Journal of Plastic, Reconstructive & Aesthetic Surgery (2009) **62**, 1580–1588

ELSEVIER

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Masseteric-facial nerve coaptation — an alternative technique for facial nerve reinnervation☆

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Received 31 October 2007; accepted 20 May 2008

KEYWORDS
Masseteric nerve;
Facial reanimation;
Neurotisation;
Cross-facial nerve graft

Summary *Background:* Reinnervation of the facial musculature when there is loss of the proximal facial nerve poses a difficult clinical problem. Restoration of spontaneous mimetic motion is the aim and, to this end, the use of cross-facial nerve grafts has long been considered the reconstruction of choice. The nerve to masseter has been used very successfully for reinnervation of microvascular functioning muscle transfers for facial reanimation in established facial palsy but its use as a direct nerve transfer to the facial nerve to reinnervate 'viable' facial musculature has been scarce.
Methods: Electron micrographic studies of axonal counts in the nerve to masseter and nerve to gracilis in a clinical series of seven patients undergoing surgery for facial nerve palsy were made. Based on these results, and previous success with the use of the nerve to masseter for reinnervation of free gracilis transfers, we report our experience with the transfer of the nerve to masseter for direct coaptation with the ipsilateral facial nerve to restore facial motion.
Results: Our axonal counts of the nerve to masseter have, on average, 1542 ± 291.70 (SD) axons. Historical data have shown that the buccal branch of the facial nerve has 834 ± 285 (SD) where the distal end of a cross-facial nerve graft has 100 to 200 axons. Our clinical use of the nerve to masseter as a direct nerve transfer in three patients based on these data has resulted in significant improvement in facial symmetry in repose (at a minimum of 1 year follow up), restoration of facial motion with occasional spontaneous activity and minimal synkinesis without any donor morbidity.
Conclusions: The advantages of this technique include the ease of dissection, constant and reliable anatomy, powerful reinnervation of the facial muscles without donor site morbidity and the potential for return of spontaneous facial movement.

☆ Presentation: Annual Scientific Congress, Royal Australasian College of Surgeons — Christchurch, New Zealand, May 2007.
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doi:10.1016/j.bjps.2008.05.046

Facial nerve paralysis can be a disabling condition functionally, psychologically and aesthetically.[1,2] Function of the facial muscles is essential for effective communication, both verbal and non-verbal, and injury to the facial nerve can severely hinder social interaction. Paralysis of the facial muscles can also result in numerous functional deficits, particularly disturbances in eye protection, eating and drinking.[2] Management varies according to the cause, the extent and type of paralysis (total vs partial, unilateral vs bilateral) as well as the duration of paralysis.

When there has been an acquired proximal injury to the facial nerve in the presence of previously functional facial musculature, such as in acoustic neuroma surgery or temporal bone fracture, neurotisation of the distal facial nerve is an appropriate choice of management. A number of donor nerve options are available, including cross-face nerve grafts,[3–7] the hypoglossal nerve,[8–12] and the spinal accessory nerve.[11] The hypoglossal nerve transfer is the most commonly used and can be done directly, using an interposition nerve graft[13] or as part of a 'combination' procedure such as the 'babysitter' technique described by Terzis in 1984.[14] However, the use of the hypoglossal nerve is not without its limitations, notably subsequent hemilingual atrophy and facial synkinesis.[9,10,15,16]

We present an alternative technique of facial reinnervation using a motor branch of the trigeminal nerve, the nerve to masseter, for neurotisation of the facial nerve. We believe this technique has the potential to produce powerful reinnervation of facial muscles while overcoming the problems encountered with the use of other extrafacial nerves with the potential for spontaneous motion.

