FACIAL REANIMATION USING HYPOGLOSSAL-FACIAL NEURORRHAPHY WITH END-TO-SIDE COAPTATION BETWEEN THE JUMP INTERPOSITIONAL NERVE GRAFT AND HYPOGLOSSAL NERVE: OUTCOME AND DURATION OF PREOPERATIVE PARALYSIS

MASAYUKI OKOCHI, M.D., Ph.D.,* KAZUKI UEDA, M.D., Ph.D., HIROMI OKOCHI, M.D., Ph.D., EMIKO ASAI, M.D., Ph.D., TAKAO SAKABA, M.D., and AKIYOSHI KAJIKAWA, M.D., Ph.D.

Background: In this report, we described the use of hypoglossal-facial neurorrhaphy with end-to-side coaptation between the jump interpositional nerve graft and the hypoglossal nerve for facial reanimation and analyzed the relationship between the outcome of surgery and duration of preoperative paralysis. *Methods:* We performed hypoglossal-facial neurorrhaphy with the jump interpositional nerve graft on nine men and 10 women with unilateral complete facial paralysis. The patients, with a mean age of 39.7 ± 18.1 years (range, 8–65 years) at the time of surgery, experienced preoperative paralysis ranging from 1 to 150 months (mean, 16.9 ± 34.9 months). The movement of the corners of the mouth was evaluated 12 months after surgery using a unique method based on the House–Brackmann grading scale. *Results:* The mean follow-up was 5.6 ± 1.6 years (range, 3–9 years). The movement of the corners of mouth was classified as excellent in two cases, good in seven cases, fair in two cases, and poor in eight cases. Nine of the 11 cases with preoperative paralysis of 6 months or less had excellent or good results, whereas none of the eight cases with preoperative paralysis of 7 months or longer yielded excellent or good results, showing a significant difference ($P = 0.01$). *Conclusions:* To achieve successful reanimation of the corners of the mouth, hypoglossal-facial neurorrhaphy with end-to-side coaptation between the jump interpositional nerve graft and the hypoglossal nerve should be performed within 6 months after the onset of facial nerve paralysis. © 2015 Wiley Periodicals, Inc. Microsurgery 00:000–000, 2015.

INTRODUCTION

Because the symptoms of facial nerve paralysis are wide-ranging, facial reanimation requires a method that reproduces natural and powerful facial expressions with symmetry rather than a method that produces mass movement.[1–20] Many authors have reported on muscle transfer for reanimation of the corners of the mouth.[14–16,18] However, this procedure is mainly performed in cases of long-term paralysis.[14–16,18] We believe that reanimating the mimetic muscle is one of the most effective procedures for reconstructing a natural smile. Nerve transplantation or neurorrhaphy should be performed before the mimetic muscles become atrophic.[3,10,12] To rehabilitate the mimetic muscle, we performed jump interpositional nerve graft hypoglossal-facial nerve neurorrhaphy. In conventional hypoglossal-facial neurorrhaphy, the hypoglossal nerve is cut and sutured to the main trunk of the facial nerve.[2] To avoid cutting the hypoglossal nerve, May et al.[12] introduced jump interpositional nerve graft hypoglossal-facial nerve neurorrhaphy. In this method, the graft nerve is sutured to the hypoglossal nerve with end-to-side coaptation. However, mass movement is observed in both methods because the main trunk of the facial nerve is used. In contrast to May's method, we used the buccal branch of the facial nerve.[1] As a result, neither mass movement nor tongue atrophy was observed. We hypothesized that our method would be useful for rehabilitating the affected side and that there would be a relationship between postoperative results and the duration of preoperative facial paralysis. Although this relationship has been reported,[3,10] there have been no studies suggesting the acceptable duration of delay in jump interpositional nerve graft hypoglossal-facial neurorrhaphy. Here, we describe the use of end-to-side jump interpositional nerve graft hypoglossal-facial neurorrhaphy for facial reanimation, in which the interpositional nerve graft was performed between the hypoglossal nerve at the level of the intermediate tendon of the digastric muscle and the buccal branch of the facial nerve, and analyzed the relationship between the outcome of surgery and duration of preoperative paralysis.

