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End-to-side "loop" graft for total facial nerve reconstruction: Over 10 years experience[☆]

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Summary *Background:* Multiple-branch reconstruction is required in order to attain facial reanimation for extensive facial nerve defects. We previously reported that end-to-side nerve grafting, with the use of a single nerve graft for defect reconstruction, was easy to perform. We have also demonstrated the efficacy of end-to-side nerve suture of the recipient nerve to the donor graft nerve, in experimental rat models and clinical cases. The regenerating axons, which extended into the nerve graft, were "distributed" to multiple recipient nerves via end-to-side nerve-suture sites.
Methods: Thirty-two patients who underwent facial nerve reconstruction (five to 10 branches) had a single sural nerve graft coapted to the proximal stump of the facial nerve in an end-to-end manner, followed by end-to-side nerve suture of the recipient nerve stumps to the side of the nerve graft. In 19 patients who were expected to undergo postoperative radiotherapy and/or chemotherapy, the distal end of the graft was connected to the side of the hypoglossal nerve for "axonal supercharging," to enhance the recovery of the facial muscles.
Results: Initial facial movements were noted at 5–12 months postoperatively, and good recovery (House–Brackmann grade III/IV) was observed during long-term follow-up in most patients.
Conclusion: End-to-side nerve suture of the recipient nerve stumps to the nerve graft requires less graft nerve material and less technical mastery to reconstruct multiple branches of the facial nerve. We also described the concept of "axonal supercharging," namely the connection

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of double-donor neural sources to the graft, and "axonal distribution," namely the reinnervation of multiple recipient nerve stumps connected to the graft in an end-to-side manner. This combination of axonal supercharging and distribution can be a useful option in facial nerve reconstruction.

Introduction

Extensive facial nerve defects after ablative surgery of the parotid gland should be reconstructed to avoid permanent postoperative facial palsy. The use of multiple cable grafts to reconstruct the defect is technically demanding, and it requires a large amount of nerve graft. We reported a new technique that uses a single nerve graft with end-to-side nerve suture to recipient branches.[1] In this end-to-side nerve-suture technique, microscissors are used to make small cuts to the donor graft nerve, and the recipient nerve is connected to these "windows" by suturing the epineurium in an end-to-side manner. The efficacy of this technique was confirmed in a rat sciatic nerve model with a two-branch reconstruction[2] and a rat facial nerve model with a four-branch reconstruction.[3] The unique approach of this technique, as compared with other end-to-side neurorrhaphy techniques, is that it inflicts an injury to the donor graft nerve by partially lacerating it, and then it coapts the recipient nerve stump to the window in the graft nerve with a significant discontinuity of nerve fibers (neurotmesis). Terminal sprouting of the regenerating fibers in the severed graft is more important for re-regenerating fibers into the recipient nerve than for those from collateral sprouting.[2,3] Thus, the regeneration process in our method seems to differ from that of the "conventional" end-to-side neurorrhaphy through an epineurial window to the mostly intact donor nerve. In our technique, the graft used looks like part of a loop configuration after nerve suture to both ends and sides. We therefore refer to it as "loop-graft" technique. End-to-side nerve suture to the nerve graft allows various types of multiple-branch reconstruction of the facial nerve. In addition, the connection of the ipsilateral hypoglossal nerve as an additional donor nerve to the other end of the graft may facilitate reanimation supercharging of the regenerating nerve fibers into the recipient nerve (Figure 1). This supercharging may be more effective for severe facial nerve palsy in patients with preoperative palsy and those undergoing postoperative chemotherapy/radiotherapy.

Patients and methods

Between 2001 and 2013, 32 patients (19 men and 13 women) underwent facial nerve defect reconstruction using this method (Table 1). The patient at surgery was 25–79 years (average, 57.3 ± 2.6 years). A single nerve graft harvested from the sural nerve was used in all cases. Parotid carcinoma was the most common ($n = 24$) reason for ablative surgery, followed by benign recurrent pleomorphic adenoma ($n = 4$), squamous cell carcinoma of the cheek or the external ear ($n = 3$), and facial nerve schwannoma ($n = 1$). Preoperative facial palsy was observed in 11 patients. In 27 patients, four areas (T: temporal, Z: zygomatic, B: buccal, and M: marginal mandibular branch of the facial nerve) were reconstructed. The number of reconstructed branches was 3–10 (average, 5.7 ± 0.26 branches). In 13 patients, the ipsilateral proximal facial nerve was used as the only neural source. The other 18 patients underwent additional axonal supercharging using the hypoglossal nerve. We performed crossover coaptation to the masseteric nerve in cases where a proximal facial nerve stump was not available.

