Journal of Plastic, Reconstructive & Aesthetic Surgery (2011) **64**, 1585–1589

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

Activation of the masseter muscle during normal smile production and the implications for dynamic reanimation surgery for facial paralysis

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Received 27 April 2011; accepted 9 July 2011

KEYWORDS
Facial paralysis;
Facial reanimation;
Free gracilis flap;
Masseter nerve;
Electromyography;
Smile;
Outcomes

Summary *Introduction:* In cases of unilateral facial paralysis, free muscle transfer with coaptation to the motor nerve of the Masseter is gaining popularity as a primary alternative to cross-facial nerve grafting. Despite initial expectations, a majority of these subjects can achieve a spontaneous smile. The mechanism behind this spontaneity is unclear. Plasticity of the cerebral cortex as well as the relative proximity of the motor centres of the mimetic and Masseter muscles has been used in explanation. This study demonstrates the involvement of the Masseter muscle during normal smile production, suggesting a more direct explanation for the spontaneous smile seen following reanimation procedures innervated by the Masseter nerve.
Methods: Twenty healthy volunteers were subjected to electromyography of the Masseter muscle bilaterally to demonstrate whether contraction of the Masseter muscle occurred during voluntary and involuntary smile production.
Results: Patient age ranged from 20 to 61 years (mean 41.6 years) with an equal male to female ratio. Activation of the Masseter occurred in 40 percent of individual muscles during smile production, occurring bilaterally in six participants, and unilaterally in four. There was no correlation between muscle activation and patient age or gender.
Conclusions: Natural contraction of the Masseter muscle during normal smile production helps to explain the high rate of spontaneous smile development in subjects with facial paralysis who have undergone a free muscle reanimation procedure powered by the nerve to the Masseter muscle.

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doi:10.1016/j.bjps.2011.07.012

Introduction

Facial paralysis is a profoundly disfiguring condition with significant psychological and functional consequences for sufferers, which presents a major challenge to the reconstructive surgeon. Prior to the introduction of microsurgical techniques, dynamic reanimation surgery commonly made use of Temporalis and Masseter muscles transfers. These have now largely been superceded by free muscle transplant in suitable, well-motivated patients. Several donor muscles have been utilized and co-apted to a variety of donor nerves to power them.[1–8] The appropriate buccal branch of the contralateral facial nerve is traditionally the donor nerve of choice, permitting synchronous and spontaneous activity of the transplanted muscle. This approach, however, has a number of drawbacks: a cross-facial nerve graft (CFNG) is required creating secondary donor site morbidity[8–10]; the procedure needs to be performed in two stages; the normal side facial nerve is exposed to injury and the procedure results in relatively low axonal regeneration and weak muscle contraction. Alternative donors include the hypoglossal nerve, although hemi-tongue atrophy and unwanted facial movements can occur.[11,12] The spinal accessory nerve has been used but may still necessitate nerve grafting, and there is difficulty with coordination of the resultant smile as well as donor morbidity.[13]

The motor nerve to Masseter offers an alternative that is gaining popularity due to its consistent anatomy, close proximity to the transplanted muscle and relative lack of donor morbidity. The reanimation procedure is carried out at a single operation and the power and excursion of the resultant muscle contraction is impressive. Coaptation of the Masseter nerve to a free Gracilis muscle has been used for dynamic reanimation with considerable success.[14-20] None of the limitations of the CFNG are apparent. There is low donor site morbidity, and movement of the oral commissure is not significantly different from that of the normal side.[17] This is probably due to the relatively high number of axons in the Masseter nerve (around 1500) when compared to the distal end of the CFNG (around 100 to 200).[21]

Use of the Masseter nerve as a donor was commonly indicated in cases of bilateral facial paralysis where the contralateral facial nerve is not available for use as a donor. Initial expectations were that patients would have to bite in order to stimulate contraction in the transplanted muscle and achieve a smile. However it soon became evident that a spontaneous smile developed in many patients. Manktelow *et al* reported that a spontaneous smile was achieved routinely in 59 percent of patients and occasionally in 29 percent of patients without the need to bite, and this was unrelated to patient age.[16] Cortical adaptation has been proposed as one possible explanation for this phenomenon. Another possible explanation is that the motor nerve to Masseter is commonly activated during normal smile production such that muscle re-education through cortical plasticity is not required for a spontaneous smile in reanimation patients.