PATIENTS AND METHODS

There were 19 patients (nine men and 10 women), with a mean age of 39.7 ± 18.1 years, who had undergone interpositional nerve graft hypoglossal-facial neurorrhaphy for unilateral complete facial paralysis at Fukushima Medical University Hospital between April 2004 and April 2012. Patients experienced preoperative paralysis ranging from 1 to 150 months (mean, 16.9 ± 34.9 months). All patients preoperatively underwent needle electromyography of the mimetic muscles on the affected side of the face. We applied our methods to the patients with fibrillation potentials on electromyography. Patients with spontaneous recovery, who could

Department of Plastic and Reconstructive Surgery, Fukushima Medical University, Fukushima City, Fukushima, 960-1295, Japan

*Correspondence to: Masayuki Okochi, M.D., Ph.D., Department of Plastic and Reconstructive Surgery, Fukushima Medical University, 1 Hikarigaoka, Fukushima 960-1295, Japan. E-mail: oktms-okt@umin.ac.jp

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Table 1. Patient Characteristics and Outcomes

No.	Age (years)	Sex	Causes of facial palsy	Affected side	Duration of preoperative paralysis (months)	Concurrent surgery	Postoperative period before movement (months)	Additional surgery (months after surgery)	Follow-up period after surgery (years)	Result
1	30	F	Acoustic neurinoma	R	1	CFNG	6	(−)	6	Excellent
2	44	M	Trauma	R	2	CFNG	8	(−)	5	Excellent
3	37	F	Acoustic neurinoma	L	5	CFNG	4	(−)	7	Good
4	38	F	Meningioma	L	5	CFNG	4.5	(−)	6	Good
5	54	F	Acoustic neurinoma	R	2	CFNG	11	(−)	7	Good
6	28	F	Acoustic neurinoma	R	2	CFNG	9	(−)	7	Good
7	45	M	Acoustic neurinoma	R	2	CFNG	7	(−)	5	Good
8	54	M	Acoustic neurinoma	L	2	CFNG GP	10	(−)	5	Good
9	28	F	Petrosal cholesteatoma	L	6	CFNG	12	LD (16)	9	Good
10	38	M	Schwannoma	L	9	CFNG	8	(−)	3	Fair
11	24	M	Acoustic neurinoma	L	6	CFNG	4	(−)	8	Fair
12	55	M	Trauma	R	9	CFNG	No movement	(−)	7	Poor
13	10	M	Trauma	L	24	CFNG GP	No movement	(−)	5	Poor
14	8	F	Trauma	L	150	CFNG	No movement	(−)	4	Poor
15	65	M	Acoustic neurinoma	R	3	CFNG GP	No movement	Temporal fascia transfer (15)	6	Poor
16	56	F	Trauma	R	16	CFNG	No movement	(−)	4	Poor
17	62	F	Bell's palsy	R	60	CFNG	No movement	(−)	5	Poor
18	65	M	Bell's palsy	L	7	CFNG	No movement	(−)	4	Poor
19	14	F	Medulloblastoma	R	10	CFNG	No movement	(−)	3	Poor

CFNG: cross-facial nerve grafting, LD: free latissimus dorsi muscle flap transfer, GP: gold plate insertion.

move the corners of the mouth without pushing their tongue against the hard palate, were excluded. The causes of paralysis were acoustic neurinoma in eight cases, trauma in five cases, brain tumor in four cases, and Bell's palsy in two cases. The neurological surgeons referred all their patients with brain tumor or trauma and who had postoperative facial paralysis to our department. Along with end-to-side jump interpositional nerve graft hypoglossal-facial neurorrhaphy, cross-face nerve graftings were performed in the 19 cases, three of which also had gold plate insertions (Table 1). The cross-face nerve grafting and gold plate insertion were undertaken to reconstruct the function of eyelid closure.