Simultaneous soft-tissue reconstruction was performed in 19 patients; the predominant flap was the pectoralis major flap in eight cases and the free anterolateral thigh flap in five cases. The areas of soft-tissue defect in these cases were limited within the parotid region or the preauricular cheek, which do not result in extensive facial muscle defect. The patients with extensive facial muscle/skin defect with the reconstruction using large flap(s) resulting in poor muscle function and poor skin pliability were excluded from this study. Duration of follow-up was 6–135 months (average, 29.0 ± 4.4 months). Disease-free patients with four-area reconstruction (TZMB) data and >18 months postoperative follow-up were evaluated based on examinations or videos at the latest visit by three plastic surgeons with at least 15 years' experience with facial nerve disorders using the Sunnybrook facial grading system[4] to assess voluntary movement, facial symmetry, and synkinesis, and the House–Brackmann (H–B) grading system[5] for a gross overview of the facial function. The most frequent or mean score in the three observers was adopted as each patient's data.

Statistical analysis

The chi-squared test was used to determine the statistical significance of differences in the postoperative H–B scores, with or without hypoglossal supercharging. The Mann–Whitney test was used to analyze differences between the groups in other variables. All differences were considered to be significant when p was <0.05.

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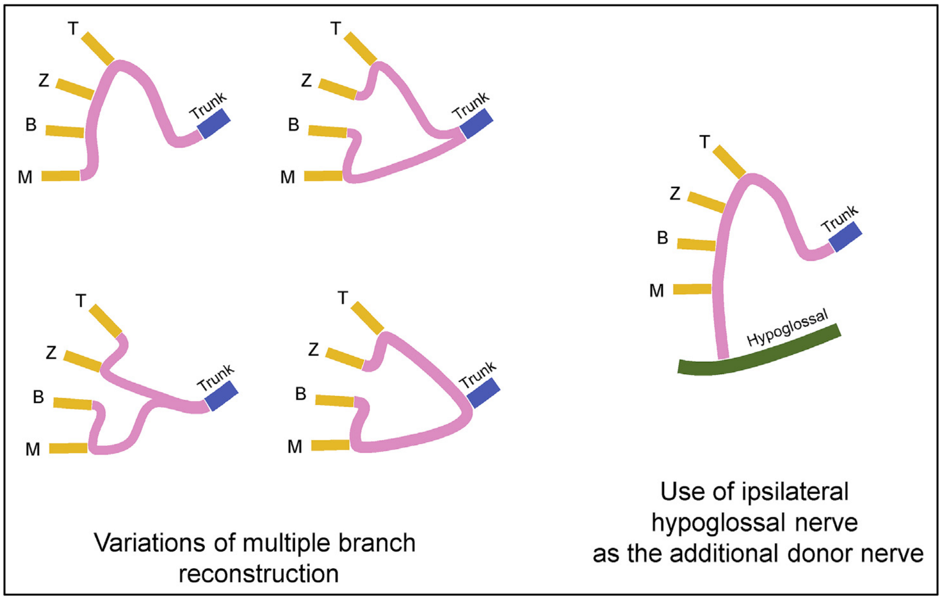

Figure 1 Use of the side of the nerve graft could allow various types of multiple-branch reconstruction of the facial nerve. Connecting the other end of the nerve graft to the side of the ipsilateral hypoglossal nerve (hypoglossal supercharging) is used to avoid the likelihood of poor postoperative regeneration in patients with preoperative facial palsy and those undergoing post-operative chemotherapy/radiotherapy (T: temporal, Z: zygomatic, B: buccal, and M: marginal mandibular branch of the facial nerve).

