Surgical Refinement Following Free Gracilis Transfer for Smile Reanimation

Jacqueline J. Greene, MD, Joana Tavares, MD, Diego L. Guarin, PhD, Nate Jowett, MD, and Tessa Hadlock, MD

Importance: Gracilis free muscle transfer is widely regarded as the gold standard functional smile reanimation in long-standing facial palsy. Although most patients achieve meaningful oral commissure movement, a subset has suboptimal aesthetic outcomes due to midfacial bulk or oral commissure malposition. Safe refinements that do not compromise excursion would be a welcome addition to the surgical armamentarium for this population.

Objectives: The goal of this study was to describe surgical approaches to the 3 most common postoperative sequelae that detract from the final result after gracilis facial reanimation and to examine how these surgical refinements affect aesthetic outcome, smile excursion, and quality of life.

Design: This was a retrospective case series.

Setting: Tertiary care center (Massachusetts Eye and Ear Infirmary Facial Nerve Center).

Participants: Of 260 gracilis transfers performed since 2003, meaningful excursion (>3 mm) but poor aesthetic outcome requiring additional surgery was noted in 21 patients and was related either to excess muscle bulk (9), resting inferior malposition of the oral commissure (9), or resting superior/lateral malposition of the oral commissure (3).

Intervention: Specific surgical interventions to address each of these negative sequelae were developed and refined, to preserve muscle functionality but eliminate the unsightly feature.

Main Outcome: Aesthetic status, determined by midfacial symmetry; quantitative smile excursion; and quality of life (using the FaCE instrument) were measured before and after revision.

Results: Patients who underwent gracilis refinement directed at either muscle debulking, or gracilis tightening or loosening experienced significantly improved aesthetics/midfacial symmetry and improved quality of life with no significant decrease in smile excursion.

Conclusions: Improved aesthetics and quality of life can be achieved through targeted revision of the gracilis free tissue transfer, without significant loss of smile excursion.

Key Words: bulk, commissure malposition, facial paralysis, facial reanimation, gracilis, gracilis free muscle transfer, revision

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Gracilis free muscle transfer (GFMT) is widely regarded as the gold standard smile reanimation procedure for long-standing or irreversible facial paralysis.[1,2] A reliable procedure with low failure rates, the GFMT will produce a meaningful smile (at least 3 mm of excursion with smile) in 84% of recipients when driven by cranial nerve (CN) VII via a cross-face nerve graft and 94% of recipients when driven by CN V.[1] In our experience of more than 260 GFMTs, a subset of patients has excellent oral commissure excursion but suboptimal aesthetic outcomes (SAOs). Before extensive inset details were well described, surgeons would experience dehiscence of the muscle from the lateral aspect of the orbicularis oris. Adhering to appropriate medial inset surgical techniques has largely mitigated this problem (see detailed inset description[3]). However, unpredictability in the operation remains, and contemporary factors contributing to SAO include excessive midfacial bulk and oral commissure malposition, either inferiorly or superolaterally.

Most facial reanimation literature has focused on the source of neural innervation or surgical inset details. The few studies that discussed revision and refinement procedures after GFMT provided only qualitative assessments of outcomes, and none included rigorous quantitative assessments with quality-of-life (QOL) measures.[4,5] The goals of this study were to describe our codified refinement techniques and examine whether surgical revisions of GFMTs for SAO negatively affected dynamic or QOL outcome. Patients were assigned to cohorts based on the type of GFMT revision: debulking, tightening (correction of an inferiorly malpositioned oral commissure), or loosening (correction of a superiorly malpositioned oral commissure). We hypothesized that debulking would improve facial symmetry without reduction in smile excursion or QOL and that repositioning th e oral commissure would likewise accomplish similar goals.

