Efficacy of Functional Training of the Facial Muscles for Treatment of Incomplete Peripheral Facial Nerve Injury

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Objective: *To investigate the efficacy of functional training of facial mimic muscles for patients with incomplete peripheral facial nerve injury.*

Methods: *Ninety-two patients with 241 injured branches of incomplete peripheral facial nerve injury were divided into a treatment group and a control group. The treatment group consisted of 58 cases that received functional training of facial mimic muscles. The rest of the cases served as controls. Assessment parameters included the House-Brackmann grading system, a quantitative facial nerve function estimating system and electroneurography. According to the three assessments, the facial nerve injury was divided into four grades: normal, minor, moderate and severe. The treatment group started training facial mimic muscle activity 2 weeks after facial nerve injury. After follow-ups of 1 to 4 years, the outcomes were statistically analysed.*

Results: *In the minor facial nerve injury group, there was no significant difference in the time needed for initial recovery (Ti, the time needed for significant recovery of the facial nerve function after injury) and final recovery (Tf, the time point after which no further improvement of facial nerve function was obtained) between the two groups ($P > 0.05$). No adverse effect was found in these cases. In the moderate facial nerve injury group, the Ti and Tf of the treatment group were shorter than those of the control group ($P < 0.05$). One case had synkinesis. In the patients with severe facial nerve injury, the recovery rate of facial nerve function in the treatment group was higher than that of the control group and the sequelae were less.*

Conclusion: *Functional training of facial mimic muscles cannot shorten the time of recovery for the patients with minor facial nerve injury but it can speed up the recovery and reduce the undesirable sequelae such as synkinesis and hemifacial spasm for the patients with moderate and severe facial nerve injury.*

Key words: *facial mimic muscle, functional training, facial nerve injury*

After emerging from the stylomastoid foramen, the facial nerve lies relatively superficially. Its superficial location makes it liable to be injured. Incomplete peripheral facial nerve injury is often caused by trauma or iatrogenic injury. The facial nerve is injured by compression, stretching or crushing with intact continuity. It may cause serious facial palsy without proper treatment but an operation is often unnecessary.

Incomplete recovery of facial nerve function following nerve injury is always accompanied by facial disfigurement. Social prejudice makes the patient unwilling to appear in public. The quality of the social life of these patients can be badly affected.

A variety of methods are used in the treatment of facial palsy. However, there is apparently no simple and effective treatment for this problem up to now.

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Table 1 The facial mimic muscles training plan*.

Forehead region
1. Wrinkle forehead. Assist the muscle toward the desired direction if movement is impossible; resist the movement by pressing above the inner corner of the eyebrow. 2. Raise eyebrows as if one feels very surprised; resist this movement from above the centre of the eyebrow.
Periocular region
1. Close the eyes as tightly as possible. Assist the eye to close by placing fingertip on the middle of upper eyelid, resist with finger pressure gently on eyelid. 2. Blink slowly.
Nasal region
1. Dilate the naris as big as possible. 2. Compress naris as small as possible. 3. Wrinkle up nose strongly. Resist this movement with fingers placed at either side of the nose.
Perioral region
1. Press the corners of the mouth together with fingers. At the same time, push lips forward as if saying 'o'. 2. Distend the mouth sideways with fingers as far as possible. 3. Grin to show upper teeth. Press the lips down with finger from the base of the nose to the lips to resist the movement. 4. Protrude the lower lips to show the lower gum. 5. Try to hold a light object between the lips and move it gently.

* A DVD was made for patients about this training plan

Physiotherapy is an acceptable method in treating facial palsy because it has minimal side effects. Commonly used techniques include electrical stimulation, routine exercise and mimic muscles massage. Their therapeutic effects are still controversial in the literature.

Functional training of facial muscles, a method in which the patient learns to exert conscious control over paralysed areas of the body, has been proposed to enhance facial motor function following long-standing facial nerve paralysis and hypoglossal-facial nerve anastomosis surgery[1-3]. However, the treatment effect of biofeedback training on incomplete peripheral facial nerve injury is rarely reported. The purpose of the present study is to investigate the efficacy of functional training of facial muscles on incomplete peripheral facial nerve injury.