Surgical procedures

We began with the end-to-end neurorrhaphy between the proximal stump of the facial nerve and one end of the nerve graft. The body of the nerve graft was then laid on the soft tissue to determine the position that would avoid tension upon the nerve suture. The mandible was often exposed after wide resection of a malignant parotid tumor. In this series, the graft was placed carefully over the surrounding well-vascularized soft tissue, to avoid the exposed mandible. The placement of the graft nerve on the well-vascularized soft tissue facilitates revascularization of the graft and good axonal regeneration. This is followed by creating windows by cutting the epineurium and perineurium of the graft with nerve fibers to allow end-to-side nerve suture to the stumps of the distal branches of the facial nerves. Five to 10 branches were usually reconstructed in this manner for patients with complete ablation of the facial nerve. The other end of the nerve graft was coapted to the most distant branch in an end-to-end fashion.[1] In cases with hypoglossal supercharging, this end of the graft was coapted to the side of the ipsilateral hypoglossal nerve in an end-to-side fashion through a window made by partial neurotomy (about one-third of the nerve). All nerve sutures resulted in the nerve graft forming a part of the "loop" configuration. Simultaneous soft-tissue reconstruction was performed in patients with significant soft-tissue defects in the parotid region.

Results

The first facial movements appeared in the nasolabial region at 5–12 months postoperatively. Facial movement then improved gradually in most patients. Postoperative radiotherapy was required for 17 patients (including 12 cases of hypoglossal supercharging), and chemotherapy was required for 10 patients (including eight cases of hypoglossal supercharging). Eighteen patients were assessed at the latest evaluation, and they were rated as grade III or IV, which is compatible with the results of previous reports on multiple cable grafting.[6–8] Mild to moderate synkinetic movements, particularly in the oral to ocular direction, were observed, mainly in the H–B grade III patients. There was no significant difference in the Sunnybrook score (including voluntary movement, resting symmetry, and synkinesis) or the H–B score between groups with or without axonal supercharging using the hypoglossal nerve. Postoperative radiotherapy and chemotherapy were more frequent among patients who had undergone axonal supercharging, although the difference was not significant in this small series (Table 2). No postoperative deficit was found in the glossal function or the glossal atrophy due to partial injury to the donor hypoglossal nerve in this series.

Case reports

Case 2

A 64-year-old man underwent wide resection for a parotid carcinoma and neck dissection resulting in an extensive defect in the left facial nerve. The five distal branches were reconstructed with an end-to-side "loop-graft" technique, without hypoglossal supercharging (Figure 2). The postoperative course was uneventful, and postoperative radiotherapy (total dose, 50 Gy) was performed. Eyebrow lifting was performed at 6 months postoperatively. The

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Table 1 Summary of patients and postoperative results.

Case	Sex	Age	Original disease	Preoperative facial palsy	Reconstructed area[a]	No. of reconstructed branches	Hypoglossal supercharging	Follow-up (months)	Flap used for soft tissue reconstruction[b]	Postoperative radiotherapy	Postoperative chemotherapy	Sunnybrook score at final follow-up[c]	H–B score at final follow-up[d]
1	F	49	Parotid ca.	−	TZBM	6	−	135	DP	+		60 − 5 − 5 = 50	III
2	M	64	Parotid ca.	−	TZBM	5	−	24		+		56 − 10 − 3 = 43	III
3	M	70	Parotid ca.	−	TZBM	5	−	8	PMMC	+	+	n.a.	n.a.
4	F	41	Parotid ca.	−	TZBM	4	−	12				n.a.	n.a.
5	M	51	Parotid ca.	+	TZBM	5	+	60	PMMC	+	+	56 − 15 − 4 = 37	III
6	F	55	Parotid ca.	+	TZBM	6	+	39	RAMC	+	+	40 − 10 − 4 = 32	IV
7	M	44	Parotid ca.	+	TZB	4	+	16	RAMC	+		n.a.	n.a.
8	M	66	Pleomorphic adenoma	−	TZBM	6	+	50	SCM			60 − 5 − 6 = 49	III
9	M	53	Parotid ca.	−	TZBM	6	+	8	PMMC	+	+	n.a.	n.a.
10	M	58	Parotid ca.	+	TZBM	7	+	10	PMMC	+	+	n.a.	n.a.
11	M	55	Parotid ca.	−	BM	4	+	19	PMMC			88 − 0 − 2 = 86	II
12	M	74	Parotid ca.	+	TZBM	7	+	30	PMMC	+	+	32 − 20 − 1 = 11	V
13	M	66	Parotid ca.	+	TZBM	7	+	43	PMMC	+		60 − 0 − 7 = 53	III
14	F	32	Pleomorphic adenoma	−	TZBM	7	+	40	ALT			60 − 5 − 5 = 50	III
15	M	73	Parotid ca.	+	TZBM	6	+, with masseteric nerve	14	PMMC	+		32 − 15 − 0 = 17	IV
16	F	38	Pleomorphic adenoma	−	TZBM	7	+	15	ALT			64 − 5 − 4 = 55	III
17	F	72	SCC (external ear)	+	TZBM	6	+	8	ALT	+		n.a.	n.a.
18	F	47	Facial nerve schwannoma	−	TZBM	5	+	6				36 − 10 − 0 = 26	V
19	M	74	SCC (cheek)	−	TZBM	5	+	21	ALT	+		60 − 15 − 3 = 42	III
20	M	66	Parotid ca.	+	TZBM	7	−	26				60 − 10 − 4 = 46	III
21	F	69	Parotid ca.	+	TZ	4	+	79	DP			48 − 15 − 3 = 30	IV
22	F	79	Parotid ca.	+	TZBM	5	−	24				40 − 15 − 4 = 21	IV