Background

In children with Moebius syndrome, bilateral facial nerve palsies preclude cross-face nerve grafts for facial reanimation. If the trigeminal nerve is functional, then the nerve to masseter represents a suitable donor nerve to innervate the functional free gracilis transfer.[2,8] The senior author commenced using the masseteric nerve to innervate the functional free gracilis transfer in patients with Moebius syndrome in 1995. The contractions were strong and able to be controlled voluntarily. Mass movements of the face or dyskinesis were not observed. Because of the excellent results with the use of the nerve to masseter as the donor nerve for reinnervation of transferred gracilis muscles in the Moebius group of patients,[2,8] combined with our own previous variable results of cross-face nerve grafts for neurotisation of gracilis muscle transfers, the masseteric nerve was also used to neurotise the gracilis motor unit in patients with unilateral facial palsy. This method has some advantages. By using a local donor nerve, the facial reanimation can be undertaken as a single procedure. It can also be done without the need for an interposition nerve graft. It became apparent that the neurovascular free muscle transfers started functioning much earlier than muscle transfers which were innervated by cross-face nerve grafts, with the average time to function of the transplanted gracilis being 9.7 weeks in our series.[17]

In the senior author's reported series on the management of established facial palsy of either a congenital or acquired cause, 35 single-stage gracilis transfers with coaptation to the ipsilateral masseteric nerve were performed between 1995 and 2003.[17] This procedure has been used for both unilateral and bilateral facial palsies in patients from 3 to 53 years of age. In seven patients in this series, operative neural biopsy specimens of the nerve to masseter and the nerve to the gracilis motor unit were obtained, in order to delineate the number of motor axons available from the nerve to masseter for innervation of the transplanted gracilis muscle.

Methods

Biopsy specimens of the nerve to masseter and the nerve to gracilis functional motor unit were obtained in a series of seven patients undergoing surgery for facial nerve palsy, as detailed above. The age of the patients ranged from 4 to 53 years of age with a mean age of 18.2 years. Nerve biopsy specimens were fixed in 2.5% glutaraldehyde diluted in 0.1 M Cacodylate buffer for a minimum of 2 h, postfixed in 2% buffered osmium tetroxide in distilled water, en-block stained by 3% uranyl acetate and embedded in Spurrs' resin. Diamond knife cut semi-thin sections of 0.5 micron were stained by 0.5% methylene blue and photographed by a Leica camera on an Orthoplan light microscope at $\times$100 magnification. Prints at a final magnification of $\times$460 were analysed by computer-assisted planimetry (Carl Zeiss, MOP-3, Germany). The number and diameter of myelinated nerve fibres, including myelin sheaths, were determined.

Results

The number of myelinated axons contained in the masseteric nerves ranged from 1114 to 1834 with a mean of 1543 and a standard deviation (SD) of 292 (Figure 1). Interfasicular dissection of the obturator nerve was done to isolate the fascicles to the selected anterior gracilis muscle motor unit. These neural pedicles, in our patients, contained between 184 and 571 myelinated axons with a mean of 343 and a standard deviation of 158. Most of the axons ranged between 12 and 29 μm in diameter.[17]

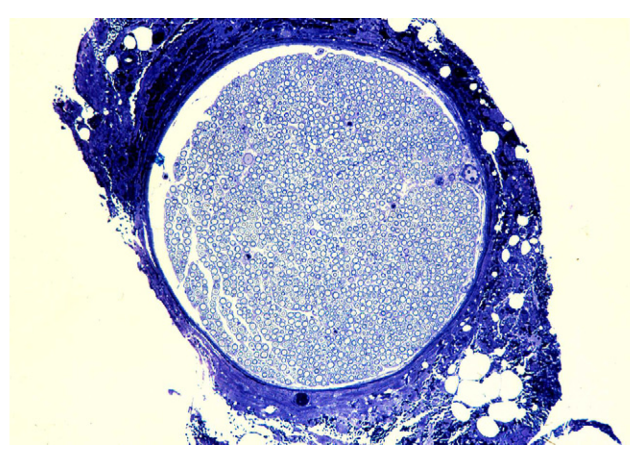

Figure 1 Light microscopy section of the nerve to masseter demonstrating a high density of myelinated axons.

Case studies

As a result of our success,[17] and that reported in the literature,[2,8] with use of the nerve to masseter to innervate transplanted gracilis muscle units for facial reanimation, accompanied by our electron microscopy (EM) studies of axonal counts in the nerve to masseter, we have used this nerve on three occasions as donor for direct neurotisation of the distal facial nerve in patients with reinnervatable facial musculature.

