determining the ideal procedure to offer an individual patient, however, is not always straightforward, as each procedure offers different benefits and limitations. The T3 procedure carries advantages of shorter surgical time, quicker recovery, and an earlier visible result but is limited by a fixed vector of smile excursion, lack of spontaneity, and risk of creating facial asymmetry. Gracilis free muscle transfer has the potential for spontaneous activation and more opportunities to adjust the vector of smile and commissure position but is limited by the need for specialized microsurgical training and equipment, requires longer operative and recovery time, has longer time until initial movement, involves a second surgical site, and may add additional bulk to the midface. In addition, it is not currently known whether one technique is superior in restoring lower facial symmetry or dynamic motion as direct comparisons of these procedures are lacking.

The aim of this study was to evaluate the quantitative restoration of oral commissure symmetry at rest and dynamic commissure excursion among patients with longstanding facial paralysis treated with either T3 or gracilis free muscle transfer.

Key Points

Question What are the objective differences in oral commissure position and smile excursion between facial reanimation with temporalis tendon transfer and gracilis free muscle transfer?

Findings In this case series of 28 patients, oral commissure symmetry and smile excursion improved with both temporalis tendon transfer and gracilis free muscle transfer. Improvement in excursion was greater among patients treated with a gracilis free muscle transfer compared with temporalis tendon transfer.

Meaning While both interventions improve oral symmetry and smile excursion, there appears to be better excursion, on average, with gracilis free muscle transfer.

Methods

Participants

Adults treated for longstanding unilateral facial paralysis with either a T3 or gracilis free muscle transfer between July 1, 2010, and July 30, 2014, at Johns Hopkins Hospital tertiary academic medical center were evaluated retrospectively. Patients underwent a preoperative evaluation including history, physical, standardized photography, and ancillary testing comprising nerve testing or imaging as indicated. The severity of paralysis was graded according to the House-Brackmann facial grading scale (from I to VI, with VI indicating total paralysis).[6] Based on the nature of each patient's paralysis and desire to undergo dynamic smile restoration, options for T3 or gracilis free muscle transfer intervention were presented, and the choice for surgical intervention was determined based on alignment of patient goals with realistic surgical expectations. Ultimate determination of the selected surgical technique was often made by the patient after a discussion of the benefits, risks, and limitations of each procedure.

The lower facial reanimation was carried out as part of global facial paralysis treatment and often included upper and midfacial interventions as warranted. After surgery, patients participated in directed facial retraining therapy to optimize facial symmetry and develop a temporalis smile for those undergoing T3 or gracilis free muscle transfer powered by the masseteric nerve. Patients were followed up at regular intervals with standardized photography. Those undergoing additional interventions that would affect the position or excursion of the mouth were excluded from the study to better understand the outcome of the selected interventions. Patients were also excluded for incomplete data that precluded comparison of preoperative and postoperative photographs.

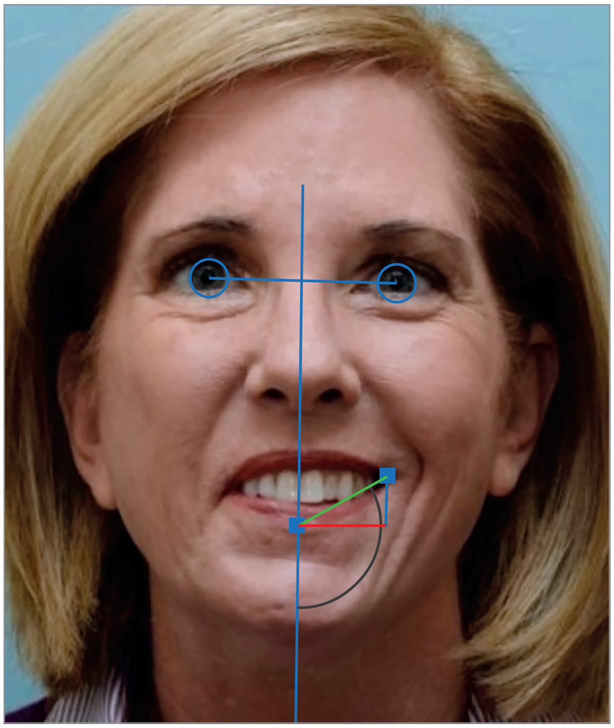
This study was approved by the institutional review board at Johns Hopkins Hospital. Written consent was collected for all procedures and use of photography.