The aim of this study was to determine whether Masseter muscle contraction occurs during voluntary and spontaneous smile production using electromyography (EMG), which allows the detection of individual muscle contractions.

Materials and methods

Twenty healthy volunteers (10 male, 10 female, age range 20–61 years) were recruited to the study. Bilateral Masseter muscle EMG was performed by a consultant neurophysiologist on each subject using a single-use 0.3 mm Ambu® Neuroline concentric needle electrode (Ambu A/S, Ballerup, Denmark) and the Dantec Keypoint® recording system (Dantec Co, Skovlunde, Denmark). Subjects were asked to clench their teeth and the needle electrode was inserted using an aseptic technique through the skin of the cheek into the thickest part of the Masseter muscle adjacent to the angle of the mandible. The needle was inserted as far as the mandible and then withdrawn slightly to ensure correct placement of the needle within the body of the Masseter muscle. Subjects were again asked to clench their teeth and correct placement of the needle was confirmed by the observation of marked electromyographic activity with this manoeuvre. They were then asked to make a variety of other facial movements, including eyebrow elevation, eyelid closure, lip pursing, depression of the lower lip and contraction of Platysma to further ensure that the electrode was in the correct position and would only respond positively to contraction of the Masseter muscle (Figure 1).

Subjects were then induced to smile. This was achieved by asking them to perform a full authentic voluntary smile and subsequently by resorting to humour to provoke a spontaneous smile. The presence or absence of motor unit potentials on the EMG was noted. Without adjusting the needle position, the EMG was repeated several times to

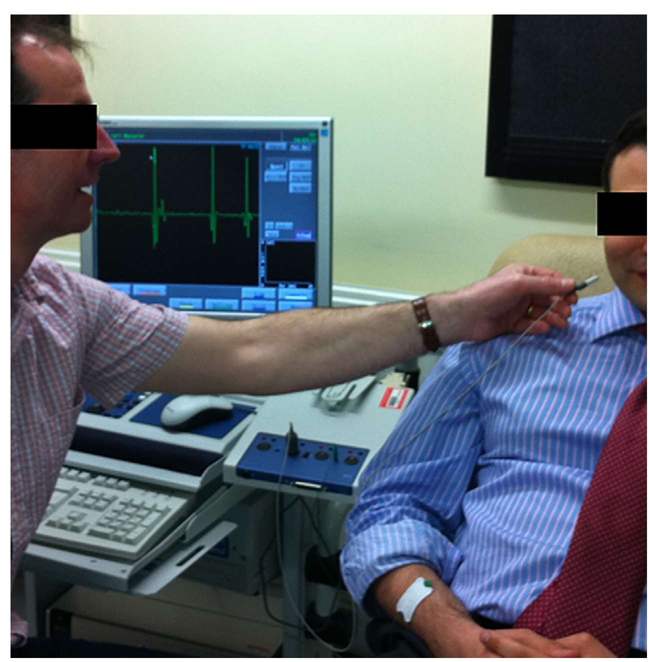

Figure 1 Set up and procedure for EMG of the Masseter muscle.

ensure the consistency and reproducibility of the response. A response was only described as positive if electromyographic activity was consistently observed when smiling and this activity ceased with the smile. Subjects were instructed not to clench their teeth during smiling and in those subjects where teeth clenching was evident, the procedure was repeated. Whilst this was not a quantitative methodology, we found that it was possible to describe the response as negative, weakly positive or strongly positive according on the level of the electromyographic activity present. The same procedure was then performed on the contralateral side of each patient.

Data analysis

The Student's *t*-test was used at 95% confidence intervals, and two-tailed *P*-values given. Fisher's exact test was used for nominal variables, with two-tailed *P*-values given. SPSS 17 software was used for statistical analysis (Chicago, IL).

Results

The EMG was recorded from the Masseter muscle bilaterally in all 20 subjects (40 muscles). There were no exclusions.