Surgical Technique

After each patient received general anesthesia and was placed in the dorsal position, an incision of $5-7$ cm was made in the lower jaw, the platysma was cut, and the submandibular gland was identified. The lower end of the submandibular gland was then pulled upward with the intermediate tendon of the digastric muscle to expose the hypoglossal nerve. To carry out nerve suture, a window was made only in the epineurium of the side of the hypoglossal nerve. Next, a skin incision was made slightly caudal to the center of the cheek on a perpendicular line from the lateral canthus to identify the buccal branch of the facial nerve. The sural nerve or lateral femoral cutaneous nerve was then harvested for a graft. Finally, the caudal side of the harvested nerve was sutured to the hypoglossal nerve in end-to-side fashion (Fig. 1) and to the facial nerve in end-to-end fashion, with interrupted 10-0 nylon sutures (Fig. 2).

Evaluation of the Outcomes

We recorded data on the cause of paralysis, duration of preoperative paralysis, and duration from surgery to the first movement of the corners of the mouth. After surgery, plastic surgery specialists regularly examined the patients' mimetic muscles and tested for Tinel's sign. Electromyography was also used when necessary. Movement of the corners of the mouth only induced by pushing the tongue against the hard palate was evaluated. For assessment, we used a unique method focusing on this movement, a modified version of the House–Brackmann scale, which was created in a previous study to assess facial movements (Table 2).[17] Grades I and II on the House–Brackmann scale were regarded as excellent, III and IV as good, V as fair, and VI as poor. Postoperative results were classified into two groups, excellent/good and fair/poor, based on the assessment results. Tongue atrophy and functional disorder were also examined.

Statistical Analysis

The relationship between preoperative duration of paralysis and postoperative results was examined using a

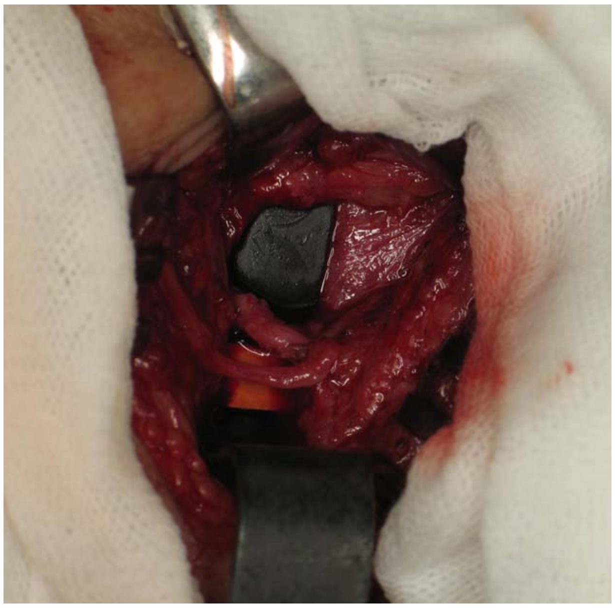

Figure 1. The right hypoglossal nerve was exposed. Neurorrhaphy was performed in end-to-side fashion between the graft nerve and the hypoglossal nerve.