Surgical Technique

All procedures were performed by one of us (K.D.B. or P.J.B.). The minimally invasive T3 technique had been described previously by investigators, including these authors.[7,8] Briefly, the temporalis tendon is approached either through a direct incision in the nasolabial fold for patients with a defined fold or through an intraoral incision corresponding to the external location of the fold for those with minimal nasolabial fold. Blunt dissection is carried through the buccal space to expose the ascending ramus of the mandible. The temporalis tendon is elevated off the mandible, preserving as much length and substance of the tendon as possible. The superior aspect is kept attached to the coronoid, and a coronoidectomy is performed to liberate the tendon and associated bone. The tendon is then advanced to the oral commissure and inset in multiple locations to best mirror the contralateral commissure position. Optimal inset tension is determined with surface electrode stimulation of the temporalis muscle while varying the length of the tendon.[9] If there is inadequate reach, an interposition fascia lata extension graft is placed.

Gracilis free muscle transfer is carried out in a similar fashion as described by Chuang.[10] Facial dissection is performed in the subsuperficial muscular aponeurotic system plane to expose the oral commissure and natural modiolus. The facial artery and vein are isolated and reflected to allow adequate reach for anastomosis. Flap harvest includes only a portion of the gracilis muscle, and in vivo excursion is tested with electrical stimulation of the obturator nerve to determine the most active section of the muscle for harvest. The passive resting length of the

Figure 1. Example of Facial Measurements Using Facegram Software



Horizontal and vertical axes are determined from the location of each iris. The intersection of the vertical axis with the lower lip vermillion serves as a reference point from which the position and angle of the oral commissures are measured in a horizontal, vertical, and angular direction.

muscle is marked in intervals prior to harvest to ensure facial inset at this same optimal length. The gracilis tendon is typically inset around the modiolus with the distal end inset over the zygoma near the origin of the zygomaticus muscle with care to match the muscle vector to the smile pattern of the opposite side. Vascular anastomosis is performed to the facial vessels. Neural anastomosis is performed to a previously placed cross-facial nerve graft, to the ipsilateral masseteric nerve, or dual innervation with both nerves is used.

Measurements and Outcomes

Each patient was evaluated with standardized photography using a fixed focal-length, digital, single-lens reflex camera. Images were archived (Mirror medical imaging software, version 7.4; Canfield Scientific Inc). Photoanalysis was carried out using Facegram facial analysis software (Sir Charles Bell Society).

Oral commissure symmetry was evaluated based on the position of the commissure in a vertical, horizontal, and angular dimension relative to the contralateral healthy side. The Facegram software uses the identified position of each iris to define fixed horizontal and vertical facial planes from which accurate measurements in millimeters are determined. Vertical commissure symmetry was defined as the difference in vertical height between each commissure and the horizontal plane connecting the midpoint of each iris. Lower values indicate more symmetry, with a value of 0 signifying perfect symmetry. Horizontal symmetry was defined as the difference in horizontal distance from the facial midline to each commissure, in which lower numbers indicate better symmetry. Angular symmetry was defined by the difference in angles formed between the facial midline intersection with the lower lip and each commissure (**Figure 1**).

Smile excursion was defined by the distance between the facial midline intersection with the lower lip and the oral commissure on each side. Gain in smile excursion after reanimation surgery was determined by evaluating this measurement during maximal smile after reanimation to the same measurement during smile prior to reanimation. This measurement was compared with the excursion on the healthy side.

Statistical Analysis

Categorical comparisons between the T3 and gracilis free muscle transfer groups were evaluated using the Fisher exact test and ordinal values were compared using a 2-tailed *t* test. A paired *t* test was used for repeat measurements within the same patient (preoperative to postoperative changes) and unpaired *t* test was used for comparisons between different patients. Results are given as the mean (SD) or the mean (95% CI). Effect size between groups was measured with the Cohen *d* test. Statistical analysis was carried out using GraphPad Prism, version 7.0 (GraphPad Software Inc).