23	M	68	Parotid ca.	+	TZBM	4	+	26		+	+	44 − 15 − 3 = 26	IV
24	M	38	Parotid ca.	+	TZBM	5	+	35				44 − 15 − 3 = 26	IV
25	M	55	Parotid ca.	+	TZBM	8	−	18	Local			44 − 10 − 3 = 31	IV
26	F	74	Parotid ca.	+	TZB	3	−	22		+	+	64 − 10 − 5 = 49	III
27	F	31	Parotid ca.	+	TZBM	5	−	22			+	60 − 10 − 4 = 46	III
28	M	25	Pleomorphic adenoma	−	BM	4	−	18	ALT			88 − 5 − 1 = 82	II
29	F	56	Parotid ca.	+	TZBM	7	−	20				52 − 15 − 3 = 34	IV
30	F	68	Parotid ca.	−	TZBM	10	+	36				56 − 10 − 5 = 41	IV
31	M	58	Actinomycosis	−	TZBM	6	−	24				52 − 10 − 5 = 37	IV
32	M	65	Parotid ca.	+	ZB	6	−	22		+	+	68 − 15 − 4 = 49	III
Mean			(SEM)		57.3 (2.6)				5.7 (0.26)		29.0 (4.4)		

[a] Area of reconstruction — T, temporal branch; Z, zygomatic branch; B, buccal branch; M, marginal mandibular branch.
[b] Flap used for reconstruction — DP, deltopectoral flap; PMMC, pectoralis major myocutaneous flap; RAMC, free rectus abdominalis myocutaneous flap; SCM, sternocleidomastoid flap; ALT, free anterolateral thigh flap.
[c] Sunnybrook facial grading: (symmetry of voluntary movement score) − (resting symmetry score) − (synkinesis score) − (composite score).
[d] n.a.: Not assessed due to tumor recurrence or distant metastasis.

Table 2 Characteristics of patients who did and did not undergo hypoglossal supercharging.

	Hypoglossal supercharging ($n = 10$)	No hypoglossal supercharging ($n = 8$)	p-value[a]
Age	59.2 ± 4.7	57.3 ± 4.9	0.778
Sex (M:F)	7: 3	4: 4	0.477
Preoperative palsy	6 (60.0%)	5 (62.5%)	0.929
Postoperative radiotherapy	6 (60.0%)	2 (25.0%)	0.214
Postoperative chemotherapy	4 (40.0%)	1 (12.5%)	0.328
Final Sunnybrook score			
1. Voluntary movement	51.2 ± 3.3	53.0 ± 2.7	0.676
2. Resting symmetry	11.0 ± 1.9	10.6 ± 1.1	0.870
3. Synkinesis	4.1 ± 0.5	3.9 ± 0.3	0.723
Composite score (1 − 2 − 3)	36.7 ± 4.2	37.9 ± 3.7	0.834
Final H–B score			
III	5 (50.0%)	4 (50.0%)	
VI	4 (40.0%)	4 (50.0%)	
V	1 (10.0%)	0 (0.0%)	0.637

[a] The chi-squared test was used for H–B score, and the Mann–Whitney test was used for other variables.