Case 1

A 3-year-old girl was referred to our clinic 12 months after resection of a posterior fossa ependymoma and adjuvant radiotherapy. Prior to surgery she had no evidence of cranial nerve deficits. Despite careful dissection and maintenance of an anatomically intact facial nerve at the time of tumour resection, she developed a complete left-sided nuclear facial nerve palsy. She did have corneal protection with an active Bell's phenomenon, with only a small degree of lagophthalmos.

After discussion of the treatment options the decision was made to proceed with a facial nerve neurotisation. From our previous use of the masseteric nerve as donor nerve for gracilis transfer in facial reanimation, it was decided that the distal facial nerve trunk would be directly neurotised with the ipsilateral nerve to masseter. The operation was performed through a left intertragal incision with a small submandibular extension. Dissection extended below the superficial musculo-aponeurotic system (SMAS) to identify buccal branches of the extra-temporal facial nerve, which were then traced in a retrograde fashion to the facial nerve trunk at its origin from the stylomastoid foramen. The nerve to masseter was then identified within the masseter muscle between the intermediate and deep layers. After intramuscular dissection of the nerve, neurotomy was performed to allow the nerve to masseter to be transposed to a more superficial position. The trunk of the facial nerve was subsequently divided and coaptation between the distal stump of the facial nerve with the masseteric nerve performed using 10/0 nylon epineural sutures. The postoperative course was uncomplicated.

Figure 2 Preoperative image of Case 1 in repose — note marked facial cant and lip droop.

At review 6 months following nerve transfer, the patient demonstrated improved facial symmetry at rest with some evidence of voluntary facial movements. At 12 month review there was significant improvement, with good facial muscle tone, virtual resolution of facial cant, excellent voluntary movement of her upper lip levators and occasional evidence of spontaneous movement of the orbicularis oris. On full activation of the transferred nerve to masseter there was mild synkinesis with reduction of the palpebral aperture with upper lip elevation (Figures 2 and 3). There was no clinical evidence of wasting of the ipsilateral masseter muscle which still had contractile function.

Case 2

A 54-year-old lady presented with complete left-sided facial nerve palsy 11 months after resection of an acoustic neuroma. The original procedure had been complicated by postoperative cerebrospinal fluid (CSF) leak and meningitis, from which she had completely recovered with no evidence of other cranial nerve deficits. At presentation she had had previous surgery for insertion of a gold weight into the left upper eyelid yet still suffered from ocular complications from corneal exposure, dryness and increased scleral show.

The decision was made to perform coaptation of the masseteric nerve to the buccal branch of the facial nerve. This was to be combined with a left facial sling and bilateral facelifting procedures. The buccal branches were identified deep to the SMAS and a communicating branch was seen to pass from the buccal branch to the zygomatic branch. The main buccal branch was identified by retrograde dissection, neurotomised and transferred to the nerve to masseter which was isolated in a similar way to the previous case. The coaptation was performed with 10/0 nylon epineural sutures. The zygomatic and frontal branches were dissected and protected. The left palmaris longus tendon was then harvested and used as a sling from the modiolus to the body of the zygoma to elevate the left side of the lip and a bilateral facelift was performed.

Six months following surgery the patient demonstrated left-sided motion in zygomaticus with improved tone and position of the left lower eyelid with loss of previous scleral show. Twelve months following surgery the patient had excellent voluntary movement of her left upper lip elevators and excellent tone in the lower eyelid. She had the ability to produce a symmetrical smile with good position at rest without evidence of synkinesis. Her philtral deviation to the non-paralysed side had reduced and the length of her paralysed upper lip segment had also reduced in length at rest (Figures 4 and 5). As the nerve to masseter transfer was only done to the buccal branch, which had distal arborisations to the zygomatic branch, all motion is due to this neurotisation as the other procedures performed simultaneously were all of a static nature. The ipsilateral masseter muscle was clinically functional and, significantly, she and her husband reported occasional appropriate spontaneous motion at 6 months post transfer.

Figure 3 Postoperative images at 12 months showing virtual resolution of facial cant in repose and very good upper lip motion.

