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Smile Outcomes When Using Masseteric Nerve-based Nerve Transfers versus Direct Muscle Neurotization in Facial Palsy Patients

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Background: When dealing with a weak smile, nerve transfer is a viable strategy. We evaluated outcomes of masseteric nerve to facial nerve transfers and compared them with direct muscle neurotization (DMN).
Methods: In a retrospective cohort study of 20 patients (n = 20), we compared nerve transfer versus DMN over a 6-year period (2016–2021). Outcomes were measured using the validated Sunnybrook score, Ackerman Smile Index, and Terzis scores. Statistical analysis was performed using the Wilcoxon sign rank and Mann-Whitney U tests.
Results: Comparing pre- versus postoperative scores after nerve transfers, there was a significant improvement in median overall Sunnybrook score (24 versus 47, $P = 0.043$), lip elevation (1 versus 2, $P = 0.046$), open mouth smile (1 versus 3, $P = 0.003$), and Terzis scores (1 versus 3, $P = 0.005$), with no difference in resting symmetry (−15 versus −5; $P = 0.496$). Compared with DMN, there was no difference in median Terzis score improvement from preoperative to postoperative state (2 versus 1, $P = 0.838$), median smile improvement (2 versus 2, $P = 0.838$), resting symmetry (10 versus 5, $P = 0.144$) or overall Sunnybrook score (23 versus 21, $P = 1.000$). Lip elevation improvement was in favor of nerve transfers (1 versus 0, $P = 0.047$).
Conclusions: This is the first study evaluating nerve transfer neurotization of smile-mimetic muscles and comparing the outcomes with DMN, with masseteric nerve as donor. Nerve transfer leads to improved facial mimetic function, smile excursion and open mouth smiles, as does DMN, with improvement in lip elevation in favor of nerve transfer. Nerve transfer was preferred for more severe smile weakness. *(Plast Reconstr Surg Glob Open 2023; 11:e4939; doi: 10.1097/GOX.0000000000004939; Published online 13 April 2023.)*

INTRODUCTION

In the past, all cases of facial palsy were managed as completely paralyzed faces. No effort was made to distinguish between paralysis and a weak smile. Although this may hold true in cases of Moebius syndrome, a significant proportion of facial palsy cases present with a weak smile, wherein some residual facial muscle movement is present. In these cases, nerve transfers[1] have a significant edge over pedicled or free muscle transfers, as they can provide similar smile reanimation without adding bulk to an already stigmatizing condition. This is a major drawback of muscle transfer procedures in general.

Nerve transfers were first described in 1903 by Kortes, wherein the hypoglossal nerve (XII) was used to substitute an unavailable or damaged ipsilateral facial nerve.[2] Scaramella further expanded on this principle with the description of cross-facial nerve grafts in the 1970s.[3] Although seen as effective in two-stage free-functioning muscle transfers for smile reanimation, its use in primary facial reanimation surgery has been limited due to poor results for primary cross-facial nerve grafts. It was, however, the use of the masseteric nerve as a facial

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nerve substitute,[4,5] which has provided a real alternative to muscle transfers in facial reanimation. The next big question is whether nerve-to-nerve coaptation or nerve-to-muscle neurotization is the better technique. To answer this, we have compared both techniques in the masseteric nerve setting based on a review of our clinical practice.

METHODS

A retrospective cohort study was conducted based on a review of our clinical practice, which was approved by the clinical governance and audit department at Queen Victoria Hospital, East Grinstead, UK (Audit 1488). Direct muscle selective neurotization were the previous gold standard in our unit, but we wished to compare this with nerve transfer neurotization in our clinical practice. The indication for the procedures is described in Table 1.