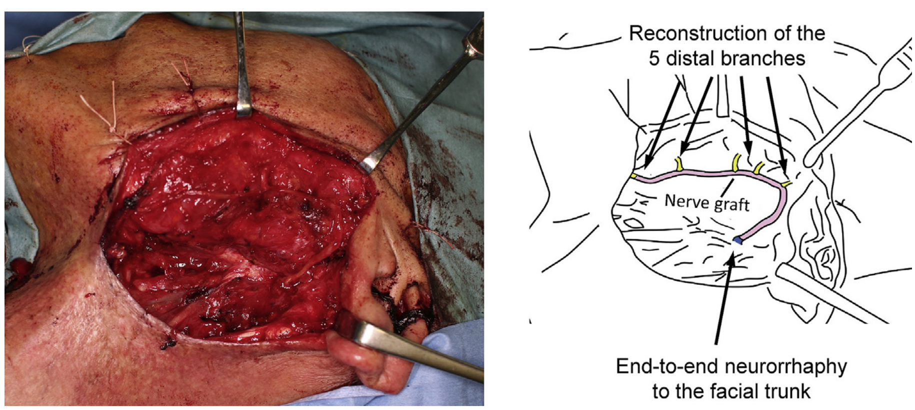

Figure 2 Intraoperative photograph of patient 2, and a schematic illustration of the reconstruction. The five distal branches were reconstructed with an end-to-side loop graft.

initial facial movement appeared at 8 months postoperatively. The final Sunnybrook and H–B scores at 24 months postoperatively were 56 − 10 − 3 = 43 and grade III, respectively (Figure 3). As the facial tonus and movement improved, mild synkinetic movements mainly oral to ocular and oral to forehead direction appeared (Video 1).

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.bjps.2015.04.005.

Case 5

A 51-year-old man underwent wide resection for recurrent parotid carcinoma, which resulted in an extensive defect of the left facial nerve. Because the patient had complete facial paralysis preoperatively, and postoperative radiotherapy and chemotherapy were planned, five distal branches were reconstructed with an end-to-side "loop graft" with hypoglossal supercharging. The soft-tissue defect was reconstructed with a pectoralis major myocutaneous flap. The postoperative course was uneventful, and the patient underwent postoperative radiotherapy (total dose, 50 Gy) and chemotherapy. Unlike most of the other cases, the initial facial movement appeared in the depressor labii at 6 months postoperatively. This movement was accompanied by tongue movement, suggesting regeneration from the hypoglossal nerve. Then, the facial movement and tonus recovered gradually, and the final Sunnybrook and H–B scores at 50 months postoperatively were 56 − 15 − 4 = 37 and grade III, respectively, which were better than the preoperative scores (Figure 4). Mild synkinetic movements, which were mainly oral to ocular direction, were present; however, the tongue movement did not cause any facial movement at this time (Video 2).

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Case 8

A 66-year-old man underwent wide resection of a re-recurrent pleomorphic adenoma strongly suspected of

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Figure 3 Postoperative photographs of case 2 patient at rest (left) and while grinning (right) at 2 months (above) and 24 months (below) post operatively. No additional surgery was performed except for eyebrow lifting at 6 months post operatively. The final Sunnybrook and H–B scores were 56 – 10 – 3 = 43 and grade III, respectively.

being a malignant conversion of the tumor, resulting in an extensive defect in the left facial nerve. The six distal branches were reconstructed with an end-to-side loop graft technique with hypoglossal supercharging. A soft-tissue defect was reconstructed with a sternocleidomastoid muscle flap (Figure 5). The postoperative course was uneventful, and histological examination of the resected tissue revealed that the tumor was benign. Postoperative radiotherapy was thus not required. The initial facial movement appeared at 7 months postoperatively. The final Sunnybrook and H–B scores at 50 months postoperatively were 60 – 5 – 6 = 49 and grade III, respectively (Figure 6). Mild to moderate synkinetic movements, which were mainly oral to ocular direction, were present; however, the tongue movement did not cause any facial mass movement (Video 3). A four-channel electromyography showed double innervation of the facial muscles (i.e., one facial muscle is reinnervated from both the facial and hypoglossal nerves) and an axonal distribution (one stimulation of the nerve graft causes compound muscle action potentials of the multiple facial regions) from dual donors (the two neural sources) (Figure 7).

Supplementary video related to this article can be found at http://dx.doi.org/10.1016/j.bjps.2015.04.005.