Case 3

A 45-year-old lady presented with complete right-sided facial nerve palsy 6 months following resection of a facial nerve schwannoma. The initial surgery had been complicated by a CSF leak requiring further surgery but her recovery was otherwise uneventful. At presentation she had had insertion of a gold weight to the upper eyelid and limited tarsorrhaphy providing adequate corneal protection.

The patient subsequently underwent transfer of the ipsilateral masseteric nerve to the trunk of the facial nerve. The right facial nerve trunk was identified and transected at the level of the mastoid. This was then mobilised and transferred to the ipsilateral nerve to masseter that had been dissected intramuscularly and isolated in similar fashion to the above cases.

Postoperative recovery was uneventful, and at the 3 month review the patient demonstrated some improvement in facial tone and occasional voluntary facial movements. At 11 months following surgery the patient had significant improvement in facial tone and symmetry in repose (Figures 6 and 7). She had marked improvement in position of her lower eyelid with loss of her previous scleral show and was able to smile voluntarily. Similar to the previous cases, the masseter muscle was functional despite intramuscular harvest of its motor nerve.

Discussion

Numerous techniques for facial reanimation have been developed over time, with the ultimate goal being the restoration of both function and form. In early cases of facial paralysis, when the ipsilateral facial muscles remain viable, reinnervation of the facial nerve is considered most desirable, either by direct coaptation of the transected nerve ends or by ipsilateral interpositional nerve grafting using autogenous neural grafts.[1,18]

In the absence of a proximal facial nerve stump, cross-facial nerve grafts,[4–7] extra-facial nerve transfers[2,8–12] and combination procedures[14] have been described, with varying degrees of success in returning facial nerve function.

Figure 4 Preoperative images of Case 2 in repose and smile — note facial cant, scleral show and left upper lip segment length.

Figure 5 Postoperative images at 11 months showing resolution of facial cant, scleral show and shortening of the left upper lip segment in repose, symmetrical small smile (middle image) and strength of reinnervated upper lip elevators.

The classical cross-face procedure was first described in the 1970s and is believed to provide the best option for facial paralysis — the contralateral facial nerve as motor donor was believed to be the only one capable of restoring both voluntary and spontaneous mimetic expressions.[4,5] However, most studies published have indicated variable results in terms of restoration of facial symmetry, facial tone and strength of voluntary expression.[4,6,19,20] Furthermore, the cross-facial procedure is a two-stage operation with surgical intrusion on to the normal side of the face, subsequent potential weakening of the contralateral facial nerve and the need for harvest of a nerve graft from a separate site.[6,19] The need for nerve axons to grow across two points of coaptation may exacerbate 'drop-off' of motor axons and lead to weaker reinnervation of contralateral facial muscles.

In patients with bilateral facial paralysis, or in whom the contralateral facial nerve is not available, a different nerve is required for innervation.[2,8,21] Use of an extra-facial nerve offers the advantage of a one-stage procedure, single coaptation and possibly stronger reinnervation than that which is possible with a cross-face graft.[2,5,11] Although the glossopharyngeal, phrenic, spinal accessory, hypoglossal and lingual nerves have all been described as potential donor nerves, only the spinal accessory and hypoglossal nerves, by themselves or in combination with cross-facial nerve grafts, have been used extensively.[9,14,22–26]

The spinal accessory nerve was the first extra-facial nerve used for transfer to the facial nerve, being first performed by Drobnik in 1879.[27] While this technique has been reported as providing strong return of facial symmetry, tone and voluntary expression, loss of function of the ipsilateral trapezius muscle results in significant impairment of patient function with shoulder pain and stiffness a common complaint.[24,26] Use of the spinal accessory nerve also requires intense practice and training in order for patients to produce voluntary facial expression with minimal shoulder movement, with mass facial contractions while using the upper limb also a problem.[24–26] Return of spontaneous facial expression is also

Figure 6 Preoperative images of Case 3 in repose, lip purse and smile showing typical features of complete right-sided facial palsy.