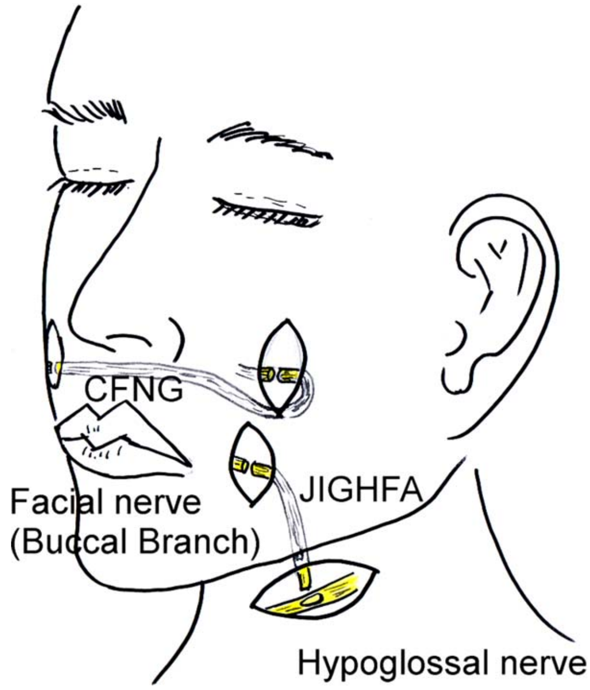

Figure 2. Schema of our procedure. An incision of 5 – 7 cm was made in the lower jaw. A window was made only in the epineurium of the side of the hypoglossal nerve. A skin incision was made slightly caudal to the center of the cheek on a perpendicular line from the lateral canthus to identify the buccal branch of the facial nerve. The caudal side of the graft nerve was sutured to the hypoglossal nerve in end-to-side fashion and to the facial nerve in end-to-end fashion, with interrupted 10-0 nylon sutures.

two-sided *t*-test. Distribution of the assessment results was analyzed with Fisher's exact test. All statistical tests were performed using SPSS ver.21 (IBM, New York), and $P < 0.05$ was considered significant.

RESULTS

Patient characteristics and outcomes are shown in Table 1. The follow-up period after surgery ranged from 3 to 9 years (mean, 5.6 ± 1.6 years). Our assessment results were excellent in two cases, good in seven cases, fair in two cases, and poor in eight cases. The movement of the corners of the mouth was induced by pushing the tongue against the hard palate in all cases except for those classified as poor. In the excellent/good group, the mean preoperative paralysis period was 3.0 ± 1.8 months, whereas this period was 29.5 ± 45.5 months in the fair/poor group. There was a significant difference between the two groups in the preoperative duration of paralysis ($P = 0.049$; Table 3). No significant difference was found in the age of patients between the two groups ($P = 0.491$; Table 3). Nine of the 11 cases with preoperative paralysis of 6 months or less had excellent or good results, whereas none of the eight cases with preoperative paralysis of 7 months or longer yielded excellent or good results, showing a significant difference ($P = 0.01$; Table 4). No wound infection occurred, and neither tongue atrophy nor functional disorder was observed. In case 9 (Table 1), although the movement of the corner of mouth was classified as good, the patient wanted more of powerful movement. Therefore, free latissimus dorsi muscle flap transfer was performed. In case 15 (Table 1), the result of cross face nerve graft was not sufficient. Therefore, temporal muscle transfer was performed to improve eye lid closure. These procedures were successfully performed.

Case Reports

Case 1. A 30-year-old woman underwent resection of the acoustic neurinoma by a neurosurgeon. Although the tumor was separated from the facial nerve, she had complete right-side facial nerve paralysis. She was referred to our department 1 week after the operation (Fig. 3a). Electromyography was performed, and fibrillation potential was examined. We performed interpositional nerve graft hypoglossal-facial neurorrhaphy. Preoperative duration of facial paralysis was 3 months. The patient had no postoperative bleeding or infection. Seven months after the operation, the patient was able to lift the corners of the mouth. One year after the operation, the movement of the angle of the mouth showed excellent results (Figs. 3b–3d).

Case 2. A 44-year-old man was admitted to the emergency department with a temporal bone fracture as a result of a traffic accident. Immediately after hospitalization,

Table 2. Evaluation of Movement

House–Brackmann grading scale	Evaluation	Movement	Result
I	Normal	Normal movement	Excellent
II	Mild dysfunction	Strong but slightly asymmetrical oral angle movement	
III	Moderate dysfunction	Strong but asymmetrical oral angle movement	Good
IV	Moderately severe dysfunction	Asymmetrical oral angle movement even at ease	
V	Severe dysfunction	Slight movement of the oral angle	Fair
VI	Total dysfunction	No movement	Poor

Our grading scale was based on the House–Brackmann grading scale.