MATERIALS AND METHODS

Institutional review board approval was obtained from the Massachusetts Eye and Ear Infirmary (MEEI) Human Studies Committee. A retrospective chart review was conducted for all patients who underwent revision for SAO following GFMT at the MEEI Facial Nerve Center from June 2003 to October 2017. Patients with missing data, those with bilateral facial reanimation for conditions such as Moebius syndrome, or those who had not completed a sufficient recovery period were excluded.

Data Collection

Demographic data including age, sex, and etiology of facial paralysis were recorded. Preoperative and postoperative photography and videography were used to measure baseline post-GFMT smile excursion using GIMP (v2.8.22; Spencer Kimball, Peter Mattis, GIMP Development Team), a free online photography measurement software, and Emotrics (v2.0; MEEI, Boston, Mass).[6] The FaCE instrument[7] was used to assess QOL for patients preoperatively, post–gracilis surgery, and post–revision surgery. All GFMT operations were performed as previously described.[8] Intraoperative details, including gracilis weight at the time of inset and neural innervation source, were recorded. The time between GFMT and subsequent revision was recorded.

Surgical Revision Following GFMT for SAO

The decision to proceed with revision to the GFMT for SAO should occur at minimum 12 months postoperatively to permit sufficient muscle innervation, atrophy, or foreshortening. In cases of excessive midfacial bulk, the precise areas of midfacial bulging should be marked preoperatively at rest and while smiling. Debulking and repositioning the gracilis are accomplished through the preexisting preauricular incision as used for GFMT inset. A superficial flap is elevated directly over the superficial surface of the gracilis muscle, or

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From the Division of Facial Plastic and Reconstructive Surgery, Department of Otolaryngology, Harvard Medical School, Massachusetts Eye and Ear Infirmary, Boston, MA.
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Reprints: Jacqueline J. Greene, MD, Harvard Medical School, Massachusetts Eye and Ear Infirmary, 243 Charles St, 9th Floor Facial Nerve Center, Boston, MA 02114. E-mail: jacqueline_greene@meei.harvard.edu.

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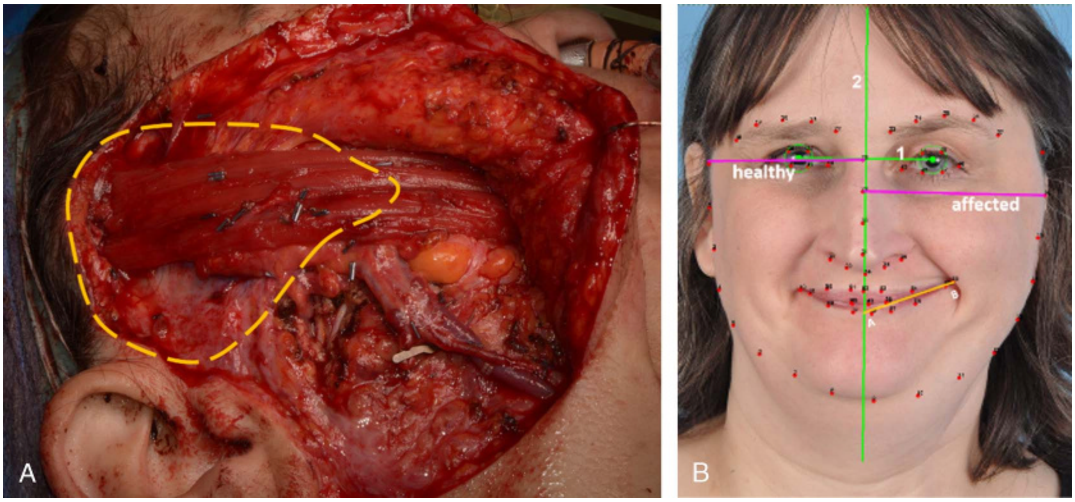

FIGURE 1. A, Intraoperative gracilis revision: the yellow dotted line delineates the deep area of dissection when debulking, taking care to avoid the neurovascular pedicle. Note that this photograph was taken at the time of original GFMT inset, not at the time of revision. B, Facial analysis: 1. horizontal interpupillary line, 2. central axis = vertical line bisecting and perpendicular to horizontal interpupillary line. A, Intersection of central axis with vermillion border of lower lip, (B) oral commissure. Hemiface width ratio $= \frac{\text{affected (mm)}}{\text{healthy (mm)}}$, smile excursion (mm) = difference in commissure position relative to central axis intersection with vermillion border (line AB) with smile and at rest (mm).

fascia lata, if present, using particular caution over the region of the neurovascular pedicle.