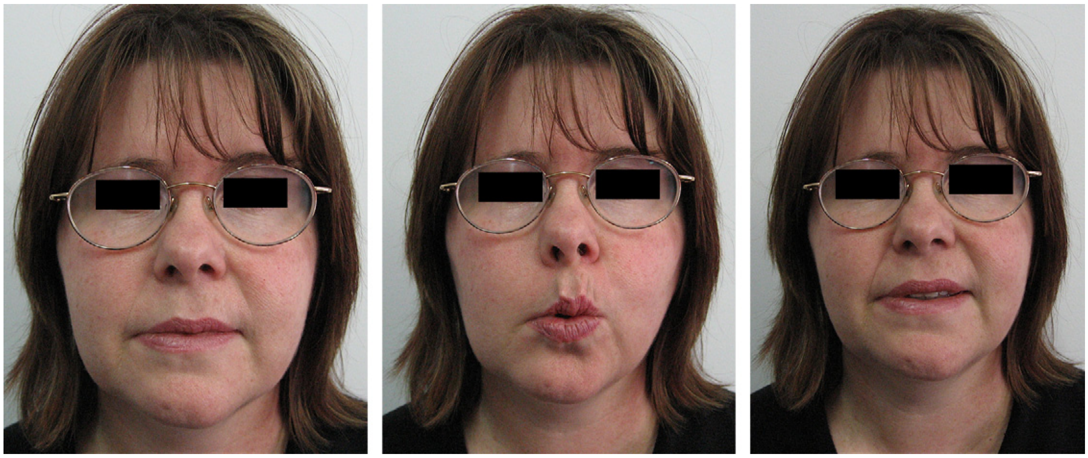

Figure 7 Postoperative images at 7 months showing correction of scleral show, resolution of facial cant, virtually symmetrical smile and absence of synkinesis.

unlikely due to the markedly different cortical representations of the shoulder and face.

In 1903, Ballance suggested that use of the hypoglossal nerve may be preferable to the spinal accessory, as cortical representations of the tongue and face are closer than those of the shoulder and face.[27] Widely popularised by Conley and Baker, hypoglossal-facial anastomosis remains the most popular and acceptable extra-facial nerve transfer for reanimation.[11] However, morbidity relating to loss of the ipsilateral hypoglossal nerve is not negligible, particularly in the presence of other cranial nerve deficits. Hypoglossal nerve transfer has the well recognised complications of hemilingual atrophy and deviation, facial hypertonia, 'mass movements' (synkinesis) with normal tongue movement and absence of spontaneous facial expression.[9,10,15,16] Conley and Baker reported a series of 137 patients undergoing hypoglossal-facial anastomosis with 78% experiencing hypertonia, usually of the middle-third of the face, while up to 16% reported complaints related to speech, swallowing and mastication. Aspiration is also a potential risk, particularly in the presence of glossopharyngeal or vagal nerve injury.

Given the potentially severe complications associated with loss of function of the hypoglossal nerve, several techniques have been described which attempt to preserve the integrity of the nerve. These include partial nerve transfer, jump interpositional grafts, end-to-side neurorraphy and repair of the hypoglossal nerve with the ansa cervicalis.[8–10,18,28,29]

While these techniques aim to minimise complications associated with loss of hypoglossal innervation, this must be balanced with the need to provide an adequate number of axons to produce strong contraction of the facial muscles.

In 1988 Terzis introduced the 'babysitter' concept using the ipsilateral hypoglossal nerve to reinnervate and maintain the 'functional viability' of the denervated facial muscles while waiting for axonal growth in simultaneously placed cross-facial nerve graft.[14] In a second stage procedure, the distal end of the cross facial nerve graft is then coapted to selected branches of the facial nerve whose muscles have been maintained by the XII to VII transfer. This procedure has helped to minimise donor site morbidity within the tongue and has the prospect of providing spontaneity of facial motion but requires two operative procedures and still has the potential for synkinesis.

The nerve to masseter

It has been concluded by Rayment[30] that the problem of poor symmetry of synergistic facial movement in patients who had successful reinnervation of the transplanted muscle was directly related to the number of axons which managed to cross the cross-face nerve graft to the muscle.