Discussion

As compared to the reconstruction with multiple cable nerve grafting, our loop-graft technique requires less graft nerve, and it is less demanding technically. While conventional multibranch cable grafting will sometimes be required for patients with surgically exposed mandibles, our loop grafts can often be placed away from the exposed bone and onto the well-vascularized soft tissue. In a previous experimental study,[2,3] we showed that the regenerating axons from the proximal stump of the facial nerve extend into the nerve graft, and they are distributed to each distal stump of the branches via windows created on the sidewall of the graft. These findings imply that regeneration is mainly achieved by terminal sprouting from the severed nerve fiber instead of collaterals sprouting from the internodal space. We conclude from these observations that end-to-side nerve suture to the windows created on the sidewall of the nerve graft works by creating new side pathways for the regenerating axons as they pass through these windows into the distal branches and reach the target muscles. This phenomenon, which we refer to as "axonal distribution," is quite useful in multibranch reconstruction of the facial nerve. Our research indicates that the nerve graft required in this procedure was about half[2] or even one-third[3] that is necessary to achieve equivalent results

Figure 4 Postoperative photographs of patient 5 at rest (left) and while grinning (right) at 2 months (above) and 60 months (below) post operatively. The final Sunnybrook and H–B scores at 60 months post operatively were 56 – 15 – 4 = 37 and grade III, respectively, and they were even better than the preoperative scores.

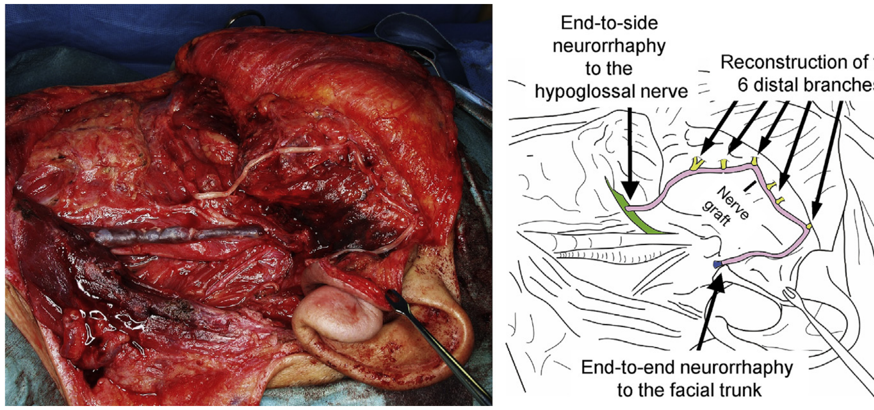

Figure 5 Intraoperative photograph of patient 8 and a schematic illustration of the reconstruction. The six distal branches were reconstructed with an end-to-side loop graft, and the other end of the nerve graft was coapted to the side of the hypoglossal nerve.

with conventional reconstruction using multiple cable grafts.

In addition, we introduced a supplementary technique, axonal supercharging,[9] that is easily performed by connecting the other end of the graft to the hypoglossal nerve or other neural sources. This procedure induces axonal regeneration from dual neural sources, and it is thus referred to as axonal supercharging or "neural signal augmentation"[10] in other reports. In our series of patients undergoing hypoglossal supercharging, the regenerating axons from two neural sources extend into the nerve graft from different directions, and then they distribute to the distal branches of the facial nerve. This suggests that a single nerve graft can allow simultaneous bidirectional regenerating axons. This phenomenon was demonstrated using an allonerve grafting model in transgenic mice of the *thy-1-YFP-H* strain[11] (Jackson Laboratory, Bar Harbor, ME, USA), with the approval of the institution's animal care and ethics committee. In that study, a defect in the tibial and peroneal nerves was reconstructed with a single "loop" nerve graft taken from the wild-type C57B/6J mice, which contain no fluorescence. This allograft model allowed direct visualization of the regenerating axons in the nerve graft.[12] Both ends of the graft were coapted to the proximal stump of the tibial and peroneal nerves in an end-to-end fashion, and each distal stump was coapted to the windows created on the side of the nerve graft. Three months later, the entire sciatic nerve, including the graft and distal branches, was harvested, and whole-mount fluorescent

