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Spontaneity of smile after facial paralysis rehabilitation when using a non-facial donor nerve

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Introduction: The current focus in dynamic reanimation of facial paralysis lies not only in restoring movement but also regaining smile spontaneity. It has been argued that a spontaneous smile can only be achieved using the contralateral facial nerve as donor via cross-face nerve grafting. Techniques based on the motor nerve to the masseter, however, have shown good rates of spontaneity as well.

Patients and methods: Patients with complete facial paralysis reanimated using free gracilis to masseteric nerve or masseteric-to-facial nerve transfer were included. Patients were grouped according to gender comparing the rates of spontaneous smile.

Results: Thirty-six patients (17 women and 19 men) underwent gracilis innervated by the masseteric nerve whereas masseteric-to-facial nerve transfer was performed in 30 cases (14 women and 16 men). For both techniques, women showed significantly higher rates of spontaneity. Additionally, women recovered spontaneity earlier than men.

Conclusions: Along with providing a strong and reliable commissural pull, the motor nerve to the masseter is able to restore spontaneity as well. Women seem more prone to achieving it. Brain plasticity and the close relationship between the cortical areas of the masseteric and facial nerves are most likely the mechanisms underlying smile spontaneity.

1. Introduction

Over the past decades, numerous techniques have been described for smile reanimation in facial paralysis. While traditional goals were mainly focused on restoring commissure excursion of the paralyzed side, today the mainstay of treatment points toward a more global and integral concept of reanimation involving motion, dissociation and spontaneity of the smile. Smiling is either a voluntary expression, or is the involuntary result of experiencing a spontaneous emotion; furthermore, it has been well documented that emotional and volitional facial expressions are commanded by distinct neural substrates (Iwase et al., 2002, Wild et al., 2006). Indeed, the absence of a spontaneous smile is what brings more problems to patients suffering from facial paralysis since it impairs an essential part of human communication and social interaction (Ho et al., 2012).

Despite the evident final aim of facial paralysis rehabilitation, which is obtaining both a voluntary and involuntary smile, the most adequate surgical technique to achieve it, however, remains controversial for cases in which the proximal ipsilateral facial nerve stump is not available. Historically, facial nerve via cross-face nerve grafting (CFNG) has been regarded as the best option based on that assumption that a harmonious, coordinated and synchronous movement with the healthy side is likely to be obtained. Besides, this technique avoids further morbidities in other non-facial nerves, which also need to be triggered for movement (Terzis and Olivares, 2009; Terzis and Tzafetta, 2009; Terzis and Karypidis, 2011). For these reasons, CFNG has been widely used since its description by Scaramela in the seventies (Scaramella, 1975). Notwithstanding, despite previous assertions and beliefs, CFNG has shown some major downsides, namely not being able to produce sufficient excursion on the affected hemi-face, which is probably due to a limited donor axonal load and the presence of two sites of coaptation, and more critically, the CFNG does not guarantee

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recovering the spontaneous smile in all cases (Manktelow et al., 2006; Hontanilla et al., 2013).

Among all described non-facial nerves in literature for facial nerve transfer or muscle transfer neurotization, the masseteric nerve has become another good option. Although its first description was in 1977 by Skpira, it was only after almost two decades that several anatomical and clinical articles popularised its use. The advantages of this nerve are such that it allows a relatively easy surgical technique, the absence of nerve grafting and the generation of a strong commissural pull. Another important benefit of the masseteric nerve is its scarce donor-site morbidity. Furthermore, masseteric nerve transfer has shown excellent results in terms of symmetry with the contralateral healthy side. Altogether, the masseteric nerve has become a reliable alternative as a donor nerve in facial paralysis rehabilitation (Cotrufo et al., 2011; Borschel et al., 2012; Hontanilla and Marre, 2012).

On the issue of spontaneity, controversy remains as to the nerve(s) capable of producing it, especially after the observation of an effortless smile seen by some authors in patients reanimated using the motor nerve to the masseteric. Contrarily, others have staunchly defended CFNG as the only technique with which spontaneity can be achieved. Consequently, interesting debates on this matter have taken place through scientific publications and meetings.

In the following paper we present our rates of spontaneity in patients with facial paralysis reanimated using the masseteric nerve and discuss two possible factors that influence both aspects: gender and time since reanimation.