Results

Patients

A total of 28 patients meeting the inclusion criteria with adequate follow-up and sufficient data were included in this study. Of these, 19 (68%) were women; mean (SD) age was 51.7 (17) years. Demographic information for each group is presented in **Table 1**. Patients treated with T3 were a mean of 16.3 years older (95% CI, 4.2-28.3 years) than those undergoing gracilis free muscle reconstruction, but there were no other significant differences between the 2 groups. Fascia lata extension was used in 7 of 14 patients who received a T3. Gracilis free muscle innervation consisted of cross-facial nerve graft in 6 patients, masseteric nerve in 5 patients, and dual innervation in 3 patients. Representative patient photographs taken during smile before and after reanimation surgery are shown in **Figure 2**.

Oral Commissure Symmetry

Changes in symmetry of the commissure in the vertical and horizontal dimension as well as the angle of the oral commissure are presented in **Table 2**. Vertical asymmetry in repose improved more in the gracilis free muscle transfer group (2.7 mm; 95% CI, 0.5-4.8 mm) compared with the T3 group (0.4 mm; 95% CI, −2.4 to 3.2 mm), with both groups showing similar reductions in vertical asymmetry during smile (gracilis free muscle transfer: 7.5 mm; 95% CI, 4.4-10.6 mm; T3: 8.3 mm 95% CI, 4.6-12.0 mm). Horizontal asymmetry in repose did not improve significantly with either surgical treatment, but the gracilis free muscle transfer group demonstrated a larger improvement in horizontal symmetry during smile (gracilis free muscle transfer: 6.9 mm; 95% CI, 2.6-11.2 mm; T3: 2.3 mm; 95% CI, −1.9 to 6.4 mm). The T3 group had more improvement in angle sym-

Table 1. Demographic Details of 28 Patients Undergoing Dynamic Facial Reanimation[a]

Characteristic	No. (%) T3 (n = 14)	No. (%) Gracilis Free Muscle Transfer (n = 14)
Age, mean (SD), y	59.8 (17)	43.5 (13)
Duration of paralysis, mean (SD), y	7.3 (8.1)	7.0 (7.7)
Sex		
Male	3 (21)	6 (43)
Female	11 (79)	8 (57)
Side		
Left	7 (50)	9 (64)
Right	7 (50)	5 (36)
Cause	0	1 (7)
Congenital	0	1 (7)
Bell palsy	2 (14)	3 (21)
CPA tumor	4 (29)	3 (21)
Parotid tumor	5 (36)	2 (14)
Brain tumor	1 (7)	3 (21)
Idiopathic	2 (14)	2 (14)
Complications	6 (43)	5 (36)
Revision surgery	4 (29)	4 (29)

Abbreviations: CPA, cerebellopontine angle; T3, temporalis tendon transfer.

[a] Percentage sums for groups may not equal 100% owing to rounding.

Figure 2. Representative Patient Photographs During Smile Before (Left) and After (Right) Reanimation Surgery

metry in both repose (5.3 mm; 95% CI, 0.2-10.4 mm) and during smile (12.0 mm; 95% CI, 6.0-18.0 mm) compared with the gracilis free muscle transfer group (repose: 4.8 mm; 95% CI, −1.6 to 11.3 mm; during smile: 6.1 mm; 95% CI, −0.5 to 12.7 mm).

Smile Excursion

Prior to surgery, the maximum excursion of the paralyzed and healthy side during smile was significantly different for both groups (**Figure 3**). In the T3 group, the mean difference was 9.3 mm (95% CI, 4.6 to 13.9 mm; Cohen *d*, 1.7) and the mean difference in the gracilis free muscle transfer group was 15.0 mm (95% CI, 15.8 to 19.3 mm; Cohen *d*, 3.0). After surgery, the smile excursion in the T3 group improved by 4.8 mm (95% CI, 0.2 to 9.3 mm) and the gracilis free muscle transfer group improved by 11.3 mm (95% CI, 7.0 to 15.5 mm). The gracilis free muscle transfer group demonstrated greater improvement in commissure excursion than the T3 group by a mean of 6.5 mm (95% CI, 0.7 to 12.4 mm; Cohen *d*, 0.86). Postoperatively, there was a difference in commissure excursion between the healthy and paralyzed sides of 4.0 mm (95% CI, 0.5 to 7.4 mm) in the T3 group but a nonsignificant difference of 1.0 mm (95% CI, −2.1 to 4.0 mm) in the gracilis free muscle transfer group.