Technique

The outcomes of nerve transfer versus direct muscle selective neurotization of smile-mimetic muscles were compared in patients with facial palsy, across all age groups over a 6-year period (2016–2021). The nerve transfer cohort underwent masseteric to buccal or/and zygomatic branches of the facial nerve (VII) transfer based on clinical assessment and needle electromyography prognostication. This included the fascicular forked nerve transfer in four patients (Fig. 1), wherein the masseteric nerve was coapted to both buccal (VII_b) and zygomatic (VII_z) branches of VII. Conversely, the direct muscle neurotization cohort used the Terzis technique,[6] albeit with the masseteric nerve as the donor. In this procedure, the sural nerve is harvested, reversed, and coapted to the masseteric nerve, and its other end is opened up into its individual fascicles and directly implanted into the target muscle as described by Terzis et al.[6]

Rehabilitation

Preoperatively, patients who are due to have masseteric nerve surgery are educated about the need to bite the back teeth together. This is to create a smile initially postoperatively, with the final goal being active smile without the need to bite. Facial muscle massage and stretches are taught to ensure soft tissue stiffness, does not inhibit facial movement, and the patient begins to practice use of bite during smile to gain confidence in the correct bite technique before surgery.

Table 1. Comparison of Case Etiology between Those with Nerve Transfers and Direct Muscle Neurotization

Etiology			
Nerve Transfers	**n**	**Direct Neurotization**	**n**
Iatrogenic	6	Iatrogenic	5
Congenital	0	Congenital	3
Trauma	1	Trauma	1
Bell palsy	1	Bell palsy	2
Cerebrovascular accident	1	Cerebrovascular accident	0

Otherwise similar, the only discernible difference was with the relative preponderance of congenital facial paresis cases being treated with direct muscle neurotization.

Takeaways

Question: Are the outcomes of masseteric nerve-to-facial nerve transfers superior to those with direct muscle neurotization?

Findings: Nerve transfer neurotization leads to improved facial mimetic function, smile excursion and open mouth smiles, as does direct neurotization with improvement in lip elevation in favor of nerve transfer neurotization. Nerve transfer neurotization was preferred for more severe cases of smile weakness.

Meaning: Both techniques are effective; however, nerve transfer neurotization was preferred for more severe cases of smile weakness when compared with direct neurotization.

Postoperatively, patients are advised to avoid soft tissue work for 6 weeks whilst the nerve graft stabilizes, but are encouraged to continue coordinating biting with active smiling. At 6 weeks, patients recommence soft tissue work and begin scar massage. Formal bite smile training commences at 6 weeks with patients practicing bite smile with mirror feedback five times per day for approximately 5 minutes. Initially, patients are taught to use 10/10 maximal bite effort whilst creating a gentle, balanced, symmetrical smile in the mirror. This often requires control of the unaffected side to avoid excessive excursion and compensatory lower lip depression. Some patients benefit from placing a small sweet or swab between the back teeth to improve bite effectiveness. Patients are also taught to use visualization of something that makes them happy to combine both voluntary and spontaneous smile pathways during training.

Outcome Measures

The data for direct muscle zygomaticus major (ZM) and levator labii superioris (LLS) neurotization were previously published by our group.[7] Outcomes were measured using the validated Sunnybrook, Ackerman Smile Index (the intercommissural width divided by the interlabial gap, and the lower the number, the more youthful/optimal the smile), and the Terzis scores. Needle electromyography was not chosen as an outcome measure because it is a site-specific test, better suited to prognostication rather than a measure of a meaningful smile. The scoring was performed by an expert facial palsy surgeon, not blinded to the intervention. The outcomes were evaluated 1 year postoperative.

