INTRODUCTION

Facial paralysis may arise from congenital syndromes, acquired conditions, trauma, or malignancy, and poses significant functional and psychosocial burdens on patients regardless of etiology. Functional impairments include difficulty with forming facial expressions, speaking, eating, and drinking. Facial disfigurement leads to increased psychological distress, including anxiety and depression, with a direct correlation between patients’ perception of their deficit and degree of distress experienced.

Treatment strategy for facial paralysis often varies based on the chronicity of paralysis. Acute facial paralysis, lasting on the order of weeks, is typically treated with facial nerve decompression or facial nerve repair. Intermediate duration paralysis, lasting up to 2 years, is treated with nerve transfer procedures. Meanwhile, chronic facial paralysis, lasting longer than 2 years, typically requires regional or free muscle transfer. More recently, free functional muscle flap (FFMF) transfer has become the standard of care for chronic facial paralysis, with the gracilis being most commonly used. The use of other muscles, including serratus anterior and latissimus dorsi, has also been described.

Although there have been significant surgical advancements in facial reanimation surgery, there still remains a lack of standardization for outcome monitoring. This presents a significant barrier to accurate comparison of outcomes following reanimation procedures. Historically, subjective, observer-based scales have been used because they are efficient and easy to administer. These tools aim to assess facial nerve function by evaluating outcomes, including facial symmetry and movement. However, many of these subjective measures were not initially developed for use in evaluating postsurgical reanimation outcomes, and they lack quantitative and objective data. In the past, objective instruments were not widely implemented because they were time-intensive and required specialized skillsets.

METHODS: In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, we performed a systematic review of the PubMed, Cochrane, and Embase databases to identify the reported functional outcome measurement tools used in the free muscle flap-based reanimation literature.

Results: The search yielded 219 articles, 43 of which met our inclusion and exclusion criteria. We noted an increase in publications reporting the utilization of objective measures over time, particularly software-based tools, as well as increased utilization of patient reported outcomes measures.

Conclusions: Based on the trends identified in the literature, we suggest standardization of outcome measures following facial reanimation surgery with free muscle-flap using a combination of the Facial Assessment by Computer Evaluation (FACEgram) software and the Facial Clinimetric Evaluation (FaCE) Scale. (Plast Reconstr Surg Glob Open 2021;9:e3492; doi: 10.1097/GOX.0000000000003492; Published online 18 March 2021.)
METHODS

Search Strategy
This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Three electronic databases (PubMed, Embase, and Cochrane CENTRAL) were queried from inception through September 13, 2020 with the following search terms: “facial reanimation” or “facial paralysis surgery” or “reanimation surgery” or “Bell’s palsy” or “facial palsy” and “free muscle graft” or “free muscle transfer” or “free muscle flap” or “muscle transposition” or “muscle transfer” and “outcomes” or “objective measurements” or “functional outcomes” or “scoring system” or “scale” or “objective analysis” or “functional outcomes” or “subjective analysis” or “subjective outcomes.”

Selection Criteria
All resulting articles were compiled, and duplicate titles were removed. Two independent reviewers (JJP, RRC) screened the remaining titles and abstracts. Disagreements regarding article identification and final selection for inclusion were resolved by a third reviewer (DB). All studies reporting outcomes for FFMM reanimation procedures were included. Although regional flaps are also used for reanimation, we focused our study on FFMM, as it is the gold standard for chronic facial paralysis. Studies that described facial reanimation via regional muscle transfer or nerve transfer and studies that reported outcomes of revision surgeries following facial reanimation were excluded, as were case reports, non-English articles, cadaveric studies, technical papers, and systematic reviews. If relevance could not be determined from the abstract alone, full text was retrieved and reviewed.

Data Collection
Included articles were examined and the following data points were recorded: author, year of publication, and functional outcome measurement tool used. Additional operative information on specific muscle and nerve used and coaptation technique were collected when available. If studies appeared to contain some but not all of the same patients, they were listed together in the data table but counted as individual studies when tallying total studies. We classified a tool as subjective if the evaluation relied on observer interpretation or patient input, and thus may vary based on observer or patient. We classified a tool as objective if it utilized a quantifiable measure that could be readily replicated and was not susceptible to interpretation.

RESULTS

Description of Studies
Our initial database search yielded 219 articles based on our search parameters, and 43 were included in our study (Fig. 1). Thirteen studies reported only subjective functional outcome measures, 11 used only objective functional outcome measures, and 19 used a combination of objective and subjective outcome measures (Table 1). We identified an increase over time in utilization of objective outcome tools, including software-based tools. Additionally, while the use of subjective outcomes measures has declined overall in the last 10 years, the use of patient reported outcomes measures (PROMs) has become increasingly popular. Figure 2 summarizes the trends in utilization of subjective, objective, and combination tools from 1998 to 2010 versus 2011 to 2020.