Debulking

Debulking a GFMT is accomplished by removing approximately 30% of the thickness of the superficial surface of the gracilis in the zone overlying the zygoma, adjacent to the temporal area. The overlying skin flap is simultaneously extensively defatted in the area corresponding to bulk, and in cases where there is both an area of bulk and an area of volume deficit, the fat can be repositioned to correct the volume deficit (Fig. 1A).

Repositioning

Correcting an inferiorly malpositioned oral commissure is achieved by plication of the superolateral portion of the muscle overlying the true temporalis fascia. After the skin flap is raised off the entire superficial surface of the muscle, the muscle is detached off the true temporalis fascia, and a plane deep to the muscle is also developed, moving superiorly to inferiorly, for approximately 5 cm. Care is taken to halt dissection before the hilum and neurovascular pedicle are encountered. Correcting a superolaterally malpositioned oral commissure is the most difficult of the refinements for SAO and is achieved by aggressive mobilization and repositioning of the flap inferomedially, with detachment and more caudal reattachment of the lateral portion of the flap to the true temporalis fascia. This maneuver requires 360-degree mobilization of the lateral and medial aspects of the flap, with meticulous care to avoid injury to the neurovascular bundle and cross-face nerve graft where present in the flap's central portion. Dissection to stretch the medial muscle attachment to the modiolus is occasionally necessary. The use of a lighted retractor and nerve stimulator greatly facilitates dissection and pedicle protection.

Smile Excursion

Smile excursions were calculated from 2-dimensional photographs by scaling the pixel width to the iris diameter, estimated at 11.8 mm.[1,9] Recent advances in machine learning have been applied

TABLE 1. Demographics and Operative Characteristics of Patients Undergoing Gracilis Revision

Characteristic	Debulking Cohort	Tightening Cohort
Total n	9	9
Sex, n (%)		
°Male	4 (44)	4 (44)
°Female	5 (56)	5 (56)
Age mean (SD) (range), y	24 (12.6) (9–42)	40 (17) (7–67)
Gracilis recipient side right, (%)	5 (56)	6 (67)
Gracilis recipient side left, (%)	4 (44)	3 (33)
Motor nerve, n (%)		
°Ipsilateral V	2	2
°Contralateral VII	6	7
°Ipsilateral V + contralateral VII	1	0
Mean weight (g) of gracilis initial inset (SD) (range), g	30 (12.8) (11.3–46)	33.8 (11.4) (12.6–51)
Mean time between gracilis surgery and revision (SD) (range), y	2.7 (1.6) (1.2–6.6)	2.9 (1.0) (0.7–3.5)

to develop a computer application, termed Emotrics,[6] which enables rapid, automatic facial landmark localization and computation of facial measurements from standard clinical photographs. Emotrics was used to automatically trace the contour of the face, interpupillary distance, and central vertical axis of the face (Fig. 1B). In brief, a horizontal interpupillary line was automatically plotted through the center of the pupils (Fig. 1B, line 1). This line was bisected by a perpendicular vertical line used to estimate the central axis of the face (Fig. 1B, line 2). It is possible for the central axis of the face to deviate from the position of the nasal tip and lower lip soft tissues because of facial paralysis or underlying asymmetry. Head yaw, pitch, and roll were kept neutral for photographs. Smile excursion was defined as the difference in commissure position relative to the central axis intersection with vermillion border (line AB) with full-effort smile versus at rest (in millimeters) for each side of the face.[1,9]

Linear Hemiface Width

An estimate of midfacial symmetry and bulk was determined by measuring the distance from the central vertical axis to the most lateral point along the midface contour, as marked by Emotrics (Fig. 1B) on each side of the face.[6] The ratio of hemifacial widths was then calculated between affected and healthy sides, with ratios greater than 1 indicating asymmetric facial bulk on the affected side. A linear hemiface width ratio of 1 would indicate perfect midfacial symmetry.