Electromyographic activity was demonstrated in 16 out of 40 (40%) Masseter muscles during smile production. A positive response was observed in 10 out of 20 (50%) subjects. In six subjects the response was positive in both Masseter muscles and in four the response was positive unilaterally (Table 1). Although not a quantitative assessment it was apparent that some muscles gave a strongly positive result shown as abundant EMG activity whilst others were more weakly positive. Of the 16 Masseter muscles that gave a positive response six of these could be described as strongly positive. No difference was apparent during voluntary and spontaneous smiling. There was no correlation between muscle contraction and patient age ($p = 0.78$) or gender ($p = 0.66$).

Table 1 Study results. ++ = positive result; + = weakly positive result; − = no contraction of Masseter.

Participant	Sex	Age	EMG Result	
			Right Masseter	Left Masseter
1	F	61	−	−
2	F	20	+	+
3	F	51	−	−
4	F	48	++	++
5	M	28	+	+
6	F	49	−	−
7	M	35	−	−
8	M	56	−	+
9	F	35	−	−
10	F	56	+	−
11	F	45	+	+
12	M	32	−	−
13	M	43	+	++
14	M	32	−	−
15	M	33	++	++
16	F	49	−	−
17	M	42	−	++
18	M	34	−	−
19	F	49	−	−
20	M	42	−	+

Discussion

This study has found evidence of Masseter muscle contraction during normal smile production in 40 percent of muscles examined. This fact may, in part, explain the surprisingly high frequency of spontaneous smile generation in facial reanimation patients in whom the Masseter nerve is used as the donor.

Free Gracilis to Masseter nerve transfer provides better excursion of the oral commissure and upper lip than that achieved by CFNG. This is done as a single operation with low donor site morbidity. In addition to its usefulness in the reanimation of bilateral facial paralysis, it has become the procedure of choice for dynamic reanimation in unilateral cases in our unit. Previous studies have suggested that a spontaneous smile is achieved in 89 percent of patients at least some of the time following smile reconstruction in adults with this technique, and routinely in 59 percent of patients.[16]

The contribution of the Masseter to the normal smile is poorly understood. We hypothesize that contraction of the Masseter in the normal population may be involved in stabilising the mandible during smile production. It has been postulated that cortical adaptation is responsible for the spontaneity of the smile seen following reanimation procedures utilising the Masseter nerve. The formation of new neural communications between the facial nerve nucleus and the adjacent trigeminal nerve nucleus within the pons may result in the activation of the Masseter branch of the trigeminal nerve and contraction of the Gracilis muscle. Reorganisation of the cerebral cortex in response to environmental changes has been termed cortical plasticity, and is thought to be mediated by strengthening of existing synapses or generation of new synapses. This process is known to occur following nerve injuries, nerve transfers, and limb amputations.[22–25] Although functional magnetic resonance imaging can demonstrate cortical adaptation, the close proximity of the two nuclei would limit its usefulness in this case. The results of this study would suggest that neural overlap exists between the facial and trigeminal nerves in a proportion of the normal population, which may be explained embryologically that either the trigeminal and facial nerve nuclei retain some cell bodies from each other, producing overlap of cranial nerve function centrally,[26] or aberrant pathways occur between the nerves. This may also explain the unilateral findings seen in this study. None of these theories are mutually exclusive and all may play a role in the outcomes seen clinically.

This study utilised EMG to demonstrate contraction of the Masseter muscle during smile production, and found activation of the Masseter in 40 percent of muscles. Exactly half of the subjects had evidence of Masseter contraction on at least one side. Manktelow *et al* have reported that 11 percent of patients were rarely able to smile spontaneously and 15 percent were rarely able to smile without making a clenching their teeth.[16] The difference between these clinical observations and those of the present study suggests that multiple mechanisms may be important in the achievement of spontaneous smile in facial reanimation. Future, prospective clinical studies will help to determine whether patients can be preselected for favourable outcomes with this type of reanimation surgery, and the technique may have utility in biofeedback mime therapy to help achieve a full authentic smile.

Conclusions

This study indicates that activation of the motor nerve to Masseter occurs during normal smile production in around half of the normal population. It seems likely that this phenomenon may be a significant contributory factor to the observed high frequency of patients achieving a spontaneous smile following free Gracilis to Masseter nerve transfer. EMG may help in the pre-selection of patients that are likely to develop a spontaneous smile following reanimation procedures where the Masseter nerve is used as the donor.

Conflict of interest

None.

Funding

None.

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