2. Patients and methods

From 1999 to 2014, 83 patients with complete, long-term (i.e.,>2 years) unilateral facial paralysis underwent reanimation with gracilis muscle innervated by either a CFNG ($n = 47$) or the ipsilateral masseter nerve ($n = 36$). On the other hand from 2007, 55 patients with complete short-term (i.e., 6 months to 2 years) unilateral facial paralysis underwent reanimation with either hypoglossal nerve transfer ($n = 25$) (from 2007 to 2010) or masseteric nerve transfer ($n = 30$) (from 2010 to 2014). In order to study the results achieved by the masseteric nerve, only patients reanimated with this particular nerve were studied. Final study groups were composed of 36 patients with gracilis muscle neurotized to masseteric nerve and 30 patients with masseteric nerve transfer. All procedures were performed by the senior author (B. H.). Patients in both groups were classified according to gender, and the following variables were registered: age at surgery, time of evolution, spontaneous smile achievement (yes/no), onset of spontaneous smile movements and follow-up in all cases. The spontaneous smile recovery was determined by means of two issues, by a questionnaire inspecting for spontaneity and by assessing a patient's video while smiling at home. The questionnaire was previously sent to the closest relative of the patient and it requested information about the presence of spontaneity during the patient's daily life. Regarding the video, we asked the patient's relative to record a video from the patient watching a funny video at home. That video was a tested funny video, which was previously sent by our team to the patient's relative. At the beginning, the patient should not know that the recording was going to be assessed regarding spontaneous smile recovery and the patient's relative should avoid advising the patient that he or she is going to receive a hilarious stimulus. Posteriorly, after recording, the patients were informed properly about the purpose of the video and asked about their consent for assessing their spontaneous smile recovery and for publishing. Three independent blinded investigators determined spontaneous smile achievement in the videos during the follow-up visits. Therefore, we have considered a spontaneous smile recovery only when the questionnaire had a positive answer and the three independent blinded investigators certified that in the video. In all cases, a complete evaluation including physical examination, standard photographs and video, electromyography, and Facial Clima were conducted preoperatively and every 6 months after surgery. All patients were instructed to carry out a biofeedback rehabilitation protocol consisting of smiling in front of a mirror for 10 min daily starting 4 weeks after surgery.

Quantitative variables were analysed using the Mann–Whitney *U* test. Comparison between sexes for spontaneous smile recovery was conducted using Fisher's exact test. SPSS v17.0 (SPSS, Chicago, IL) was used to analyse results and perform all statistical tests, setting significance at $p < 0.05$.

3. Results

Of the 36 patients with gracilis muscle neurotised to the masseteric nerve, 17 were women and 19 were men. The total number of patients who reached spontaneity in this group was 20 (55.55%). Patients' demographics regarding age, time of evolution and follow-up between genders did not show significant differences. When comparing the number of women to that of men who recovered spontaneous smile, women showed a significantly higher value of achievement ($p = 0.023$). Similarly, analysis of onset of a spontaneous smile showed significant differences between women and men with earlier establishment in the former ($p = 0.015$) (Table 1).

Of the 30 patients with masseteric transfer, 14 were women and 16 were men and the total number of patients who reached spontaneity was 17 (56.66%). Patients' demographics regarding age, time of evolution and follow-up between sexes did not show significant differences between them. When comparing spontaneous smile recovery between sexes, women showed a significantly higher rate of achievement ($p = 0.029$). Like the former case, analysis assessment of spontaneous smile movement onset showed significant differences among women and men with earlier establishment in women ($p = 0.011$) (Table 2).

All of these data were obtained after a statistics consultation that evaluated positively the sample size and the types of statistical analysis performed in this study.

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4. Discussion

The definition of spontaneous smile is the presence of an effortless smile in response to a funny comment or a funny video clips (Rozen, 2011, Iacolucci et al., 2015). Validating a standard method to detect a subjective spontaneous smile and its frequency is difficult and easy at the same time. Firstly, it is easy because the investigator only has to detect the presence of a commissure motion when a funny stimulus is presented to the patient. On the other hand, it is difficult because cultural variations between patients, different psychological states of patients at the moment of investigation, and even intrapersonal ways of reaction when giving a funny stimulus could influence the presence or not of a spontaneous smile. Furthermore, some biased or influenced smiles can be observed if the patients know that the physician is looking forward to observing a spontaneous smile. Besides, patients leaving their ordinary environment from home to the hospital and clinics also modify their natural social interaction and they could force themselves to smile and to express gratifying responses different from normally. In order to eliminate these possible biases we determined the spontaneous smile recovery by means of a questionnaire from a

Table 1
Comparison between sexes of age, time of evolution, follow up, spontaneity recovery and onset of spontaneous smile movements in patients with gracilis muscle transfer neurotized to the masseter nerve. Regarding patients' demographics, Mann–Whitney *U* test shows no significant differences between women and men. Contrarily Fisher's exact test shows significantly higher rate of spontaneous smile recovery in women. Equally, Mann–Whitney *U* test also shows earlier onset of spontaneous smile in women. y: years; m: months; d: days; S.D: standard deviation.