Materials and methods

Patients

Ninety-two patients with unilateral incomplete peripheral facial nerve injury were studied. All of the patients were consulted at Peking University Hospital of Stomatology during the period between 1995 and 2001. Forty-eight patients were male and 44 were female. The ages ranged from 11 to 74 years with a median age of 43 years. The patients were divided randomly into the treatment group and the control group according to age and gender. All patients received regular neurotrophic drugs (vitamin B12 and vitamin B1) and electrical stimulation therapy. The patients were not treated with any surgical methods. The treatment group started facial mimic muscle training 2 weeks after facial nerve injury. The control group had the same treatment procedure as the treatment group except for the facial muscle training.

The procedures involved in facial muscle training included the massage of the facial muscles two to four times per day, 3 to 5 minutes each time, and specific muscle training in four regions: forehead, periocular region, nasus and perioral regions, which are innervated by the temporal, zygomatic, buccal and mandibular marginal branches of the facial nerve, respectively. The training methods for these four regions are listed in Table 1.

Key training points

- Stay in a quiet environment to concentrate on the training.
- Slow and tonic muscle control is desirable. Each motion is repeated four to five times.
- Only the affected side should be trained; relax muscles of the uninvolved side as much as possible.
- Assist the muscles towards the desired direction if movement is not possible. Resist this movement with

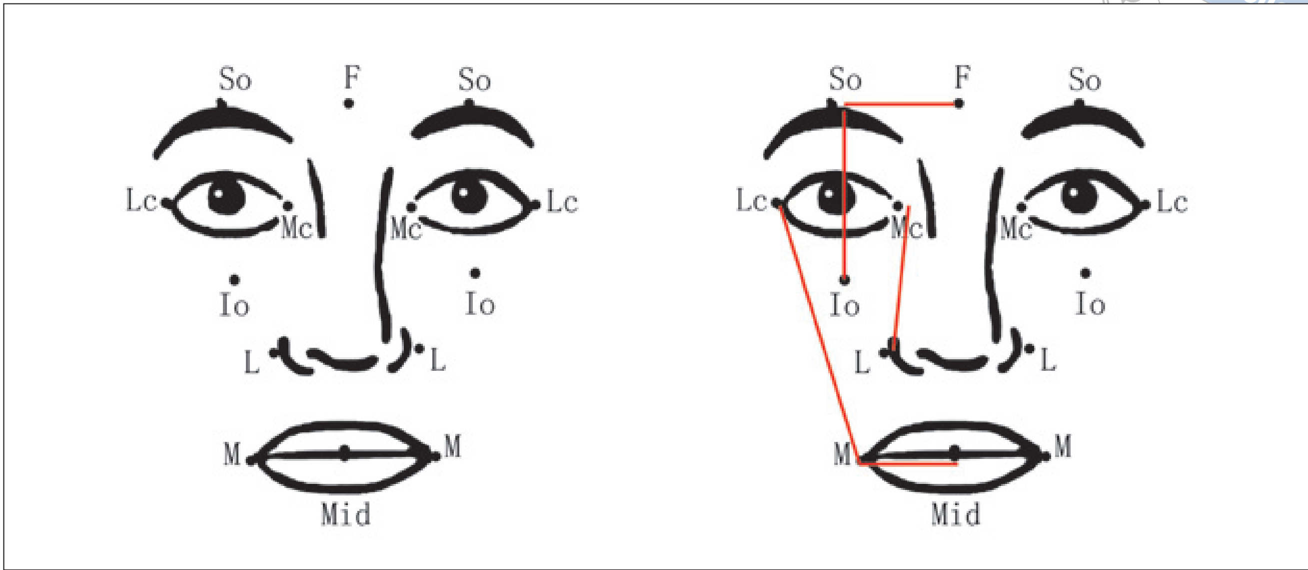

Fig 1 Quantitative facial nerve function estimate.