Table 3. Relationship Between Patients' Age or Preoperative Paralysis Period and Postoperative Result

	Excellent, good ($n = 9$)	Fair, poor ($n = 10$)	P
Age (years)	39.8 ± 10.2	39.7 ± 23.7	0.4915
Months of preoperative paralysis	3.0 ± 1.8	29.5 ± 45.5	0.0493

Table 4. Frequency Table of Preoperative Paralysis Period and Postoperative Evaluation[a]

Duration of preoperative paralysis	Excellent, good	Fair, poor
6 months or less	9	2
7 months or longer	0	8

[a]P = *0.01.*

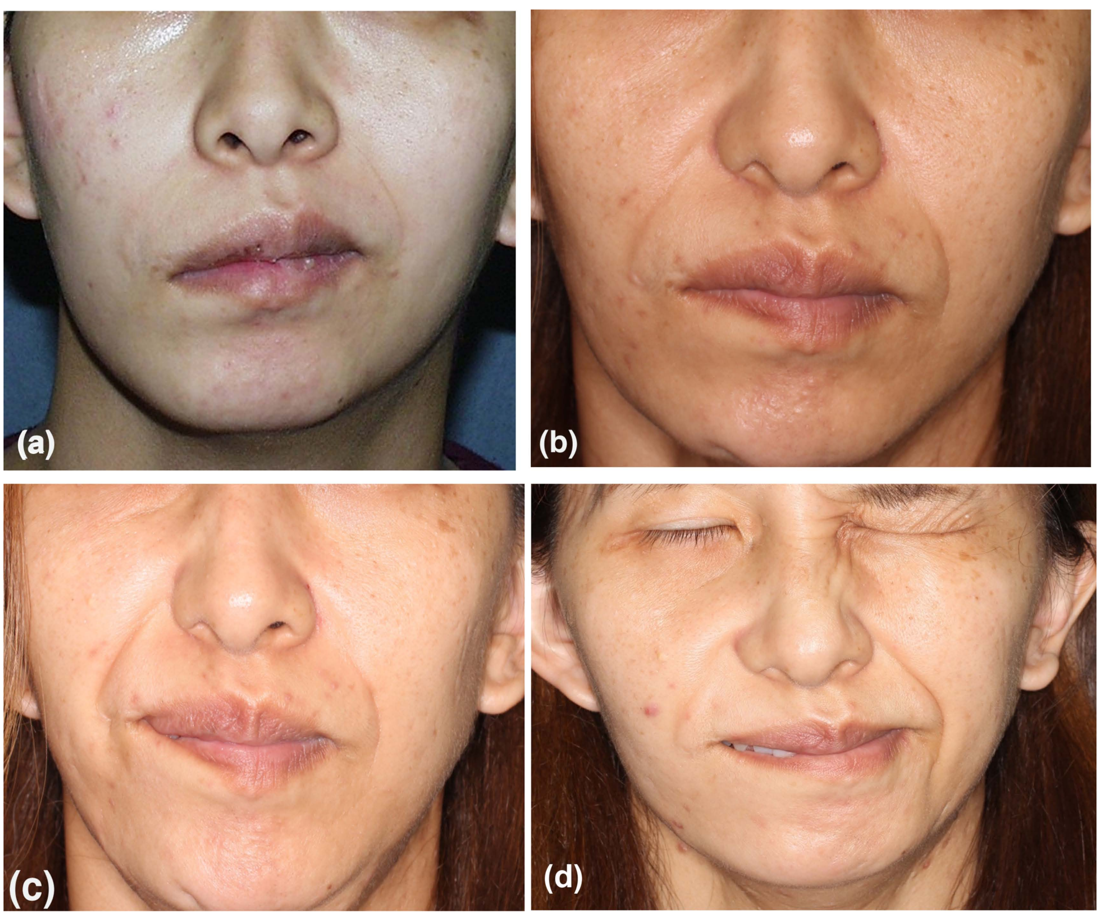

*Figure 3. (**a**) Preoperative view of patient. No movement was observed. (**b**) One-year postoperative view. Patient at rest. (**c**) One-year postoperative view. Powerful and symmetrical smile was observed. (**d**) One-year postoperative view. Maximum effort of both sides. The movement of the corners of the mouth was not observed.*