Surgical technique	No. of women	No. of men	*p* value
Gracilis free muscle neurotized to masseter nerve	17	19	
Age, y – (mean ± SD)	44.2 ± 5.3	43 ± 5.6	.56
Time, mo – (mean ± SD)	60.9 ± 21.9	64.7 ± 16.2	.75
Follow-up, mo – (mean ± SD)	48.7 ± 15.7	45.6 ± 24.5	.84
Spontaneous smile recovery, *n* (%)	70.59	42.11	.023
Onset of spontaneous smile, d – (mean ± SD)	459 ± 123.5	724 ± 251.6	.015

Table 2
Comparison between sexes of age, time of evolution, follow up, spontaneity recovery and onset of spontaneous smile movements in patients with masseter transfer. Regarding patients' demographics, Mann–Whitney *U* test shows no significant differences between women and men. Fisher's exact test shows significantly higher rate of spontaneous smile recovery in women. Equally, Mann–Whitney *U* test also shows earlier onset of spontaneous smile in women. y: years; m: months; d: days; S.D: standard deviation.

Surgical technique	No. of women	No. of men	*p* value
Masseter transfer	14	16	
Age, y – (mean ± SD)	43.4 ± 4.5	48 ± 3.4	.55
Time, mo – (mean ± SD)	17.3 ± 4.6	18.6 ± 2.5	.74
Follow-up, mo – (mean ± SD)	47.6 ± 14.5	42.4 ± 11.9	.76
Spontaneous smile recovery, *n* (%)	71.43	43.75	.029
Onset of spontaneous smile, d – (mean ± SD)	329 ± 209.2	623 ± 178.3	.011

patient's relative asking for spontaneity during their daily life and a patient's video while watching a funny video at home. On the other hand, a different concept that should not be confused with spontaneity is dissociation. Movement dissociation is defined as the ability to smile independently from the original movement controlled by the donor nerve, which is tongue protrusion (or pressing against teeth) in the case of hypoglossal nerve and teeth clenching in the case of masseteric nerve. Thus, when dissociation ensues, in order to activate a full smile, patients need only to "trigger" the original movement without completely performing it. The most illustrative picture of movement dissociation in a patient reanimated with the masseteric nerve is seeing how he or she is able to smile with an open mouth. Nevertheless, while some authors describe assessment of postoperative spontaneous smiling and dissociation, most post-intervention measurements fail to ascertain whether patients are able to do both movements, and therefore miss essential information for smile evaluation.

Despite using the aforementioned tools for spontaneity and dissociation assessment, some authors are not prone to accept that the masseteric nerve does restore the patient's ability to smile spontaneously, maintaining that CFNG is the only procedure that can provide a spontaneous smile (Terzis and Olivares, 2009; Terzis and Tzafetta, 2009; Terzis and Karypidis, 2011). Similarly, Faria et al., exposed that spontaneous smile was presented only when using the contralateral facial nerve graft but not the masseteric nerve (Faria et al., 2007). Subsequently, Goushel and Arasteh reported their results in 655 cases of facial paralysis reanimation (Gousheh and Arasteh, 2011). Interestingly, a spontaneous smile was recovered in all patients (536 patients) where neurotization depended on the contralateral facial nerve, but in none of the patients with neurotization by non-facial nerve or with a temporalis myoplasty developed spontaneous smile. Unfortunately, the masseteric nerve was not considered in that study. Also, Yoshioka and Tominaga carried out masseteric nerve transfer for short-term facial paralysis in seven patients (Yoshioka and Tominaga, 2015). After a mean follow-up of 46 months, none of the patients were able to achieve an effortless spontaneous smile. Finally some authors have exposed contradictory results throughout their series regarding spontaneous smile recovery when using the masseteric nerve. Although they firstly confirmed various cases of spontaneous smile and they based their findings in previous literature, they have recently precluded the masseteric nerve as a available option for this purpose (Biglioli et al., 2012; Sforza et al., 2014, 2015). For this reason, the authors advocated performing a double innervated gracilis transfer by both the CFNC and masseteric nerve to ensure the advantages of both nerve sources. The core concept of using double innervation is that the disadvantages of one technique could be compensated by the other one. Additionally, if one of the two motor inputs failed to provide reinnervation, the other could fulfill it. However, a fifteen percent failure rate was reported (Sforza et al., 2014). Furthermore, spontaneous smile was observed in 69.23% but not in all patients and values of commissural displacement were lower than values in muscle transfer neurotized by only the masseteric nerve in other series (Hontanilla et al., 2013). These results could question the synergic effect of double innervation, and call for further comparisons between unique and double innervated gracilis muscle transfer. In an attempt to overcome the uncertain utility of simultaneously using both nerves, Mutsumi et al. developed a hybrid method using a dual muscle transfer with independent innervation from masseteric nerve and CFNG respectively (Mutsumi et al., 2015). Three of the four reported cases developed a spontaneous smile but no valuable information regarding spontaneity was presented.