Quality of Life

Quality-of-life data were acquired by routine administration of the FaCE instrument at the patient's initial clinic visit, following the GFMT, and following revision surgery. An effort was made to contact all patients by telephone and e-mail when this study was conducted, if they did not have routinely scheduled follow-up, and an electronic version of the survey was additionally offered.

Statistical Analysis

Smile excursion, hemifacial widths, and QOL data were compared before and after surgical refinement for SAO using pairwise t tests when there was an adequate sample size. All statistical analysis was performed using the R Statistical Package version 3.2.3. Statistical significance was defined as $P < 0.05$.

RESULTS

Patient Demographics

Of the 260 GFMTs performed at the MEEI Facial Nerve Center since 2003, 21 GFMT patients suffered from SAO deemed significant enough to require surgical revision and had complete preoperative and postoperative photography or videography. Nine patients underwent debulking, 9 underwent tightening (repositioning of an inferiorly

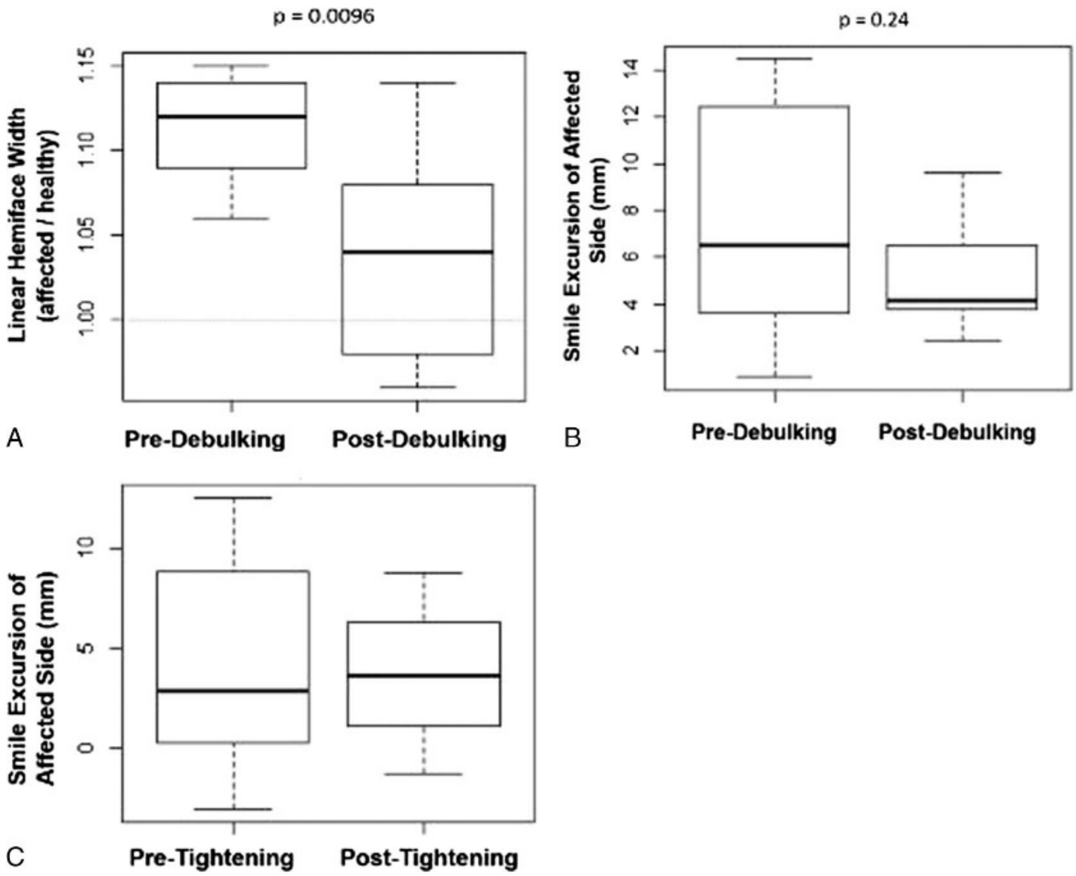

FIGURE 2. Quantitative facial analysis: (A) linear hemiface width ratio and (B) smile excursion of patients who underwent post–gracilis debulking, shown in box-and-whisker plots. The HWR was taken as the ratio of the midfacial width of the affected (gracilis recipient side) divided by the healthy side (refer to Fig. 1). The dotted line indicates perfect symmetry at 1. The HWR decreased significantly following debulking ($P = 0.0096$). No statistically significant change in smile excursion occurred following debulking. C, Smile excursion before and after tightening of the gracilis. No significant change or loss of smile excursion occurred following revision.

malpositioned oral commissure), and 3 patients underwent loosening (repositioning of a superiorly malpositioned oral commissure). Because of the small number of patients who underwent loosening, this cohort was not able to be formally analyzed for smile excursion.

The gender split of the debulking and tightening cohorts were even: 4 were male and 5 were female. The average age at debulking was 24 years (range, 9–42 years), whereas the average age at tightening was 40 years (range, 7–67 years). Within both groups, more patients underwent a 2-stage GFMT by CN VII. Within the debulking cohort, 2 patients had also undergone a separate stage fascia lata external nasal valve correction as previously described.[10] The mean interval between GFMT and debulking surgery was 2.7 years and between GFMT and revision tightening was 2.9 years.