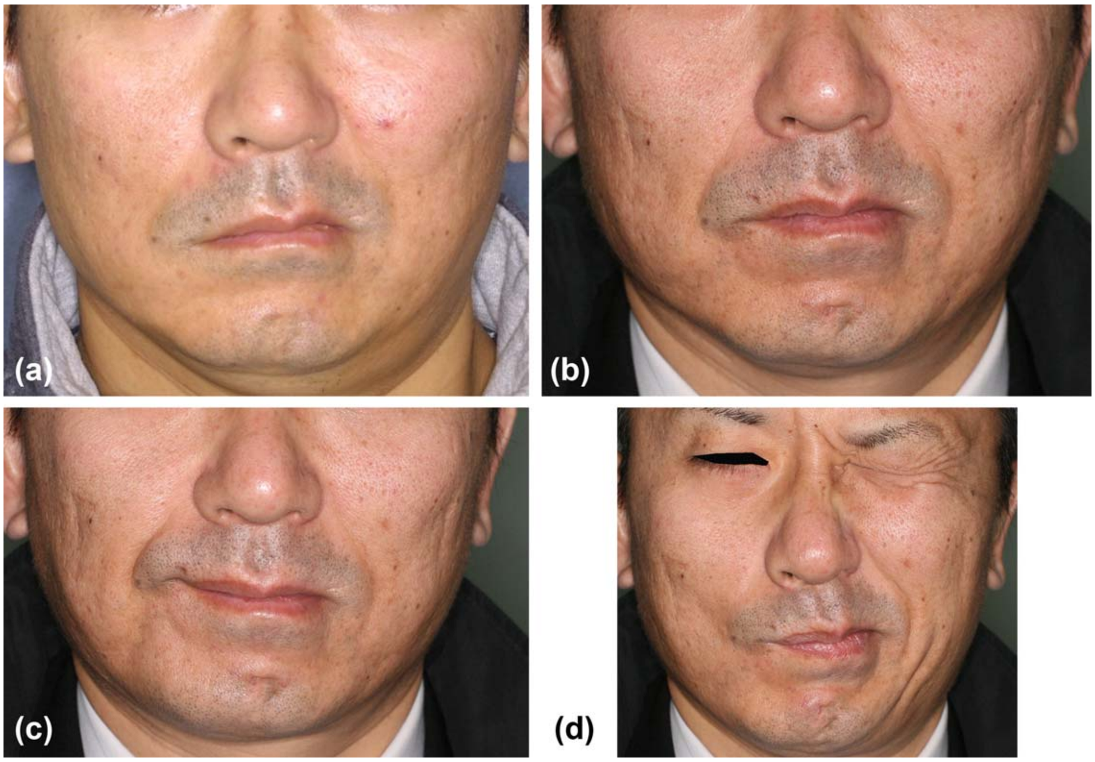

*Figure 4. (**a**) Preoperative view of patient. No movement was observed. (**b**) One-year postoperative view. Patient at rest. (**c**) One-year postoperative view. Powerful and symmetrical smile was observed. (**d**) One-year postoperative view. Maximum effort of both sides. The movement of the corners of the mouth was not observed.*

right-side facial paralysis was observed. One month after the onset of facial palsy, he was referred to our department (Fig. 4a). Electromyography was performed, and fibrillation potential was examined. We performed interpositional nerve graft hypoglossal-facial neurorrhaphy. The preoperative duration of facial paralysis was 2 months. Eight months after operation, a lift of the corners of the mouth was observed. Four months later, the result was classified as excellent (Figs. 4b–4d).

DISCUSSION

Good or excellent results were obtained in 47.3% of our cases. Furthermore, 90% of the patients whose preoperative period of paralysis lasted 6 months or less achieved good or excellent results. These results suggest that our method needs to be performed within 6 months from the onset of paralysis to achieve good results.