Subjective Measures
Subjective functional outcome measures were most commonly reported. Thirty-two papers included a subjective measure, and it was the only outcome tool reported in 13 of those studies. Our findings also suggest a decrease in the prevalence of subjective tools used in recent years. Between 1998 and 2010, 41.2% (7/17) of studies utilized subjective measures as their sole form of functional outcome tracking, whereas only 23.1% (6/26) did so between 2011 and 2020. In total, all papers from 1998 to 2010 contained a form of subjective measurement, whereas only 57.7% (15/26) had the same from 2011 to 2020. Overall, 11 studies included PROMs, 63.6% (7/11) of which were published between 2011 and 2020. The most frequently employed measure was the Terzis grading scale (8 studies), followed by the Facial Clinimetric Evaluation (FaCE) and Harii grading scales (6 studies each) (Table 2).

Objective Measures
Overall, 30 papers included some form of objective functional outcome assessment, with 11 reporting it as their sole form of assessment. While we noted a decrease in the use of subjective measures, we found the use of objective tools has become more common, with 42.3% (11/26) of papers from 2011 to 2020 utilizing them as the sole instrument, up from 0% from 1998 to 2010. The number of publications reporting use of objective tools rose from 58.8% (10/17) from 1998 to 2010 to 76.9% (20/26) from 2011 to 2020. Facial Assessment by Computer Evaluation (FACE) software, also referred to as FACEgram, was the most common objective tool used (9 studies). Software-based tools accounted for 85% (17/20) of objective tools used from 2011 to 2020 (Table 3).
Combined Measures
The use of a subjective measure in combination with an objective measure was described in 19 papers. From 1998 to 2010, 58.8% (10/17) of articles used a combination of measures, whereas 34.6% (9/26) did so between 2011 and 2020. The most frequent combination was a software-based-tool used along with a PROM (Table 4).

**DISCUSSION**
Intact and functional facial musculature dictates our ability to perform essential communication and other vital tasks, such as verbalization, expression, and feeding. Loss of these functions, as seen in chronic facial paralysis, is associated with impaired function and poor quality of life (QoL).\(^6\) Surgical management of chronic facial paralysis, which aims to return function to the paralyzed musculature, has seen many advancements in recent years. However, outcome comparison between different procedures and techniques has been limited by the lack of a universally accepted functional outcome monitoring tool.\(^1\,^6\)

To move toward a widely accepted, standardized form of outcome tracking, the instrument of choice must be easy to use, objective, and reproducible with strong intrarater reliability. Moreover, such a tool could be beneficial in parallel fields, such as facial transplantation, which face similar challenges in evaluating patients’ subjective and objective recovery. In this study, we aimed to identify the historical trends in functional outcome tracking within the FFMF facial reanimation literature to establish a consensus for outcome tracking.

In our review, we found an increase in utilization of objective outcome tools, particularly software-based tools. While the overall use of subjective tools has declined in the last 10 years, the use of PROMs has become increasingly popular. Although we had initially believed PROMs, House-Brackmann, Terzis scale, and the Hari scale to all be examples of subjective tools, our findings suggest PROMs to be in a category of their own. More specifically, many of these other tools were initially designed to serve as objective tools but have since been found to be highly user-dependent. PROMs, on the other hand, are subjective in design and execution. Therefore, while the use of other tools has declined, the use of PROMs has increased along with other new, technologically advanced objective tools. Our investigation...
suggests that PROMs, in combination with an objective tool, offer surgeons a genuine pair of subjective and objective tools, which had previously been unavailable.

In analyzing these studies, there was no clear standardization in the timing of scale utilization postoperatively. The most frequently utilized measures have been FACEgram (a software-based objective tool) and FaCE scale (a PROM focusing on QoL). Although multiple outcome tracking tools were identified, we will focus our discussion on those most frequently used.