The etiology of facial paralysis for the debulking and tightening patients varied. The most common cause of facial paralysis was an intracranial neoplasm (22%), followed closely by infectious (17%), vestibular schwannoma (11%), congenital (11%), and iatrogenic injury (11%). Other less common causes included temporal bone fracture and idiopathic causes (Table 1).

Quality-of-Life Assessment

Preoperative FaCE scores were variable, representing the range of facial palsy presenting to the Facial Nerve Center (10–70, n = 13). Following GFMT, the FaCE score improved an average of 15 ± 14 points (range, 3–47; n = 8). Following revision for SAO (either debulking or repositioning of the oral commissure), the FaCE score improved on average by an additional 10 ± 14 points (n = 5). Given the limited conclusions permissible from a small paired data set (n = 5), statistical analysis was not included.

Debulking Results

Linear Hemiface Width Ratio

The average hemiface width ratio (HWR), which we used as a proxy for midfacial asymmetry, decreased significantly from 1.12 ± 0.03 to 1.04 ± 0.07 following debulking ($P = 0.009$) (Fig. 2A).

Smile Excursion Following Debulking

One patient was excluded from smile excursion analysis because of a concurrent commissureplasty from a previous scar. Of the remaining 8 patients, the average smile excursion before and after debulking decreased but did not change significantly (7.5 ± 5.2 mm, 5.1 ± 2.3 mm, respectively; $P = 0.24$) (Fig. 2B). Three patients did have a slight decreased smile excursion following debulking but improved symmetry and overall aesthetic outcome. A selected patient's photographs are shown in Figure 3. No patient lost function of their GFMT following debulking.

Gracilis Repositioning

Of the tightening cohort, selected patients' initial, post-GFMT, and posttightening photographs are shown (Fig. 4). Smile excursion did not change significantly following tightening of the GFMT (Fig. 2C). Photographs of a patient who underwent loosening of their GFMT to correct a superiorly malpositioned oral commissure are shown in Figure 4.