Frey[31] found that facial nerve branches used as donors for cross-face nerve grafts (CFNG) had on average 834 (SD 285) myelinated nerve fibres. The normal sural nerve graft in the seven patients in their series had 1074 (SD 419) fibres. At the time of muscle transplantation, the distal end of the CFNG had only 100 to 200 myelinated nerve fibres. This amounted to only approximately 20% of the axons counted in branches of the healthy facial nerve.[31] This is consistent with findings by Harrison who found that only 20 to 50% of total possible axons will grow across a nerve graft.[32] This 'axonal drop off' along the CFNG therefore results in a diminished and probably sometimes inadequate number of nerve fibres to allow adequate reinnervation of the transplanted muscle motor unit being used for facial reanimation. The results observed by Rayment[30] are most likely due to this phenomenon of axonal drop off.

The nerve to masseter can be sacrificed without noticeable impairment of mastication.[15,22] It is a motor nerve with an average of 1542.67 (SD 291.70) myelinated axons in our series.[17] This represents up to fifteen times more axons than found in the distal end of a CFNG.[31] As the nerve fascicle to gracilis had an average of 342 axons (SD 158) in our series, the axon ratio of donor nerve to the nerve to gracilis was approximately 4.5 to 1 when the nerve to masseter was used as the donor. Historically on Frey's data, if a CFNG was used as the donor nerve for the gracilis motor unit, the ratio was only approximately 0.5 to 1.

The masseteric nerve has been widely used to innervate free functioning muscle transfers (FFMT) for facial reanimation.[2,15,21] As found in our electromicrographic studies, the motor nerve to masseter provides a large number of axons for neurotisation of recipient neural pedicles, overcoming the problems associated with axonal drop off. It is capable of providing powerful and reliable reinnervation of free muscle transfers when used for smile reconstruction, and this is particularly advantageous in a situation when the contralateral facial nerve or other cranial nerves are not available. Even in situations where the contralateral facial nerve is available, the masseteric nerve has been shown to be capable of providing stronger and more reliable innervation of the transferred muscle.[5]

In reinnervating the facial muscles an adequate number of donor motor axons needs to be provided so that the axon:muscle fibre ratio is 'near normal'. As discussed by Urso-Baiarda et al., muscle force production in the presence of a near normal axon:muscle ratio will then be limited by muscle fibre number not axonal number.[33]

Use of the motor nerve to the masseter for direct neurotisation of the facial nerve has previously been described by Spira[23] and Bermudez.[9] Spira reported a series of three patients who had successful transfer of the masseteric nerve to lower divisions of the facial nerve, while Bermudez reported the case of a soldier with traumatic facial nerve palsy who had successful transfer of the masseteric nerve to the main trunk of the facial nerve. Both authors commented on the ease of dissection and coaptation as well as the low morbidity and minimal deformity resulting from loss of function of the masseter muscle. The function of the masseter muscle can be preserved, as shown in our patients with an intra-masseter muscle nerve harvest. All of the patients in our series demonstrated no clinical evidence of masseter muscle wasting.

The motor nerve to masseter is from the anterior division of the mandibular branch of the trigeminal nerve. As described by Fournier, it is the largest of the three motor branches of the trigeminal nerve.[15] After exiting the cranial cavity through the foramen ovale, it passes over the lateral pterygoid muscle and through the coronoid notch to enter the posterior surface of the masseter muscle near its origin.[22] Importantly, the masseteric nerve is relatively constant in its anatomy and is of sufficient length to allow direct coaptation with the facial nerve.[15,23] This is supported by Escat (1925 – cited by Brenner et al.) who measured the distance between the coronoid notch and entrance to the masseter, finding the average length to be 32 mm, sufficient to allow tension-free neurorrhaphy.[22] Fournier, in an anatomic study of the masseteric nerve, reported that unilateral paralysis of the motor root of the trigeminal nerve does not cause a functional problem, compensation being made by the contralateral muscles during mastication.[15] This is supported by Carter and Harkness[34] who reported a study of the effect of masseteric nerve denervation in Wistar-derived rats. Following denervation he found relatively little change, with the masseter muscle being somewhat smaller and the temporalis muscle somewhat larger when compared with controls. Furthermore, Brenner found that in 27 of 36 (75%) cases studied, the nerve consisted of two or more branches at the level of the mandibular notch and in 35 of 36 (97%) specimens, multiple branches innervated the masseter at the level of the muscle entrance, suggesting that transfer of a branch to the facial nerve may not result in severe dysfunction of the masseter muscle.[22] As we found in our cases, masseter function can be preserved with intramuscular harvest of the nerve to masseter between the deep and middle planes of the masseter muscle.