### OBJECTIVE TOOLS

**FACEgram**

The most frequently described functional outcome tool in this review, FACEgram, was developed at Massachusetts Eye and Ear Infirmary as a more comprehensive and accessible version of their SMILE software. FACEgram, unlike SMILE, does not require access to MATLAB. 9] FACEgram is a validated tool that uses a number of important facial landmarks to analyze key facial movements as identified by facial reanimation specialists. These include oral commissure movement and palpebral fissure narrowing during eyelid closure, among others. FACEgram also evaluates symmetry during these movements. 9] FACEgram utilizes standard photographs, distinguishing it from other objective tools that require a 3-dimensional camera or other advanced technology that may limit accessibility. 9] Furthermore, FACEgram allows remote analysis of photographs, which is beneficial for the many patients who would otherwise travel long distances for appointments. A limitation of FACEgram, however, is that it cannot discern whether patients are able to effectively express emotions, as it exclusively detects facial movement. Additionally, FACEgram does not address the psychosocial effects of facial reanimation surgery, limiting its ability to offer a comprehensive assessment of patients' functional outcome.

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**Table 1. Included Studies in Reverse Chronological Order**

| Author                  | Year     | Category of Tool | Tool                                                                 |
|-------------------------|----------|------------------|----------------------------------------------------------------------|
| Kim MJ, et al           | 2020     | Combined         | FACE software (FACEgram), 3D spatiotemporal analysis, Terzis grading scale |
| Roy M, et al            | 2019     | Objective        | FACE software (FACEgram)                                             |
| Mohanty AJ, et al       | 2019     | Objective        | FACE software (FACEgram)                                             |
| Sakuma H, et al         | 2019     | Subjective       | Terzis grading scale                                                 |
| Over SL, et al          | 2018     | Objective        | FACE software (FACEgram)                                             |
| van Veen MM, et al      | 2018     | Combined         | FACE software (FACEgram), FaCE QoL scale                            |
| Greene JJ, et al        | 2018     | Combined         | Emotics, FaCE QoL scale                                              |
| Amer TA, et al          | 2018     | Objective        | SMILE software                                                       |
| Faris C, et al          | 2018     | Combined         | FACE software (FACEgram), FaCE QoL scale, eFACE facial grading scale |
| Braig et al             | 2017     | Objective        | Oral commissure excursion measurement                               |
| Sforza C, et al         | 2015     | Objective        | 3D and 2D facial motion measurement                                  |
| Okazaki M, et al        | 2015     | Subjective       | Harii scale                                                          |
| Snyder-Warwick AK, et al| 2015     | Objective        | SMILE software                                                       |
| Cardenas-Mejia A, et al | 2015     | Combined         | Terzis grading scale, EMG                                            |
| Lindsay RW, et al       | 2014*, 2014| Combined         | FACE software (FACEgram), FaCE QoL scale, Facial Grading Scale       |
| Placheta et al          | 2014     | Objective        | Three-dimensional video analysis of facial movements and blink reflex |
| Hontanilla B, et al     | 2013     | Objective        | FACIAL CLIMA system                                                  |
| Takushima A, et al      | 2013     | Subjective       | Harii scale                                                          |
| Liu AT, et al           | 2012     | Subjective       | Toronto Facial Grading System, Facial Nerve Function Index           |
| Vakharia KT, et al      | 2012     | Combined         | SMILE software, FaCE QoL scale                                       |
| Harrison DH, et al      | 2012     | Subjective       | Clinical improvement scale, Hay score                                |
| Gousheh J, et al        | 2011     | Objective        | Oral commissure excursion measurement                               |
| Lin CH, et al           | 2011     | Subjective       | Terzis grading scale                                                 |
| Hadlock TA, et al       | 2011     | Combined         | FACE software (FACEgram), FaCE QoL scale                             |
| Krishnan KG, et al      | 2010     | Combined         | Commisural excursion indices, investigator determined smile reaction, patient self-evaluation of function |
| Terzis K, et al         | 2010     | Combined         | Terzis grading scale, EMG                                            |
| Terzis K, et al         | 2010     | Combined         | Terzis and Bruno methodology of interpalpebral distance ratios      |
| Takushima A, et al      | 2009     | Combined         | FEMAS-1 (Facial Expression and Motion Analysis System-1) software     |
| Terzis K, et al         | 2009, 2009| Combined         | Terzis grading scale, EMG                                            |
| Mankelow RT, et al      | 2006     | Combined         | FaceMS, patient survey on the functional effects on eating, drinking, and speech |
| Sajadian A, et al       | 2006     | Combined         | Facial Grading System, EMG                                           |
| Kuilhanen SC, et al     | 2006     | Subjective       | House-Brackmann grading scale                                       |
| Yla-Kotola TM, et al    | 2004, 2005, 2008 | Subjective | House-Brackmann grading scale                                       |
| Takushima A, et al      | 2002     | Subjective       | Harii scale                                                          |
| Schliephake H, et al    | 2000     | Combined         | Harii scale, SF-36 questionnaire, oral commissure excursion measurement, EMG |
| Wei W, et al            | 1999     | Subjective       | Clinical evaluation, patient questionnaire for appearance          |
| Harri K, et al          | 1998     | Subjective       | Harii scale                                                          |