Statistical Analysis

The Shapiro-Wilk test was used to determine the nature of the data as nonparametric. Statistical analysis was then performed using the Wilcoxon sign rank and Mann-Whitney U tests, with statistical significance at *P*

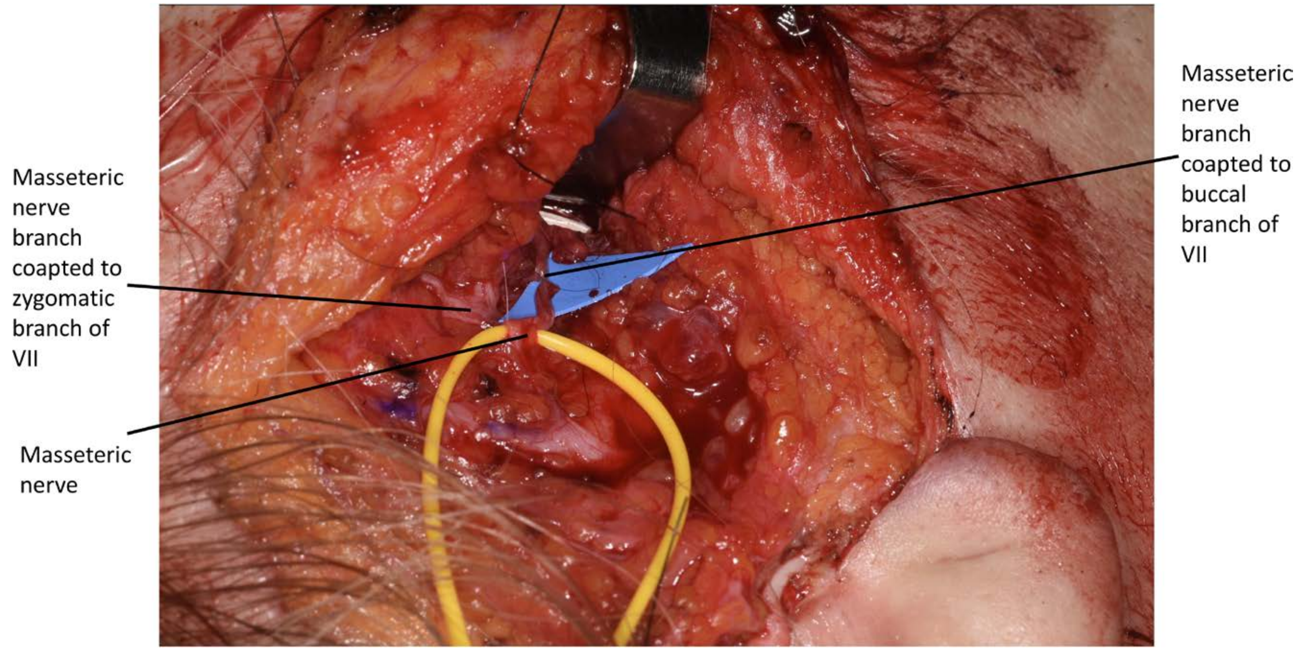

Fig. 1. An intraoperative image of the forked fascicular transfer technique of innervating both zygomatic and buccal branches of the facial (VII) nerve.

less than 0.05. Smile index comparison between the two groups was analyzed using the two-way ANOVA test.

RESULTS

A total of 20 patients were included in this review of our clinical practice with a male-to-female preponderance of 1:1. The mean age of the nerve transfer neurotization (n = 9) cohort was 47 years (range 16–70 years), with time since facial palsy onset of 3–10 years. Mean in-hospital stay in this subcohort was 2 days. As per our previously published work,[7] the mean age in the direct muscle subcohort (n = 11) was 42 years with a time since the onset of facial palsy, ranging from 15 months to 63 years. Longer durations in this study alluded to congenital cases of facial paresis. The specific case etiology has been shown in Table 1. The mean in-hospital stay in the direct neurotization group was 1.5 days. An estimated 72% of these patients had neurotization to both the ZM and LLS muscles. Two patients in the nerve transfer group (22%) and three of the eleven patients (27%) in the direct neurotization group had preexisting synkinesis, with no worsening synkinesis in the nerve transfer group and increased synkinesis in the direct neurotization cohort, which did not reach statistical significance.[7]