The metric points:
So: superior orbit, directly above pupil and the highest point of the brow arch
Io: inferior orbit, directly below pupil
Lc: bony lateral canthus
Mc: medial canthus
F: middle point of bilateral point So
L: junction of nasolabial fold
M: corner of mouth
Mid: midline at centre of mouth

The following metric indices were evaluated at rest and relative to facial motions:
a) forehead raise: SoIo
b) eyes closed tight: SoIo;
c) eyebrows knit tight: SoF
d) nose wrinkled: McL
e) smile: LcM and MMid
f) pout: LcM and MMid
g) mouth open to maximal: MMid
h) eyes closed normally and tightly: distance of the palpebral fissure

Count formulae:
PD = $|d1-d2| / |D1-D2|$
RFNI = the sum of the PD of one region/sum of the motion times
PD: percent of distance move
RFNI: regional facial nerve index
d1: the metric distance of the uninvolved side at rest
d2: the metric distance of the uninvolved side during motion
D1: the metric distance of the involved side at rest
D2: the metric distance of the involved side during motion

light finger pressure when the muscle movement is visible in order to improve the muscle strength.
- Persist with the training for as long as possible.

Training procedures

First, the doctor designed a training program according to the degree and location of nerve injury and gave the patient appropriate training instructions according to the training DVD. Second, after acquiring the proper training technique, the patient did the exercise at home in front of a mirror on his/her own or with the help of others. Third, the patient was followed up at regular intervals for the evaluation of the training effect. The training program was adjusted accordingly.

Methods of evaluation

Facial mimic muscular motor function was objectively quantified before and at 1, 3, 6 and 12 months after treatment by three kinds of facial nerve functional estimating systems as follows.
- House-Brackmann grading system (HB grade)[4,5]: the results were given by two doctors who worked in this field for more than 10 years. The facial nerve function was estimated by the classic HB grading system[4] and a modified HB grading system[5] in all patients during the follow-up.
- Quantitative facial nerve function estimating system (QFES, Fig 1)[6]: maximal facial expressions were quantified by linear measurement of surface

Table 2 The classification of the facial nerve injury*.

Degree	Facial nerve function	QFES (RFNI)	HB	Delayed percentage of the LT (DPLT)
I	Normal	≥ 80%	I	< 10%
II	Mild dysfunction	70% ≤ RFNI < 80%	II	10% < DPLT ≤ 25%
III	Moderate dysfunction	50% ≤ RFNI < 70%	III or IV	25% < DPLT ≤ 40%
IV	Severe dysfunction	< 50%	V or VI	> 40%

* QFES: quantitative facial nerve function estimating system
RFNI: regional facial nerve function index in QFES
HB: House-Brackmann grading system; LT: latency time

Table 3 The recovery after mild facial nerve injury (N = 61).

Groups	N	Ti	Tf	Percentage of recovery (%)	Percentage of sequelae (%)
Treatment group	36	2.1 ± 0.72	4.0 ± 1.26	100	0
Control group	25	2.3 ± 1.02	4.3 ± 1.17	100	0

N: the number of injured nerve branches; Ti: initial recovery time (months); Tf: final recovery time (months)

Table 4 The recovery after moderate facial nerve injury (N = 83).

Groups	N	Ti	Tf	Percentage of recovery (%)	Percentage of sequelae (%)
Treatment group	56	3.2 ± 1.07*	7.2 ± 1.88*	94.6	0
Control group	27	5.3 ± 1.39	9.8 ± 2.05	85.2	3.7

N: the number of injured nerve branches; Ti: initial recovery time (months); Tf: final recovery time (months); *$P < 0.05$ vs. control group

Table 5 The recovery after severe facial nerve injury (N = 97).

Groups	N	Percentage of recovery (%)	Percentage of unsuccessful cases (%)			Percentage of sequelae (%)
			Mild	Moderate	Severe	
Treatment group	61	31.1*	16.4	34.4	18.1	11.1*
Control group	36	16.7	2.78	33.3	47.2	61.5

N: the number of injured nerve branches; Mild: mild facial nerve dysfunction; Moderate: moderate facial nerve dysfunction; Severe: severe facial nerve dysfunction; *$P < 0.05$ vs. control group

anatomic landmarks according to research by the Department of Oral & Maxillofacial Surgery, Peking University School and Hospital of Stomatology (Fig 1). The distances between landmarks at rest and during seven standard facial expressions (raise eyebrows, wrinkle forehead deeply, close eye tightly, wrinkle nose, grin, pout and open mouth) were measured. The percentages of the displacement of these landmarks were compared between the normal and paralysed side. The details of this method are shown in Figure 1.