*This study does not include Facial Grading Scale.
PATIENT REPORTED OUTCOME MEASURES

FaCE Scale

As facial paralysis may have a significant impact on patients’ interpersonal relationships, career success, and overall wellbeing, validated QoL measures are essential for a holistic approach to the evaluation of outcomes following facial reanimation surgery. The use of PROMs has been proposed to evaluate these aspects and are becoming increasingly important across multiple fields, even considered a requirement by some. FaCE scale, developed in 2001, is a validated questionnaire for disease-specific patient reported QoL in facial palsy. It readily evaluates important secondary effects of facial paralysis, such as oral incompetence, difficulty communicating, eye irritation, excessive lacrimation, facial pain, and social stigmatization. FaCE scale has been widely used to report QoL following multiple treatments for both flaccid and non-flaccid facial paralysis. This allows for comparison among patients who have undergone FFMF as well as those who have undergone local muscle or nerve transfer. FaCE scale has also been validated in several languages, improving accessibility. If conducted pre and postoperatively, clinicians can use FaCE scale to evaluate patient-reported functional and psychosocial recovery. Scales which omit this critical metric are limited in their ability to offer a comprehensive assessment.

SUBJECTIVE TOOLS

House-Brackmann Scale

The House-Brackmann grading scale (HBGS), developed in 1983, is the most frequently used tool to assess degree of facial weakness. Although it has been used to evaluate outcomes following facial reanimation surgery, it was initially created to grade facial nerve disability. The HBGS has documented pitfalls, including that it does not fully represent facial function, lacks sensitivity to subtle...
other clinician-based tools, in that it independently ana-
tially significant tool, eFACE, overcomes a limitation of
evaluation of facial movement. These include Emotrics and
clinician-graded literature, although they were less frequently seen in our
coming following facial reanimation surgery. Unlike other
cal recovery and certain functional outcomes, making it a
scale fails to provide important information on psychoso-
tial facial functions, nor does it assess psychosocial recov-
track improvement over time, limiting its utility.

**Table 4. Combination Subjective and Objective Tools in Reverse Chronological Order**

| Author          | Year       | Tool                                                                 |
|-----------------|------------|----------------------------------------------------------------------|
| Kim MJ, et al   | 2020       | FACE software (FACEgram), 3D spatiotemporal analysis, Terzis grading scale |
| van Veen MM, et al | 2018     | FACE software (FACEgram), FaCE QoL scale                              |
| Greene J, et al | 2018       | Emotrics, FaCE QoL scale                                              |
| Faris C, et al  | 2018       | FACE software (FACEgram), FaCE QoL scale, eFACE facial grading scale  |
| Cardenas-Mejia A, et al | 2015 | Terzis grading scale, EMG                                             |
| Lindsay RW, et al | 2014, 2014 | FACE software (FACEgram), FaCE QoL scale, Facial Grading Scale        |
| Vakharia KT, et al | 2012     | SMILE software, FaCE QoL scale                                        |
| Hadlock TA, et al | 2011     | FACE software (FACEgram), FaCE QoL scale                               |
| Krishnan KG, et al | 2010     | Commisural excursion indices, investigator determined smile reaction, patient self-evaluation of function |
| Terzis JK, et al | 2010       | Terzis grading scale, EMG                                             |
| Terzis JK, et al | 2010       | Terzis and Bruno methodology of interpalpebral distance ratios measurement, Terzis and Bruno blink grading scale |
| Takushima A, et al | 2009     | FEMAS-1 (Facial Expression and Motion Analysis System-1) software, Harii scale |
| Terzis JK, et al | 2009, 2009 | Terzis grading scale, EMG                                             |
| Terzis JK, et al | 2009       | Terzis grading scale, EMG                                             |
| Manktelow RT, et al | 2006     | FaceMS, patient survey on the functional effects on eating, drinking, and speech |
| Sajjadian A, et al | 2006     | Facial Grading System, EMG                                            |
| Schlierphae H, et al | 2000     | Harii scale, SF-36 questionnaire, oral commissure excursion measurement, EMG |

*This study does not include Facial Grading Scale.

differences in severity of weakness, and has documented high inter-observer variability. Some limitations were addressed in 2009 with the updated HBGS, known as Facial Nerve Grading Scale 2.0, but the scale is still tailored to patients with acute facial paralysis, limiting its generalizability for use in chronic cases.

