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Functional and anatomical basis for brain plasticity in facial palsy rehabilitation using the masseteric nerve

Javier Buendia [a,e], Francis R. Loayza [b,c,d,e], Elkin O. Luis [b,c], Marta Celorrio [b,c], Maria A. Pastor [b,c,*], Bernardo Hontanilla [a]

[a] *Plastic and Reconstructive Surgery Department, Clinica Universidad de Navarra, University of Navarra, 31008 Pamplona, Spain*
[b] *Functional Neuroimaging Laboratory, Division of Neurosciences, Center for Applied Medical Research (CIMA), University of Navarra, 31008 Pamplona, Spain*
[c] *CIBERNED, Centro de Investigación Biomédica en Red de Enfermedades Neurodegenerativas, Instituto de Salud Carlos III, 28031, Madrid, Spain*

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Summary Several techniques have been described for smile restoration after facial nerve paralysis. When a nerve other than the contralateral facial nerve is used to restore the smile, some controversy appears because of the nonphysiological mechanism of smile recovering. Different authors have reported natural results with the masseter nerve. The physiological pathways which determine whether this is achieved continue to remain unclear.

Using functional magnetic resonance imaging, brain activation pattern measuring blood-oxygen-level-dependent (BOLD) signal during smiling and jaw clenching was recorded in a group of 24 healthy subjects (11 females). Effective connectivity of premotor regions was also compared in both tasks.

The brain activation pattern was similar for smile and jaw-clenching tasks. Smile activations showed topographic overlap though more extended for smile than clenching. Gender comparisons during facial movements, according to kinematics and BOLD signal, did not reveal significant differences. Effective connectivity results of psychophysiological interaction (PPI) from the same seeds located in bilateral facial premotor regions showed significant task and gender differences ($p < 0.001$).

The hypothesis of brain plasticity between the facial nerve and masseter nerve areas is

* Corresponding author. Plastic Surgery Department, Clinica Universidad de Navarra, University of Navarra, C/Pío XII 36, 31008, Pamplona, Spain.
E-mail addresses: mapastor@unav.es (M.A. Pastor), bhontanill@unav.es (B. Hontanilla).
[d] Actual affiliation: Neuroimaging and Bioengineering Laboratory, Faculty of Mechanical Engineering, Littoral Polytechnic University (ESPOL), EC090112 Guayaquil, Ecuador.
[e] Both authors contributed equally to this article.

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supported by the broad cortical overlap in the representation of facial and masseter muscles.

Introduction

Several techniques have been described for smile restoration after facial nerve paralysis. Depending on the origin of the facial palsy and its evolution over time, the patient may require a muscle transfer, either free or transposition, a nerve graft/transposition, or both.

Traditionally, the best donor nerve for restoring the smile is the contralateral facial nerve. This cross-nerve grafting provides a physiological result, achieving spontaneous smile, but requires nerve grafting and occasionally a two-stage procedure. Using this technique, when the patient smiles with the healthy side of the face, the crossed innervation provides contralateral movement. Despite its initial attraction, the risk of injuring the healthy side must be considered, and some authors prefer to use other donor nerves regardless of the good outcomes achieved with this technique. During recent years, the masseter nerve has become more popular because it provides a large axonal load resulting in powerful muscle contraction in a one-stage procedure, demonstrating advantages compared to hypoglossal or contralateral facial cross nerve, with objective methods of measurement.[1,2]

To grade the degree of nerve damage in facial palsy or assess the results of surgery, different scores have been reported. These methods include qualitative assessment, as in House-Brackmann, Burres-Fisch and Sunnybrook,[3] or quantitative assessment with automatic three-dimensional (3D) motion capture systems as in facial CLIMA.[2,4] Thus, better outcomes have been demonstrated for surgical rehabilitation of short-term facial palsy with the masseter nerve in comparison to cross-facial nerve graft neurotization, with excellent symmetry and a higher degree of recovery.[5]

Several studies have reported a positive outcome of natural smile on masseter nerve facial rehabilitation, but the physiological pathways remain unclear. Brain plasticity is thought to be the mechanism responsible for masseter nerve efficiency when it is used for dynamic rehabilitation of the smile.[1] This is especially interesting considering reports that patients can dissociate smiling from jaw clenching when a trigeminal branch is used for smile restoration. In addition, spontaneous smiling has been described with the use of masseter nerve.[6] The question arises when some patients develop spontaneous smiles and others do not. It has been reported that some people naturally contract the masseter muscle during a normal smile possibly explaining this phenomenon.[7]

The muscles responsible for the smile are innervated by the facial nerve, and chewing muscles are innervated by the third branch of the trigeminal nerve. These two muscular groups are closely represented in the somesthetic and motor cortex. The cortical somatotopic organization of the primary motor cortex has been extensively investigated by invasive imaging techniques, such as electrical stimulation of the cortical surface, carried out as exploratory maneuvers.[8] Recently, using functional magnetic resonance imaging (fMRI), a noninvasive method with superior spatial resolution has proved useful for the study of the functional organization of the human brain, with the possibility of creating individual brain maps.[9–12]

The aim of this study is to define the activation of the facial somatomotor area during smiling and jaw clenching in healthy volunteers. The maps obtained provide the basis to understand functional changes in cortical plasticity after injury or neuro-reconstructive surgery of facial paralysis.[13–19] We hypothesize, based on clinical findings (dissociated and spontaneous smiles after facial palsy surgery), that facial muscles, recruited for smiling, and the masseter group share cortical representation. The aim of this study is to determine the possible interactions between these two neuronal populations in an attempt to explain the potential implications for facial palsy surgery.

Patients and methods

Participants

This study recruited 24 healthy volunteers (11 women), mean age = 28.6 (range 21–58 years). None of the subjects had a history of neurological (including facial palsy) or psychiatric disease. Exclusion criteria were clinical depression and specific magnetic resonance imaging (MRI) safety considerations. All participants were right-handed, as assessed by the Edinburgh Handedness Inventory. Before scanning, all subjects gave written informed consent, and the University of Navarra Ethics Research Committee approved the study.

*f*MRI study

Before the scanning session, all subjects underwent a training session outside the scanner to ensure the correct understanding and familiarity with the task. The volunteers were asked to perform three simple orders: slight smile, jaw clench and rest. To be able to study nonemotional expressions of mimicry and avoid imitating expressions that could lead to emotional cerebral activation, the experiment was designed in blocks with a simple emoticon per task (Figure 1). The tasks were voluntary and repetitive movements, visually guided by emoticons, in blocks of 20-s duration consisting of 20 repetitive visual instructions to move at a frequency of 1 Hz. The baseline control task was