- Electroneurography (ENoG): a four channel electromyographic instrument (OTE Biomedica, Genoa, Italy) was used in the present study. Surface electrodes with 2 cm polar distance were placed on the skin over the facial muscles, aligning supposed muscle fibre directions with conductive paste and attached using adhesive tape. The stimulating electrode was placed on the skin behind the mandibular ramus and right below the earlobe. With a supramaximal stimulus applied transcutaneously to the facial nerve, the latency time (LT) of the facial nerve was recorded.

The delayed percentage of the LT (DPLT) was used as a quantitative standard for diagnosis of facial palsy.

$$DPLT = |LT2 - LT1| \div LT1$$

LT1 was the LT of the control side and LT2 was the LT of the facial palsy side.

The degree of facial nerve injury was divided into four grades by combining these three indexes. The classification is listed in Table 2.

The gender and age of the patients, location and degree of facial nerve injury, the initial recovery time (Ti), the final recovery time (Tf), and sequelae were recorded. Ti was defined as the time needed for significant recovery of the facial nerve function during the follow-up after injury. Tf was defined as the time after which no further improvement of facial nerve function was obtained.

Statistical analysis

All data were analysed by SPSS (version 11.0 for Windows) with an independent sample *t* test or chi-square test. A value of $P < 0.05$ was considered to be statistically significant.

Results

Ninety-two patients with 241 injured branches of the facial nerve were studied. There was no significant difference in the degree or the distribution of the facial nerve injury between the control group (88 branches) and the treatment group (153 branches) ($P > 0.05$).

The minimum follow-up period required for the patient to recover completely was 3 months. The longest follow-up period after which some patients still did not recover completely was 4 years. In total, 62% (57/92) of patients recovered within 1 year and 38% (35/92) of patients failed to recover within 1 year. The degree of injury and the recovery time are shown in Tables 3 to 5. The Ti and Tf of the mild injury were not significantly different between the treatment group and the control group ($P > 0.05$, Table 3). In the moderate injury group, the Ti and Tf of the treatment group were significantly shorter than that of the control group ($P < 0.05$, Table 4). However, no significant difference in the percentage of recovery was found between the two groups ($P > 0.05$, Table 4). In the severe injury group, the Ti and Tf of the two groups were not compared, because not all of the patients recovered fully in the first year. The recovery rate of the treatment group was superior to the control group in the first year after severe nerve injury ($P < 0.05$).

No sequelae occurred in the mild injury group. In the moderate injury group, there was only one patient that suffered from synkinesis. For the patients with severe injury, 61.5% had sequelae such as synkinesis or hemifacial spasm in the control group, but only 11.1% of patients had sequelae in the treatment group ($P < 0.05$, Table 5).

Discussion

There are currently several methods used to assess a patient's facial nerve function. Subjective grading systems include five-point gross scales, regional systems and specific scales. The House-Brackmann system is widely accepted as the simplest and most practical specific scale[4]. Yen et al modified the House-Brackmann scale for regional evaluation of peripheral facial nerve injury[5]. Objective grading systems include linear measurement[6] and electroneurography[7].

The QFES, which was developed at the Department of Oral & Maxillofacial Surgery, Peking University School and Hospital of Stomatology, was used in the present study[6]. It was well-suited for the estimation of traumatic peripheral facial nerve injury. Traumatic peripheral facial nerve injury is different from Bell's palsy. In traumatic peripheral facial nerve injury, there may either be only several of the facial nerve branches injured while the other branches remain normal or the involvement of all branches of the facial nerve to varying degrees. In Bell's palsy, all branches of the facial nerve are usually involved, and the degree of injury is correlated to the branches. Thus, the assessment of the traumatic peripheral facial nerve injury should be different from Bell's palsy. Unbiased results can be obtained from the combined use of the HB grading system, QFES and electroneurography to estimate the facial nerve function of different regions of the face.