Comparing preoperative versus postoperative scores after nerve transfer neurotization, there was a significant improvement in the median overall Sunnybrook scores [24 versus 47, P = 0.043, 95% confidence interval (CI) 0.058–0.068], Sunnybrook lip elevation (1 versus 2, P = 0.046, 95% CI: 0.119–0.132), Sunnybrook smile component (1 versus 3, P = 0.003, 95% CI 0.001–0.003), and Terzis scores (1 versus 3, P = 0.005, 95% CI 0.002–0.004). There was no difference in resting symmetry (−15 versus −5, P = 0.496, 95% CI 0.676–0.695). Data for the direct muscle neurotization group in these parameters are as previously reported in our earlier work.[7]

Comparing nerve transfer versus direct muscle neurotization, there was no difference in median Terzis score improvement from the preoperative to the postoperative state (2 versus 1, P = 0.838, 95% CI −2 to 0). There was also no difference in median smile improvement (2 versus 2, P = 0.838, 95% CI 0.867–0.880), resting symmetry (10 versus 5, P = 0.144, CI 0.182–0.197) or overall Sunnybrook score (23 versus 21, P = 1.000, CI 1.000–1.000) between the two subcohorts. It is to be noted that the preoperative Sunnybrook smile score was 1.4 in the nerve transfer group versus 2.4 in the direct neurotization group, indicating that those with little or no smiles preferentially had nerve transfer, which was chosen for smile augmentation.[7]

Sunnybrook lip elevation improvement was in favor of nerve transfer neurotization (1 versus 0, P = 0.047, CI 0.085–0.097). In terms of Ackerman smile index, there was a significant difference between nerve transfer and direct muscle neurotization (two-way ANOVA, P = 0.0012), with the nerve transfer subcohort being further away from the norm (Fig. 2). This can be explained by the fact that the cases selected for nerve transfer neurotization had more severe facial palsy compared with their direct muscle counterparts, in this study. This is an inherent limitation of this study, which compares two different techniques for two different subcohorts. This is illustrated by representative images and videos, which show the difference in both groups, before and after surgery (Fig. 3). (**See Video 1 [online],** which displays the preoperative video of a patient with smile weakness who had a direct muscle neurotization of ZM and LLS, wherein the masseteric nerve is directly implanted into

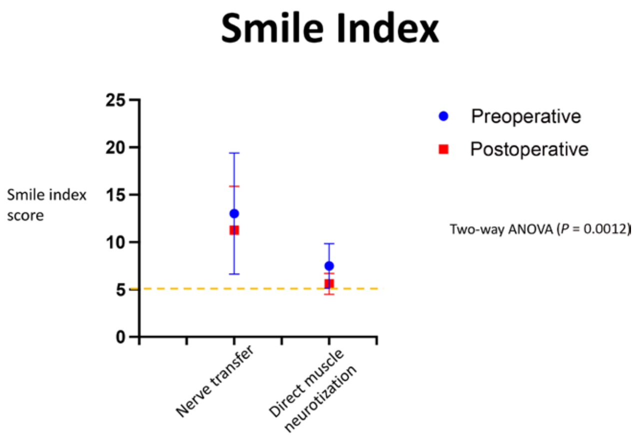

Fig. 2. Graphical representation of the comparison between types I and II ZM and LLS neurotization in terms of the smile index. Two-way ANOVA analysis showed that there was a significant difference between the starting points of these two groups.

the facial muscle to neurotize it. This was preferred for those with weak smiles, eg, Sunnybrook 3 to 4.) (**See Video 2 [online],** which displays the postoperative video of a patient with smile weakness, who had a direct muscle neurotization of ZM and LLS, wherein the masseteric nerve is directly implanted into the facial muscle to neurotize it. This was preferred for those with weak smiles, eg, Sunnybrook 3 to 4.)