Complications and Revision Surgery

No differences were found in commissure position or excursion based on operative surgeon, gracilis neural source, T3 with fascia lata extension, and age older than 50 years. In addition, complication rates were not significantly different between groups. Five patients in the T3 group experienced wound infections that were all managed with local wound care and antibiotics. One patient had no movement after T3 owing to postoperative tendon dehiscence; this complication was managed with revision surgery to reattach the tendon. Postoperative infection occurred in 2 patients treated with a gracilis free muscle transfer: 1 in the facial site and 1 in the donor site. Keloid scar formation that required scar revision occurred for 2 patients. Revision procedures were performed in 4 of the T3 patients (29%) and consisted of either lengthening or shortening the tendinous connection. Revision procedures were performed in 4 gracilis free muscle transfer patients (29%), which all involved some form of debulking, release, and repositioning of the muscle implant to optimize symmetry and vector of motion.

Discussion

Optimizing outcomes in dynamic lower facial reanimation remains a challenge for the reconstructive surgeon. No single reanimation option is capable of duplicating the nuanced movements of the mimetic facial musculature that are critical for optimal function and appearance. Currently available surgical techniques aim to restore not only resting symmetry of the mouth but also a volitional smile. For longstanding facial paralysis, the T3 and the gracilis free muscle transfer are the 2 most popular surgical techniques.

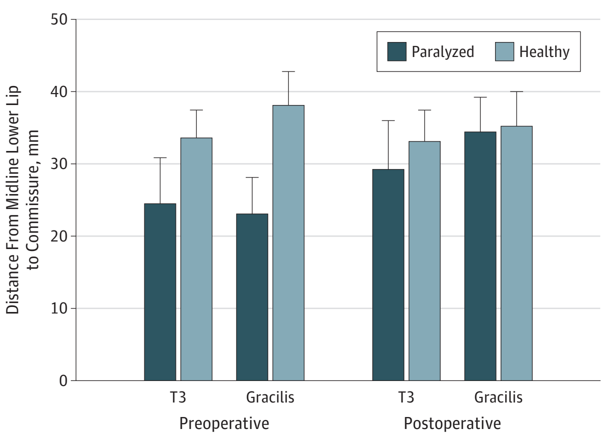
Many surgeons have a preferred reanimation technique, and much of the available literature consists of single-center case series of 1 surgical technique. A systematic review from 2016 comparing outcomes of gracilis free muscle transfer and lengthening temporalis myoplasty[11] found no randomized or controlled clinical trials related to these techniques. The authors reviewed 16 studies evaluating 867 patients treated with gracilis free muscle transfer and 53 patients treated with temporalis myoplasty, with significant heterogeneity in study populations and outcome measurements used. Studies of gracilis free muscle transfer demonstrated better excursion compared with

Table 2. Preoperative and Postoperative Changes in Commissure Symmetry With T3 Transfer or Gracilis Free Muscle Transfer