Previous studies showed that biofeedback training is effective in the treatment of long-standing facial nerve paralysis and the sequelae of facial palsy[1,3,8]. Studies have also shown the effect of electromyographic rehabilitation on facial function for hypoglossal-facial nerve anastomosis[2,9]. This training helps to alleviate patients' psychological barrier when confronted with social discrimination due to their facial disfigurement. The results of the present study showed that, for incomplete facial nerve injury, the Ti of the treatment group was shorter than that of the control group in the mildly injured group, although it had no statistical significance. The early spontaneous recovery of these mild injury nerves may explain the lack of difference of Ti and Tf between the two groups. The functional training helped the patients to establish self-confidence and take part in social activity earlier. In the moderate injury group, both the Ti and Tf of the treatment group were shorter than those of the control group. In the severe injury group, the recovery rate of the treatment group was higher than that of the control group and the percentage of sequelae was lower than that of the control group in the first year. These results indicate that functional training may facilitate the recovery of the facial nerve and decrease the percentage of sequelae when facial nerve injury is moderate or severe.

Some authors[10,11] have suggested that starting a treatment protocol before clinical evidence of reinnervation may be inappropriate and may even be detrimental to the overall outcome. It has been suggested that attempts to actively exercise before the time of reinnervation may over-activate the musculature on the intact side and further exacerbate the difference between the paralysed and uninvolved side. However, the results of the present study didn't agree with this suggestion.

Most patients have the misconception that force can be transferred from the uninvolved side of the face to the paralysed side. They tend to exaggerate the motion on the normal side of the face in order to achieve this. In the present training project, the patients were given a clear explanation of the fact that the left and right sides of the face have separate innervation. The different muscle groups are normally independently innervated. With this information, the patients could better cooperate by moving the muscles as requested by the instructor. When the training procedures were too difficult for the patients, the patients were instructed to do the same exercise in the uninvolved side slowly. As soon as they could manage the exercise, the same task on the involved side was encouraged. In the present training procedure, it was stressed that the patients should exercise in the involved side only. The uninvolved side was to be relaxed while exercising. Therefore, it was suitable for the patients to begin training earlier if the proper training procedures were followed.

The study of O'Dwyer et al[12] observed that even with practice it is not possible to use a single muscle in isolation. They concluded that a combination of different muscles contracting at the same time corresponded to different gestures. Therefore, it can be hypothesised that neuromuscular retraining of the face should include gestures which selectively stimulate functional and multiple muscle control. The study of Balliet[10] showed that fast, automatic gestures are associated with poor control and are more susceptible to fatigue. The author emphasised slow, tonic muscle control in the retraining procedure. In the present training procedure, the patients were required to fully concentrate on and hold the training gestures as long as they could. Each motion was required to be repeated four to five times, slowly and firmly. Some patients complained of no facial movement in the early stage of training. They were encouraged to keep up the training. In this stage, even though no facial movement was noted, intact nerve fibres would be activated, and the exercises would help to maintain muscle tone.

Several authors[1,3,13] have hypothesised about the mechanisms for the therapeutic effects of functional training based on brain plasticity or its adaptive response to demand. With facial nerve injury, the orderly flow of neuronal information is interrupted. Afferent or efferent neurotransmission either ceases or becomes residual. When recovery does not occur spontaneously, training for enhancement of sensorimotor integration is essential. It is thought that appropriate patterns of information delivered to the nerve system induce functional reorganisation. This feedback may substitute for missing or diminished sensory input and aids in the formation of cerebral feedback loops involved in voluntary movement.

Other authors[14] have shown that, besides ipsilateral facial nerve innervation, the facial musculature may be reinnervated by other cranial nerves. The possible alternate routes include the contralateral facial nerve, trigeminal and sphenopalatine nerves. Biofeedback training may allow the brain to make use of the ipsilateral facial nerve and alternate routes to control the facial muscles.

Although the effect of biofeedback training has been controversial in the treatment of synkinesis after Bell's palsy in a systematic review[15], many studies have shown a positive result after training, especially in reducing the rate of synkinesis.

In conclusion, functional training may facilitate the facial blood circulation, delay facial muscle atrophy, aid in the formation of the correct cerebral feedback loops and thus facilitate injured facial nerve function recovery in the involved side.

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