DISCUSSION

Direct muscle neurotization involves opening the distal nerve fascicles and directly implanting them into muscle, facilitating axonal sprouting at the neuromuscular interface. Terzis and Karypidis (who applied this in facial reanimation in 2011), however, did not use the masseteric nerve as the donor, citing concerns relating to mastication.[6] Our group subsequently conducted a prospective cohort study, using the masseteric nerve as the donor nerve for direct muscle selective ZM and LLS neurotizations.[7] We demonstrated that smile excursion could be substantially improved in facial paralysis when the masseteric nerve is used as the donor using direct neurotization techniques. However, we asked the question whether direct masseteric to VII nerve transfers with single coaptation sites and without the use of a nerve graft, could do even better as is seen in acute facial reanimation.[8] In both techniques, there is only one coaptation point, viz., at the masseteric-facial nerve interface in the nerve transfer group and at the masseteric-sural nerve graft interface in the direct neurotization group.

Earlier patients in the nerve transfer cohort had single branch nerve transfers, but as we realized from previous literature that facial muscles are different as they have multiple motor end plates (MEPs),[9] we deduced that the overall outcome of smile reanimation would be directly proportional to the number of innervated MEPs within the target muscle. For this reason, we transitioned to performing a forked fascicular technique (Fig. 1), where the masseteric nerve is split into two and coapted to both the zygomatic and buccal branches of the VII for later patients in the cohort.

The masseteric nerve as a donor has rich axonal content, which accounts for enhanced smile excursion compared with the hypoglossal neural supercharge.[10] However, when the masseteric nerve, which contains many axons,[11] neurotizes groups of smaller muscles like the ZM and the LLS, one would expect to see more movement. However, we did not see this in our cohort. Although there was increased excursion in closed lip smiles across both cohorts, on comparing the smile indices of nerve transfer and direct neurotization, we found no statistically significant intragroup improvement, although there was a statistically significant intergroup difference between them.

As to why this is, we postulate that there are two reasons. Firstly, although the masseteric nerve is rich in axons, the masseter itself is a muscle rich in slow-acting muscle fibers and when asked to reinnervate the MEPs within a fast-acting fiber-rich muscle like the ZM and LLS, axons meant for type II muscle will home in on type II MEPs. This axon-specificity is in line with the principles of neurotrophism.[12]

In direct muscle neurotization procedures, the axonal growth cone grows directly into both the ZM and LLS muscles and form new MEPs, thereby augmenting the number of MEPs.[13] Theoretically, this should provide more power to the LLS muscle but in terms of lip elevation, nerve transfer neurotization patients had superior lip elevation. This may be explained by the fact that nerve transfer neurotization innervated not only the LLS muscle but also the other lip elevators such as levator anguli oris and levator labii superior alaeque nasi, which, as a composite, worked better than directly neurotizing a single LLS muscle.

Preliminary reports from a parallel case series in our practice indicate that the use of a vascularized cross-facial nerve graft using the sural communicating nerve flap, in conjunction with the fascicular forked nerve transfer procedure, has results even superior to those of both nerve transfer and direct muscle neurotization of the smile-mimetic muscles.[14] Longer term studies are, however, required to confirm this.

There were a few limitations in this study. Patient-reported outcomes were not included and will form the basis of future work. The scoring was performed by an expert facial palsy surgeon with experience in using the validated assessment tools, not blinded to the intervention. Whilst blinding would have been preferred, we wanted to ensure that accurate assessment was done using the tools, and that the scoring was not compromised if done by an inexperienced rater.

To our knowledge, this is the first study in the available literature comparing nerve transfer and direct muscle ZM and LLS neurotization in terms of masseteric nerve as the donor. We have shown that although both nerve transfer and direct neurotization strategies lead to improved overall smile improvement, there was no significant difference in outcomes from pre- to postoperative period between them, except for superior lip elevation in favor of nerve transfers. This can be explained by a greater number of