	T3			Gracilis Free Muscle Transfer			
Outcome	Preoperative	Postoperative	Improvement (95% CI)	Preoperative	Postoperative	Improvement (95% CI)	Improvement Difference Between Groups
Vertical asymmetry, mm (SD)							
Repose	3.8 (3.3)	3.4 (2.9)	0.4 (−2.4 to 3.2)	4.9 (3.0)	2.3 (1.7)	2.7 (0.5 to 4.8)	2.3 (0.5)
Smile	12.5 (4.8)	4.2 (3.2)	8.3 (4.6 to 12.0)	12.1 (5.2)	4.6 (2.9)	7.5 (4.4 to 10.6)	0.8 (0.1)
Horizontal asymmetry, mm (SD)							
Repose	3.1 (3.1)	4.2 (3.1)	−0.9 (−3.1 to 2.7)	5.8 (5.1)	5.2 (3.9)	0.5 (−3.7 to 4.7)	0.7 (0.1)
Smile	7.2 (6.5)	4.8 (3.9)	2.3 (−1.9 to 6.4)	11.3 (6.3)	4.4 (3.9)	6.9 (2.6 to 11.2)	4.6 (0.6)
Angle asymmetry, degrees (SD)							
Repose	11.3 (8.0)	6.0 (6.4)	5.3 (0.2 to 10.4)	10.3 (11.1)	5.4 (3.6)	4.8 (−1.6 to 11.3)	0.5 (0.04)
Smile	18.3 (9.9)	6.3 (5.6)	11.9 (6.0 to 18.0)	13.6 (10.5)	7.5 (3.4)	6.1 (−0.5 to 12.7)	5.9 (0.5)

Abbreviation: T3, temporalis tendon transfer.

Figure 3. Mean Commissure Excursion in T3 and Gracilis Free Muscle Transfer Patients After Reanimation Compared With Contralateral Healthy Side



Error bars indicate 95% CI; T3, temporalis tendon transfer.

temporalis myoplasty studies, but the authors cited a relative lack of objective measurements in the temporalis group. Direct comparison of outcomes of 10 T3 and 7 free neuromuscular transfers (gracilis, latissimus, and pectoralis minor) was performed by Erni and colleagues[12] in 1999. The authors used surface measurements to record movements of several facial landmarks. Their results suggest no difference in resting symmetry between the 2 techniques, but more excursion was seen in patients treated with free neuromuscular transfers (5.5 mm) compared with the T3 group (1.7 mm). Excursion for both techniques was less than the healthy side. Observers rated the facial appearance as superior in the T3 group compared with the free neuromuscular transfer group. Gousheh and Arasteh[13] reviewed a large case series of 505 two-stage gracilis free muscle transfers to 73 temporalis muscle transfers and 4 lengthening temporalis myoplasties. Subjective smile outcome in the gracilis free muscle group was rated as excellent (14%), good (76%), satisfactory (8%), and bad (2%). Worse outcomes were seen in the temporalis muscle transfers, with no smiles rated as excellent, 30% good, 59% satisfactory, and 11% bad. All 4 lengthening temporalis myoplasty results were deemed satisfactory. None of these studies evaluated the minimally invasive T3 procedure used in this report.

The present study evaluated both surgical techniques by 2 senior surgeons who are experienced in each procedure. An improvement in resting symmetry and commissure excursion was seen with both surgical techniques. Asymmetry of the oral commissure can have vertical, horizontal, and angular components. This asymmetry is often present at rest and amplified during smile because of limited movement of the paralyzed side. Static suspension of the lower face can restore symmetry at rest but does not improve symmetry during smile. An ideal facial reanimation would restore symmetry in all dimensions during both rest and smile. Vertical symmetry improved significantly for the gracilis free muscle transfer group during repose and for both groups during smile. Measured differences between paralyzed and healthy commissures of individual patients averaged 2.3 to 3.3 mm during repose and 4.1 to 4.5 mm with smile. Previous work has identified that a vertical commissure difference of 3 mm or less is not consciously detected by layperson observers.[14] Horizontal asymmetry improved most during smile in the gracilis free muscle transfer group, while angular asymmetry improved during repose and smile in the T3 group. This variance may be partially explained by the difference in vectors of the 2 techniques. Gracilis free muscle transfer tends to be inset with a slightly more horizontal vector than the T3, and the patients treated with gracilis free muscle transfer had more horizontal asymmetry during smile than their T3 counterparts, which might have influenced the vector of inset in this group. The temporalis tendon has a relatively fixed superior attachment point and vector, creating a stronger vertical pull and better improvement in angular asymmetry.