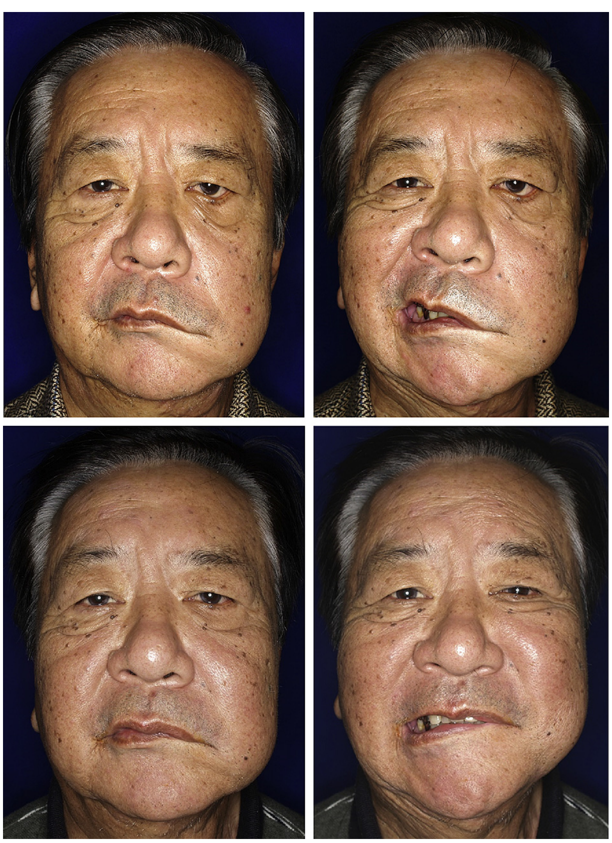

Figure 6 Postoperative photographs of patient 8 at rest (left) and while grinning (right) at 2 months (above) and 50 months (below) post operatively. The final Sunnybrook and H–B scores at 50 months post operatively were 60 – 5 – 6 = 49 and grade III, respectively.

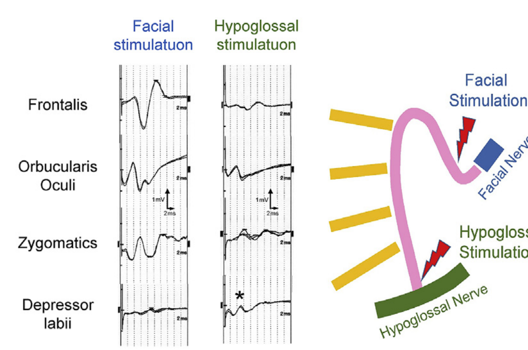

Figure 7 A four-channel evoked electromyogram for patient 8 shows actual reinnervation from both the facial and hypoglossal nerves and axonal distribution from the two neural sources (one stimulation to the nerve graft causes compound muscle action potentials (CMAPs) in multiple facial regions). *The depressor labii shows a larger CMAP and a shorter latency with hypoglossal stimulation than with facial stimulation, which indicates that regeneration from the hypoglossal nerve is dominant.

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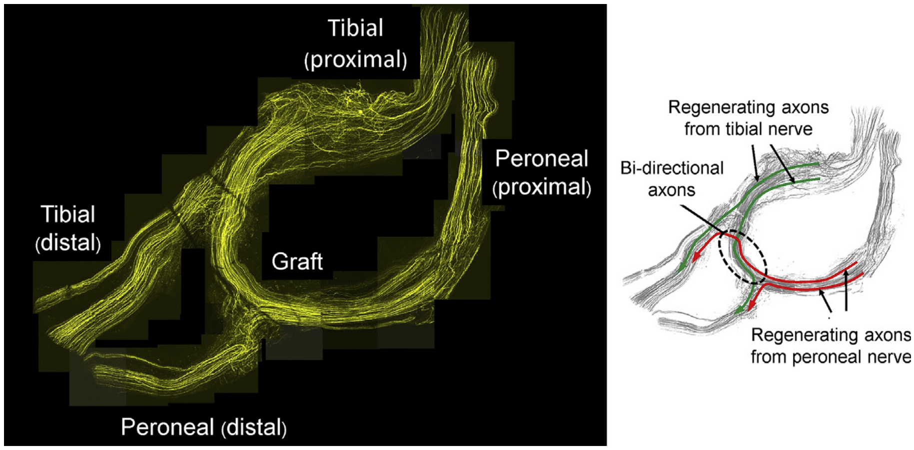

Figure 8 The whole-mount image with a confocal microscope and schematic illustration. Regenerating axons from the tibial nerve (green arrows) seem to pass through the graft and penetrate to both distal stumps, as do those from the peroneal nerve (red arrows). The middle area of the graft seems to contain bidirectional regenerating axons.