To reconstruct a natural smile, recovery of the mimetic muscles is very important. Nerve transplantation or neurorrhaphy has been performed to rehabilitate mimetic muscles.[1–13] Hypoglossal-facial neurorrhaphy was first introduced by Körte in 1903,[2] and the procedure is recognized as classic-type hypoglossal-facial nerve neurorrhaphy. In this procedure, the hypoglossal nerve is cut and directly sutured to the main trunk of the facial nerve. In classic-type hypoglossal-facial neurorrhaphy, good results were mainly obtained in patients with preoperative paralysis of 12–24 months.[2–5] In partial dissection-type hypoglossal-facial neurorrhaphy, the hypoglossal nerve is longitudinally split into two pieces for conservation and sutured to the main trunk of the facial nerve.[7,8] In this method, good results were mainly achieved in the cases with preoperative paralysis of up to 12 months.[7,8] Despite these good results, tongue atrophy and functional disorder were almost inevitable consequences of the two methods.[2–8] Especially in the classic-type hypoglossal-facial neurorrhaphy, tongue atrophy was observed in 45%[4]–90[6]% of the cases. To solve this problem, May et al. reported a new method, the jump interpositional nerve graft hypoglossal-facial neurorrhaphy, in which the hypoglossal nerve is not cut. In their procedure, interpositional nerve graft is performed between the hypoglossal nerve and trunk of the ipsilateral facial nerve. In other instances of interpositional nerve graft hypoglossal-facial neurorrhaphy, good results were mostly obtained in patients whose preoperative paralysis was within 12 months.[4,9–13] These results suggest that surgical procedure should be less invasive for the hypoglossal nerve.

In contrast to other jump interpositional nerve graft hypoglossal-facial neurorrhaphy procedures, our patients whose preoperative paralysis of 6 months or less achieved good results, showing the effectiveness of our procedure for patients with relatively short preoperative paralysis. Terzis et al.[20] reported on the effect of axonal load on the functional and aesthetic outcomes of the cross-facial nerve graft. In this report, they concluded that the axon count at the donor nerve had a stronger influence on the final result.[20] In our procedure, we only created an epineural window. We believe this is the reason why our method is required to be performed early. Other forms of jump interpositional nerve graft hypoglossal-facial neurorrhaphy require not only an epineural window on the hypoglossal nerve but also a partial resection of nerve fibers.[4,12,13] In 2014, Liu et al.[21] reported an experimental study of end-to-side neurorrhaphy with epineural window and partial neurectomy. In that study, they analyzed donor-site morbidity. Their results showed that partial neurectomy did not cause donor-site morbidity after long-term follow-up. However, they used a rat lower leg model. Additionally, they reported that decrease in function of the donor site was observed during the early postoperative period. In clinical cases with partial resection, tongue atrophy and slight or mild levels of functional disorders occurred,[4,12] whereas our method had no occurrence of tongue disorders.

Because the outcomes were poor in the cases with preoperative paralysis of 7 months or longer, early performance of our jump interpositional nerve graft hypoglossal-facial neurorrhaphy should be considered when fibrillation potentials are seen on electromyography. We use the buccal branch rather than the main trunk of the facial nerve, as our procedure only targets the reanimation of the corners of the mouth. Our method may also be selected even when spontaneous recovery is possible.

Recently, successful nerve reconstruction using vascularized nerve graft has been reported.[22–24] The vascularized nerve graft is a useful procedure to reconstruct the long nerve gap.[24] On the other hand, the gap between the hypoglossal nerve and buccal branch of the facial nerve is not long. We believe that the vascularization of the graft nerve is not required in hypoglossal-facial neurorrhaphy. However, it may warrant further investigation. Our patients could produce a symmetrical smile by pushing the tongue against the hard palate. In addition, Manktelow et al.[19] reported that the cerebral adaptation could lead to a functional and synchronized smile. Thus, although smiling was a little difficult in our patients, they were able to overcome this through rehabilitation.

CONCLUSION

The findings presented here showed that the movement of the corners of the mouth could be reconstructed by the hypoglossal-facial neurorrhaphy with end-to-side coaptation between the jump interpositional nerve graft and hypoglossal nerve. Cases in which the surgery was performed within 6 months of paralysis onset could reconstruct a natural smile with lifted angles of the mouth without mass movement. However, cases with 7 months or longer preoperative paralysis had poor results.

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