It has long been believed that use of extra-facial nerves precludes the possibility of spontaneous facial expressions.[1,8,21] Movement of the mimetic muscles after hypoglossal-facial coaptation requires conscious thought and voluntary tongue movements. The 'babysitter' procedure goes some way to address the issue of spontaneity with its use of a CFNG but requires two significant operative procedures in potentially older patients with medical comorbidities.

While facial muscle movement after transfer of the masseteric nerve would presumably also require such voluntary activity, several studies have reported the return of spontaneous movement in FFMT innervated by the masseteric nerve.[2,8,21] Manktelow reported a study of 45 free gracilis transfers in 27 patients in whom the masseteric nerve was used as motor nerve.[2] Significantly, he reported that 85% of patients were able to smile voluntarily without biting and, more significantly, that 89% of patients were able to smile spontaneously. We have noted similar rates of spontaneous motion in our patients who have undergone a single-stage gracilis transfer innervated by the ipsilateral nerve to masseter in both bilateral and unilateral facial palsy cases.[17]

Based on our own experiences and studies within the literature, we suggest the use of the ipsilateral nerve to masseter to neurotise the buccal and zygomatic branches of the facial nerve (axon ratio ~2:1). This should provide sufficient axons for powerful reinnervation of the mid-face musculature restoring facial tone, improved facial symmetry in repose, a voluntary and potentially spontaneous smile in the majority of cases and improved lower eyelid position and tone in a single operative procedure. If blink is not adequately restored then this can be augmented with other routine procedures as required. This approach restores the sphincteric functions of the facial muscles while also re-establishing the most important aesthetic qualities of facial expression. Our preference is to perform this procedure early following the onset of the facial palsy but we would not suggest this procedure in patients who have had their facial palsy for greater than 18 months duration.

Grading of outcome of facial reanimation procedures is a difficult area as the majority of grading systems are subjective in nature. In this review of our patients we have elected not to grade the outcome of the patient's reconstruction. There is no international standard in facial reanimation grading systems. As outlined by Guntinas-Lichius,[35] the popular 'House-Brackmann scale and other subjective grading systems were not designed to assess facial nerve function after nerve reconstruction'. Other objective computer-based systems are being developed but currently are probably too complicated for routine clinical use.[36–38]

In the three cases presented, all patients have demonstrated improvement in facial muscle tone, voluntary movements, minimal synkinetic movement and early occasional evidence of appropriate spontaneous muscle activity within 12 months of surgery. While the full extent of their functional recovery is yet to be seen, we are encouraged by these early results.

In conclusion, the use of the ipsilateral motor nerve to masseter offers another alternative for neurotisation of the facial nerve in patients who have an available distal facial nerve and reinnervatable muscles. Despite the recognised advantages of using the masseteric nerve as the motor nerve for transferred gracilis muscles, clinical experience is limited for its use as a nerve transfer directly to the ipsilateral facial nerve. Transfer of the masseteric nerve to the buccal and zygomatic branches provides an abundant supply of axons, overcoming the problem of axonal drop-off of CFNGs, and providing powerful reinnervation of the muscles of those nerve branches. The advantages of this technique include ease of dissection, constant and reliable anatomy, powerful reinnervation of the facial muscles, no donor site morbidity when harvested intramuscularly and the potential for return of spontaneous facial movement in a single operative procedure.

Financial disclosure

The authors of this paper have no financial interest nor any commercial association related to the information presented in this paper. There are no conflicts of interest nor any funding sources that require disclosure.

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