images were obtained using a laser confocal microscope (Zeiss, LSM 510, Germany). The image directly showed that the regenerating axons from the tibial nerve extend into both distal stumps passing though the graft and those from the peroneal nerve as well. In the middle area of the graft, the regenerating axons extended in different directions, and this condition was maintained (Figure 8). Another research group observed this phenomenon in a different animal model.[13] This phenomenon can be likened to the faucet as a neural source and the hose as a nerve graft. The sprouting of the regenerating axons resembles water flowing from holes on the side of the hose (Figure 9). The sidewall of the nerve graft allows "axonal distribution," that is, accepting the regenerating axons from dual neural sources of the proximal facial nerve end and the ipsilateral hypoglossal nerve through the nerve graft, which results in axonal supercharging.

Our patients who undergo reconstruction using the loop-graft technique still sometimes develop synkinesis. However, previous studies indicate that the expected result after severing the facial nerve is H–B grade III[7] at best, and synkinesis is a major concern in patients undergoing

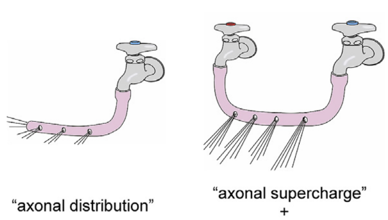

Figure 9 The concept of axonal distribution and supercharging can be compared to a model of a faucet (neural sources) and a hose (nerve graft), with water (regenerating axons) coming out of holes on the sidewall of the hose. The use of the sidewall of the nerve graft by means of axonal distribution and connection of multiple neural sources with the nerve graft means that axonal supercharging should produce more regenerating axons (water) from the sidewall of the nerve graft (hose).

reconstruction with multiple cable grafts.[14] In our series, mild synkinetic movement, especially oral to ocular synkinesis, was mainly observed in patients with good recovery; however, regained facial muscle function substantially improved facial tone and eyelid closure in most patients. Because of the difficulty of objective assessment of the synkinetic movements, it is still hard to compare the synkinesis with our procedure to those obtained with multiple cable grafting in the previous report.[6–8] Although no patient required treatment for severe synkinesis in our series, whether our procedure provides more or less synkinetic movement is still unclear.

The use of an alternative neural source for facial reanimation is not a new concept. Hypoglossal nerve transfer is a common technique for cases in which the ipsilateral facial nerve does not function as a neural source. Studies on hypoglossal nerve transfer[15–19] reported acceptable results in most cases. In addition, some cortical plasticity is present after hypoglossal–facial nerve transfer.[20]

The masseteric nerve[21,22] has been used as another useful donor for nerve transfer. However, to achieve spontaneous and natural facial expression, regeneration from the original facial nerve is preferable, when possible. To attain both strong and natural facial expressions, reconstruction using multiple neural sources, to reanimate facial muscles,[10,23] and transferred muscle[24,25] has been reported. This relatively new concept may lead to the development of new facial reanimation techniques. As was shown by the postoperative four-channel electromyography in this study, the hypoglossal supercharging allows regeneration from both the original facial nerve and hypoglossal nerve, thereby minimizing the possibility of poor regeneration, especially in patients undergoing postoperative radiotherapy/chemotherapy and those with preoperative facial paralysis. In other words, it may work as an "insurance" procedure promising good recovery of the facial muscles in patients with difficult conditions, although the significant advantage of the hypoglossal supercharging was not shown in our small series. Still, further study and cases are required for verifying the effectiveness of this technique; we think that axonal supercharging and distribution

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using the loop-graft technique can be an option for facial nerve reconstruction.

Conclusions

We reported 32 patients with facial nerve reconstruction using an end-to-side "loop" graft. We think that this easy-to-perform technique can be an option for facial nerve reconstruction to distribute the regenerating axons from single or multiple neural sources to multiple distal branches, with less nerve-graft requirement.

Ethical approval

Approval for this study was obtained from the ethical review board of the Osaka University Hospital, the Hyogo College of Medicine College Hospital, and the Niigata University Hospital. All patients provided written informed consent to participate in the study. Written informed consent to use preoperative, intraoperative, and postoperative photographs was obtained from the patients who appear in this report.

Conflict of interest

The authors have no financial conflicts of interest to disclose concerning this article.

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