On the contrary, previous reports have affirmed that the masseteric nerve restores the patient's ability to smile spontaneously. Lifchez et al. reported 2 cases of facial paralysis in patients suffering from Möbius syndrome in which a spontaneous smile was achieved after free gracilis muscle neurotized to the masseteric nerve (Lifchez et al., 2005). Those patients were able to activate their facial muscles in social situations such as hearing a joke or expressing joy. As a way of justifying the results, the authors speculated that early age at the time of operation may have allowed greater brain plasticity leading to achieving a spontaneous smile. Later on, Manktelow et al. described 89% of spontaneous smiles in their series with 37% of them occurring all or most of the time in patients with free muscle transfer innervated by the masseteric nerve. Besides, this article showed that smile dissociation was presented in 85% and 69% of patients were able to smile without biting all or most of the time, respectively (Manktelow et al., 2006). Cerebral cortical reorganization through horizontal connections was hypothesised as the subjacent mechanism for obtaining dissociation and spontaneity. For that reason, and taking into account that cortical reorganization decreases with age, it was thought that older patients would be less prone to achieving spontaneity. However, authors from the same centre did not note spontaneous smile in children reanimated with free gracilis innervated by the masseteric nerve (Bae et al., 2006), although they did acknowledge the difficulties in measuring spontaneity in children as a plausible explication. Additionally, Bianchi et al. confirmed obtaining a smile independent from closure of the jaw in muscle transfer with masseteric neurotisation (Bianchi et al., 2014). Although Bianchi did refute previous speculations limiting spontaneity to CFNG, he did not offer quantitative results in his series. At the same time, spontaneity has also been reported with techniques using muscles innervated by motor branches of the trigeminal nerve. For example, Rubin et al., using relocated halves of the temporalis and masseteric muscles to reanimate paralyzed faces, demonstrated that most, if not all paralytic faces would eventually smile spontaneously without teeth clenching (Rubin et al., 1999). They also hypothesized that some kind of “projections” between the fifth and the seventh nerves were responsible for generating a spontaneous smile. Spontaneous smile percentages over 90% were also reported by Labbé et al. using their lengthening temporalis myoplasty for facial paralysis reanimation both in adults and children (Garmi et al., 2013; Veyssière et al., 2015). They also based their results on hypothetical cerebral plasticity after muscle transposition.

Despite all these previous references describing spontaneity with the masseteric nerve and concord in spontaneous smile assessment, no videos have been reported yet. In fact, this is one of the arguments that authors rejecting the masseteric nerve use to defend their stance. Although systems to diagnose spontaneous smile have been developed and validated, clinical evaluation remains the most extended method for assessing the recovery of a spontaneous smile (Iacolucci et al., 2015). Exposure to funny video clips that generally cause laughter in the majority of the population and capturing the patients' movements on photograph and video recording are mandatory. Our findings show women are able to develop a spontaneous smile to a significantly higher extent than men after reanimation with either gracilis muscle transfer neurotized by the masseteric ($p = 0.023$) or masseteric nerve transfer ($p = 0.029$). Furthermore, for both techniques, women regain spontaneity earlier than men (i.e. $p = 0.015$ in muscle transfer neurotized by the masseteric and $p = 0.011$ in masseteric nerve transfer). Supporting our clinical results, there is some experimental studies endorsing that gender plays an important role in the rehabilitation process from others nerve pathologies (Tsuji et al., 2010). In this way, women may be more prone to develop brain plasticity and may therefore benefit more from training than their male counterparts (Marre and Hontanilla, 2012).