DISCUSSION

Over the years, the facial reanimation community has achieved greater consistency of smile results following GFMT. The number of revisions appears to be decreasing from previous reports.[5] However, GFMT may result in good dynamic function but SAO due to midfacial bulk or oral commissure malposition. Surgical revision can risk injury to the functional muscle or its neurovascular pedicle with potential compromise of smile excursion. We have found that refinements can vastly improve overall aesthetic outcomes and are feasible and safe if performed by an experienced surgeon.

Most facial reanimation literature has focused on the method or source of neural innervation or surgical inset details; however, few studies address revision of suboptimal outcomes. Takushima et al[4] described 183 patients who underwent revision to either gracilis or latissimus dorsi free tissue transfers for facial reanimation; however, only a subjective grading scale was used for analysis. Terzis and Noah[5] reported on a cohort of 100 facial reanimation procedures, 63 of which were GFMTs; 26% of the patients required subsequent debulking; however, no quantitative analysis of the revision outcomes was discussed. A recent study by Braig et al[11] reported revision outcomes for 4 patients and found reduction of oral commissure movement after debulking of the gracilis debulking but improved symmetry and aesthetic outcome.

The midfacial bulk from GFMT can be disfiguring and cause patients to avoid using their gracilis at its full capacity. We found midfacial symmetry increased significantly following debulking with a decrease in smile excursion that was not significant, and no patient lost function of their GFMT.

Of the patients who underwent tightening to correct an inferiorly malpositioned GFMT, no significant change to smile excursion occurred.

FIGURE 3. Photographs of a patient with facial paralysis on initial presentation (left), following gracilis free tissue transfer with demonstrated midface bulk (middle) and subsequently underwent a revision debulking procedure (right).