**Terzis Scale**

Created in 1997 to evaluate surgical outcomes following FFMF reanimation procedures, the Terzis Facial Grading System evaluates facial symmetry at rest and quality of smile. Shortcomings of Terzis Facial Grading System include that it does not evaluate recovery of essential facial functions, nor does it assess psychosocial recovery. Moreover, it is time-intensive and the scores fail to track improvement over time, limiting its utility.

**Harii Scale**

The Harii Scale was developed in 1998 to evaluate outcomes following facial reanimation surgery. Unlike other subjective tools, the Harii scale includes an objective measure, electromyography (EMG), as a component of the overall evaluation. However, the overall score depends primarily on the subjective component. Moreover, the scale fails to provide important information on psychosocial recovery and certain functional outcomes, making it a poor choice as a generalizable scale.

**Newer Outcome Tracking Tools**

Numerous newer tools have been reported in the literature, although they were less frequently seen in our review. These include Emotrics and clinician-graded electronic facial paralysis assessment (eFACE). Emotrics is a facial measurement software that utilizes machine learning technology for facial landmark identification and evaluation of facial movement. Another potentially significant tool, eFACE, overcomes a limitation of other clinician-based tools, in that it independently analyzes static, dynamic, and synkinetic facial features. As newer technologies are developed and their clinical utility demonstrated, they should be considered as additions to a universal outcome tracking method.

**Shared Outcome Measure**

Comparing non-standardized outcomes poses a significant challenge to further progress the field. Having a universal method for tracking functional outcomes would facilitate a data-driven comparison of surgical techniques, not only for FFMF reanimation, but for all facial paralysis interventions. These comparisons would ultimately be important for guiding appropriate selection of technique and managing patient expectations.

We propose a combined outcome tracking measure that employs FACEgram together with FaCE scale. FACEgram has proved to be user-friendly, objective, efficient, accurate and reproducible, and does not rely on special equipment or lighting. Additionally, as the utility of PROMs is well documented in both surgical and non-surgical fields, the inclusion of a PROM would provide further insight into patient-perceived QoL. To that effect, we propose the inclusion of FaCE scale in tracking postoperative outcomes, as it is a PROM specific for facial paralysis.

**Potential Applications**

In consideration of the potential impact of this work, we believe that novel, related reconstructive areas such as facial transplantation may be informed by our findings, given the degree of overlap in technique with facial reanimation. Functional outcome tracking in facial transplantation has been largely based on clinical evaluation by the transplant team, with adjunct tools occasionally employed. At our institution, we utilize clinical evaluation by a multidisciplinary team of surgeons and therapists, along with a patient questionnaire for self-reported functional outcomes. We have also employed tools such as optical tracking software (Vicon 460; Vicon Motion Systems, 2001, Denver, Colo.) and the Sunnybrook facial grading system. Like reanimation,
no consensus exists on the ideal method of tracking and reporting outcomes after facial transplantation, which limits advancement within this growing field. Although not currently utilized in facial transplantation, software-based facial analysis tools such as FACEgram are an intriguing option with the potential for significant impact within the field. Additionally, as stated earlier, PROMs are an integral aspect of assessing recovery and should be included as part of a holistic evaluation after facial transplantation.

Limitations and Future Directions

Our study is limited by the potential exclusion of relevant non-English papers or any other relevant papers that were not identified by our search strategy. Furthermore, the heterogeneity of the included studies made it difficult to draw other specific conclusions due to differences in the way studies were conducted. However, we feel this investigation enabled us to report valuable data on the functional outcome measures utilized for FFMF reanimation. As developing a universally accepted scale for all reanimation procedures has proved challenging, we offer suggestions on how to move closer to this goal. We believe initial steps may include standardizing outcome tracking tools based on individual procedures. For chronic facial paralysis treated with FFMF, we suggest investigating the use of FACEgram in combination with FaCE scale as the standardized outcome tracking method. Standardization would allow for scientifically useful comparison of the different FFMF reanimation procedures and consequently improve outcomes for patients. To facilitate accurate comparison of outcomes, a consensus on the postoperative timing of evaluations using these tools must be agreed upon.

CONCLUSIONS

Accurate comparison of outcomes between the various techniques for FFMF reanimation is essential, and a universal functional outcome assessment method is needed. Although no standardized tool currently exists to evaluate outcomes following facial reanimation procedures, there has been a trend toward more objective measures, particularly software-based tools, and toward specific subjective measures, namely PROMs. Standardizing evaluative tools and reaching consensus on their use will inform future innovations in the field of facial reanimation surgery, as well as other methods of autologous facial reconstruction and transplantation.

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