Analogously to many of the authors previously mentioned, we base our outcomes on cortical adaptation and brain plasticity. It is well documented that after central or peripheral injury, molecular and structural change in the brain occurs, leading to a certain degree of functional adaptation (Yildiz et al., 2007). Brain reorganization happens throughout life during learning processes, novel experiences, and in response to injury or even after surgery (Elbert and Rockstroh, 2004; Pascual-Leone et al., 2005) Indeed, facial reanimation constitutes an injury, which elicits a cascade of new inputs and outputs at the somatosensory and motor cortex. New studies have also shown that face sensorimotor cortex has a great propensity to neuroplastic changes when acquiring new orofacial motor skills or when any alteration in the oral environment exists (Sessle et al., 2005). In the particular case of facial reanimation with masseteric nerve, our working group has demonstrated a close proximity in the localization of smile and jaw-clenching cerebral areas at the premotor and primary motor area (Buendia et al., 2016). Using functional magnetic resonance, we were able to demonstrate the existence of cortical overlapping between smile and jaw-clenching cerebral areas in normal healthy volunteers. Supporting this finding, a recent study in operated facial palsy patients using lengthening temporalis myoplasty - innervated by the deep temporal nerves, which, as the masseteric, branch from the mandibular division of the trigeminal nerve - showed that activation areas for smiling and jaw-clenching became one after smile restoration (Garmi et al., 2013). This extreme relationship could explain why the masseteric nerve, and no other non-facial nerve, is able to lead to a natural and spontaneous smile. For example, despite the vast array of cases of facial reanimation with different techniques and variations using the hypoglossal nerve, no reports showing spontaneity have been accounted. Besides, different articles have shown the different and well-separated cortical representation of tongue and lips movements without overlapping between them (Bitter et al., 2011; Hesselmann et al., 2004). Notwithstanding, controversy also arises at this point because other authors state different representations of the smile and jaw-clenching cortical areas with minimal overlapping (Romeo et al., 2013). Another point that could also support the superiority of the masseteric nerve over other non facial nerves in achieving spontaneity is the fact that natural contraction of the masseteric muscle during normal smile does occur (Schaverien et al., 2011). This finding explains the existence of connections between masseteric and facial cortical areas even before any facial reanimation procedure with the masseteric nerve is carried out. After all these findings, Tzou et al. developed a staging system for the evaluation of results after functioning free-muscle transplantation for facial reanimation (Tzou et al., 2014). This system tries to sequence the different steps that occur during cortical adaptation after facial paralysis rehabilitation, which vary from stage I (no movement) to stage V (spontaneous smile). Masseteric nerve is included in this grading scale as an available option for reaching the final stage (i.e. spontaneous smile recovery).

As in previous reports referring to physical injury such as limb amputation or after functioning free-muscle, rehabilitation is paramount and patients need intensive training with inductive exercises (Taubert et al., 2010, 2011). Our rehabilitation protocol starts such training one month after surgery. Biofeedback rehabilitation in front of a mirror for at least 10 min per day is recommended. No formal physical therapy or other methods (i.e. neuromuscular retraining, electric stimulation, etc.) are indicated. During this period and until movement is observed, patients are told to move the reconstructed side by teeth clenching. Once motion is restored, training switches to attempting to smile by triggering the donor nerve's original action, but completing smile independently from it.

In conclusion, considering our own experience and the growing body of literature on the topic, we believe that spontaneous smile is a realistic goal in facial paralysis reanimation with the masseteric nerve, rebutting previous speculations. Furthermore, we have observed that women are more prone to recover spontaneity, achieving it earlier after surgery as compared to men. The only question that remains unclear is why some people can develop a spontaneous smile while others cannot. These discrepancies could be due to inter-individual differences, in a similar way that some people have an innate ability towards certain skills while others need training. Reasons why some authors leave the masseteric nerve margin to spontaneous smile recovery are debatable. In certain cases, they have never employed the masseteric nerve, with no results comparing CFNG to masseteric nerve as a nerve source in facial reanimation. In others, it could be possible that differences regarding the concept of spontaneity or measurement systems are behind their stance.

5. Conclusions

Although some authors have neglected it, we can conclude based on our clinical observation and functional magnetic resonance, that spontaneous smile can be re-established using the masseteric nerve both in nerve transfers and muscle transfer neurotization. However, women recover spontaneous smile at a higher rate and earlier than men. As in all nerve injuries, cortical reorganization is likely to also occur in patients with facial reanimation. Nonetheless, further studies are necessary to predict what other variables make any one patient more likely to develop a spontaneous smile.

Conflict of interest

The authors do not have any conflict of interest.

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