In addition to commissure symmetry, an important aspect of dynamic facial reanimation is commissure excursion. Our results indicate improved commissure excursion with both surgical techniques, but greater improvement in excursion was seen in the gracilis free muscle transfer group compared with the T3 group. Excursion in this report was calculated based on the straight-line distance from a reference point at the midline lower lip to the oral commissure. The position of this point during smile before surgery was subtracted from the position of the same point after reanimation to determine the improvement in excursion attributable to surgery. Our cohort included patients with partial and complete facial paralysis (House-Brackmann range, III-VI) who were specifically seeking lower facial reanimation to improve their smile excursion. Some patients maintained slight muscle activity present around the commissure prior to surgery, so this method of calculating excursion was used to control for any preexisting excursion and accurately measure the additional excursion produced by reanimation surgery. The measurements in the present study are compatible with previously reported excursions for the T3[7] and gracilis free muscle transfer procedures.[15,16] Among gracilis free muscle transfer patients after reanimation, the mean commissure position during smile differed by only 1 mm between the paralyzed and healthy side, which was statistically indistinguishable. After reanimation, the T3 patients retained a statistically significant difference between the paralyzed and healthy sides of 4 mm. Previous studies have demonstrated better excursion for gracilis free muscle transfer innervated by the masseteric nerve compared with cross-facial nerve graft.[16-19] Our results did not demonstrate this finding, but our sample size was too small to confidently determine a difference between these subgroups.

This study provides some preliminary quantitative data to help guide the reanimation surgeon in selecting the best technique for individual patients with facial paralysis. Both techniques demonstrate good improvement in vertical asymmetry. For patients with larger horizontal commissure asymmetry, gracilis free muscle transfer improves this disparity to a greater degree, while patients with more angular asymmetry may see improved benefit from a T3 procedure. Quantitative commissure excursion favors gracilis free muscle transfer over T3 if this factor is of primary importance. Although there is no significant difference in terms of complication or revision surgery rates between the 2 procedures, there is a shorter operative and recovery time as well as faster time to first facial movement for the T3 procedure. Conversely, only the gracilis free muscle transfer innervated with a cross-facial nerve graft is able to produce a truly spontaneous smile. Further investigation is needed with additional larger studies to build on these results. Future studies should also compare disease-specific quality-of-life improvements with both techniques as well as patient and observer ratings of smile appearance in dynamic, 3-dimensional settings.

Limitations

There are several limitations to consider in this study. Similar to most other facial reanimation reports, this study was uncontrolled and retrospective. Randomization of patients to each surgical arm would provide more powerful comparisons between surgical groups, and a larger sample size would add strength to the conclusions and allow the ability to differentiate among subgroups. The increased age of the patients undergoing T3 is likely related to both the patient's and surgeon's willingness to pursue the more invasive gracilis free muscle transfer procedure in advanced age; in fact, some surgeons will not offer gracilis free muscle transfer to patients of advanced age. The oldest patient treated with gracilis free muscle transfer in our study was 65 years compared with a 90-year-old patient who received a T3 procedure. This age difference may compound the results as older patients have more existing facial ptosis and less robust muscular contraction, which might limit the ultimate facial symmetry or smile excursion achieved. In addition, this study evaluated only quantitative measurements captured from 2-dimensional patient images. Although quantitative excursion is an important factor in facial reanimation, ideal evaluation of facial function would include live, 3-dimensional analysis along with patient quality-of-life factors and blinded observer assessments of overall smile restoration.

Conclusions

Both T3 and gracilis free muscle transfer reanimation techniques improve symmetry of the mouth at rest and during smile without significant differences between the techniques. Improvement in commissure excursion is greater for gracilis free muscle transfer reanimation than T3, with average smiles in gracilis free muscle transfer patients showing no difference between the healthy and reanimated side. These quantitative factors should be considered along with patient age, comorbidity, quality of life, operative risks, and length of recovery when selecting the best reanimation technique for individual patients.

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Concept and design: Oyer, Nellis, Ishii, Byrne.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Oyer, Nellis.
Critical revision of the manuscript for important intellectual content: Nellis, Ishii, Boahene, Byrne.
Statistical analysis: Oyer.
Administrative, technical, or material support: Nellis, Ishii.
Supervision: Ishii, Byrne.

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