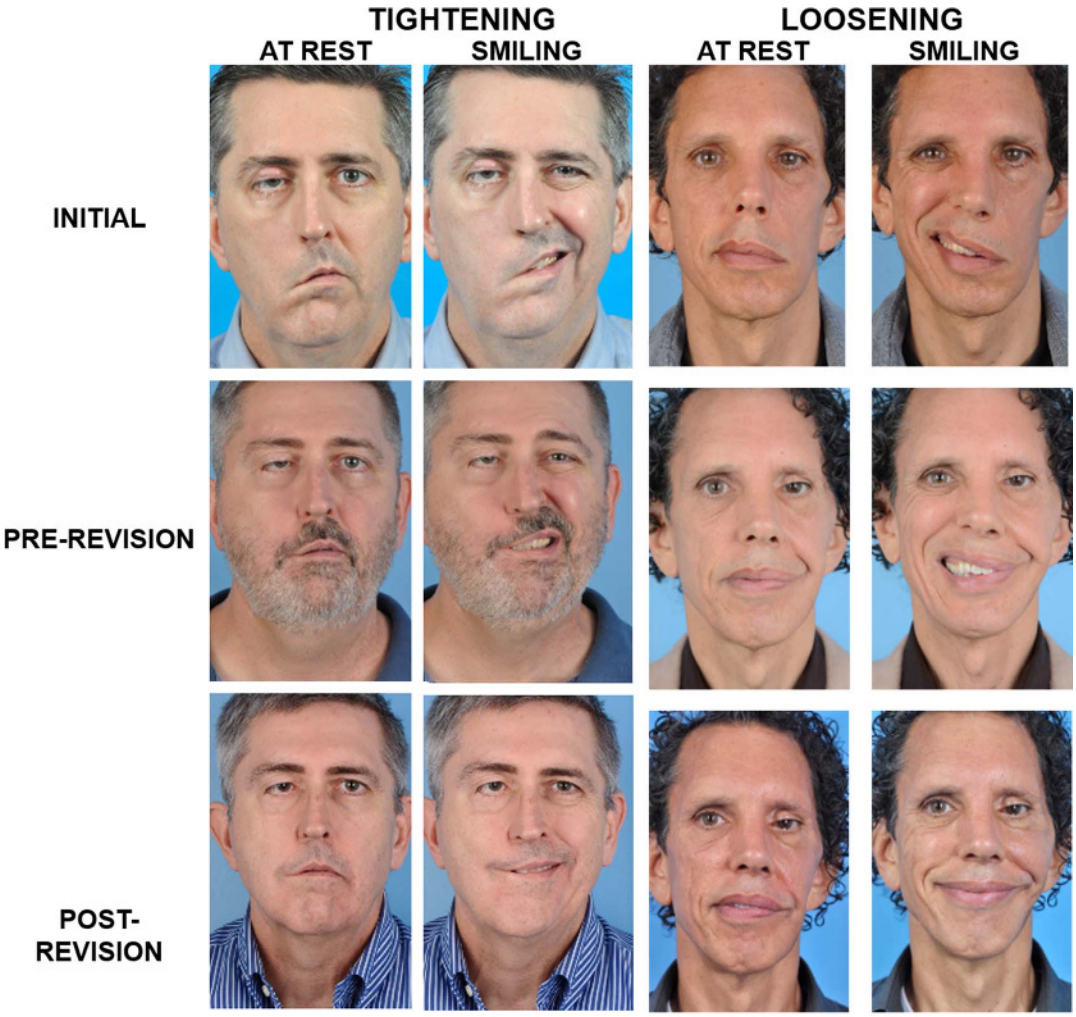

FIGURE 4. Photographs of (left patient) tightening and (right patient) loosening GFMT revisions. Left set, Rest and smiling photographs of a patient who underwent tightening to correct an inferiorly malpositioned and ptotic oral commissure after GFMT. Right set, Rest and smiling photographs of a patient who underwent loosening repositioning to correct a superiorly malpositioned oral commissure following GFMT.

The group who underwent repositioning to correct a superiorly malpositioned oral commissure was too small to analyze (n = 3); however, the overall aesthetic improvement is demonstrated in Figure 4.

Our quantitative facial analysis has limitations. We assume a uniform patient iris diameter of 11.8 mm. We found that the disfiguring midfacial bulk was present variably in relation to smiling, and so the videos were analyzed carefully to ensure the maximum example of the bulk was used for measurements. The HWR, which served as a proxy for facial asymmetry, can be affected by head position, which patients with facial paralysis may often alter unconsciously to minimize their disfigurement. To ensure proper positioning, all photography and videography are performed in a dedicated media room with patients seated with a head-rest to reduce movement. Facial paralysis can cause skewing of the nasal tip or lips with smile, so smile excursion is consistently measured relative to the intersection of the central axis of the face with the vermillion border (Fig. 1), not to the philtrum or nasal tip. Smile excursion is effort related, and patients may unconsciously minimize any perceived disfigurement by modulating their smile; therefore, patients are asked to give a gentle smile, followed by a maximum effort smile. In order to reduce subjective bias in measurements, the automated facial analysis software Emotrics[6] was used to mark the facial contour, interpupillary distance, and central axis of the face. An automated facial analysis of high-quality videography is being developed at the MEEI to address some of these issues.

Patient-reported outcomes of QOL using the FaCE instrument demonstrated on average a 15-point improvement in the FaCE score following GFMT and a 10-point further improvement following revision. Statistical analysis was limited by the number of patients completing the FaCE survey after multiple interventions; however, an overall important improvement in FaCE scores was noted following revision (either debulking or repositioning of the oral commissure).

CONCLUSIONS

Smile reanimation through GFMT can sometimes result in functional smile excursion but SAOs due to midfacial bulk or oral commissure malposition. Specific revisions to address common postoperative sequelae appear to significantly improve aesthetic outcomes and QOL and also appear to be safe (not result in smile loss) when performed by an experienced surgeon. Those who perform smile reanimation using GFMT should be aware that additional valuable gains may be achieved through methodical surgical refinements if bulk or oral commissure malposition develops despite appropriate commissure excursion.

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