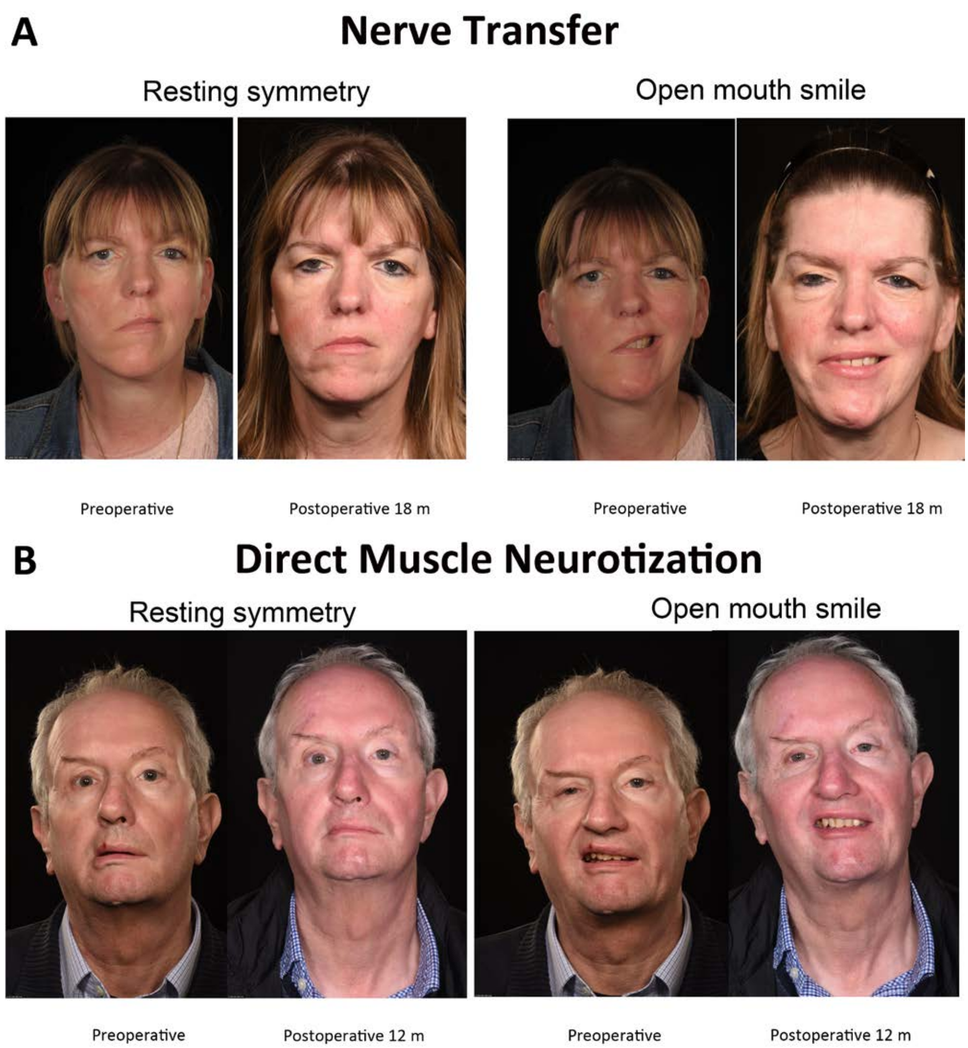

Fig. 3. Clinical photographs for nerve transfer and direct muscle neurotization patients. A, A clinical illustration of a patient who had a nerve transfer ZM and LLS neurotization. Patients who had minimal smile excursion (eg, Sunnybrook 1 to 2) were generally chosen for this procedure. The patient had a vestibular schwannoma tumour excision, presenting 4 years postoperative with facial paresis. B, A clinical illustration of a patient who had direct ZM and LLS neurotization wherein the masseteric nerve is directly implanted into the facial muscle to neurotize it. This was preferred for those with weak smiles (eg, Sunnybrook 3 to 4). The patient had a vestibular schwannoma tumour excision, presenting 1 year postoperative with complete facial palsy.

lip elevators being neurotized in this subcohort, compared with direct muscle neurotization of the LLS muscle alone. Nerve transfer neurotization seems to be better for the dense, weak smile, whereas direct muscle neurotization can be selected for more focused areas after detailed analysis of a patient's smile vector.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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