One-Stage Transfer of the Latissimus Dorsi Muscle for Reanimation of a Paralyzed Face: A New Alternative

Kiyonori Harii, M.D., Hirotaka Asato, M.D., Kotaro Yoshimura, M.D., Yasushi Sugawara, M.D., Takashi Nakatsuka, M.D., and Kazuki Ueda, M.D.

Tokyo and Tochigi-ken, Japan

The two-stage method combining neurovascular free-muscle transfer with cross-face nerve grafting is now a widely accepted procedure for dynamic smile reconstruction in cases with long established unilateral facial paralysis. Although the results are promising, the two operations, about 1 year apart, exert an economic burden on the patients and require a lengthy period before obtaining results. Sequelae such as hypoesthesia, paresthesia, and conspicuous scar on the donor leg for harvesting a sural nerve graft also cannot be disregarded.

To overcome such drawbacks of the two-stage method, we report a refined technique utilizing one-stage microvascular free transfer of the latissimus dorsi muscle. Its thoracodorsal nerve is crossed through the upper lip and sutured to the contralateral intact facial nerve branches. Reinnervation of the transferred muscle is established at a mean of 7 months postoperatively, which is faster than that of the two-stage method. In our present series with 24 patients, 21 patients (more than 87 percent) believed that their results were excellent or satisfactory, which also compares well with the results of the two-stage method combining free-muscle transfer with cross-face nerve graft. (*Plast. Reconstr. Surg.* 102: 941, 1998.)

Since the first clinical introduction of the free-gracilis muscle transplantation by Harii et al. in 1976,[1] the microneurovascular free-muscle transfer has attained an established position in the surgical treatment of long-standing or irreversible facial paralysis. Various muscles such as the gracilis,[2,3] latissimus dorsi,[4] pectoralis minor,[5,6] serratus anterior,[7] and rectus abdominis[8] have also been proposed as optimal candidates. An important factor, however, in obtaining a satisfactory result is the selection of a suitable motor nerve capable of innervating a transferred muscle segment. Harii et al.[1] first employed the ipsilateral deep temporal nerve, a motor branch of the trigeminal nerve to the temporal muscle, for innervating the transferred gracilis muscle. This was able to produce a good voluntary contraction of the muscle and subsequent smile, but exaggerated involuntary movements upon chewing and biting were problematic. Although the ipsilateral facial nerve branch, if available, may be the most desirable motor source for innervating the transferred muscle, its use would be quite limited. Also, Chuang et al.[9] reported four cases with a significant irreversible contracture of the transferred muscle innervated by the ipsilateral facial nerve and admonished indiscriminate use of the ipsilateral facial nerve.

The procedure combining free-muscle transfer with cross-face nerve grafting, on the other hand, has long been championed and promises a good result, since O'Brien et al.,[10] Harii,[11] and others[12] have proved its greater advantages. However, this procedure requires two-staged operations about 10 to 12 months apart; the first is a cross-face nerve grafting followed by free-muscle transfer. This may exert an economic burden on the patients and requires a lengthy period before contraction of the transferred muscle is obtained. Sequelae such as hypoesthesia and paresthesia in the lateral foot as well as a conspicuous scar on the leg after harvesting a sural nerve graft also cannot be disregarded, although the scar can now be

From the Departments of Plastic and Reconstructive Surgery at the University of Tokyo Graduate School of Medicine and the Jichi Medical School. Received for publication August 19, 1997; revised October 27, 1997.

Presented at the 65th Annual Meeting of the American Society of Plastic and Reconstructive Surgeons in Dallas, Texas, on November 11, 1996.

minimized by endoscopic harvesting of the sural nerve.

To overcome such drawbacks of the two-stage method, the one-stage free-muscle transfer in which the motor nerve is directly crossed through the face and sutured to the contralateral facial nerve branches has sporadically been reported, using the gracilis,[13] rectus femoris,[14] and abductor hallucis[15] muscles. The cases reported, however, have generally been few and results not promising.

In this paper, we report a refined technique involving one-stage transfer of the latissimus dorsi muscle for reanimation of long-standing or irreversible facial paralysis. The thoracodorsal nerve of the latissimus dorsi muscle is crossed through the upper lip and sutured to the contralateral facial nerve (the buccal and/or zygomatic branches) (Fig. 1). Reinnervation of the muscle is established an average of 7 months after the transfer, which apparently is faster than that of the two-stage method. Satisfactory reanimation was acquired in more than 87 percent of cases, which compares well with the results obtained by the two-stage method combining free-muscle transfer with cross-face nerve grafting.

MATERIALS AND METHODS

Operative Procedures

The patient is placed in the semilateral position with the paralyzed side up, as the latissimus dorsi muscle is usually harvested on the same side as the paralyzed face. An anesthesiologist and all anesthetic equipment are positioned on the opposite side, so that the simultaneous approach to both donor and recipient sites is facilitated for the two separate surgical teams. The face, neck, and the ipsilateral upper extremity and subaxillary region are widely prepared and draped.

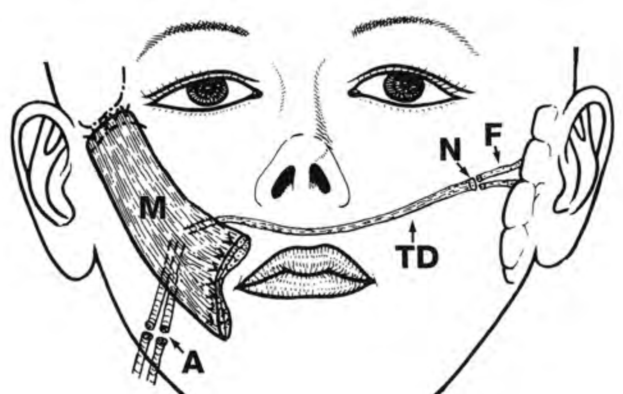

FIG. 1. Schema of the one-stage latissimus dorsi muscle transfer for a paralyzed face. M, latissimus dorsi muscle; A, site of vascular anastomosis; N, site of nerve suture; TD, thoracodorsal nerve; F, intact facial nerve.

Through a preauricular skin incision on the paralyzed cheek, the cheek skin is widely raised above the parotid fascia and superficial musculoaponeurotic system (SMAS) to create a subcutaneous pocket to accept the subsequent muscle transfer. The skin undermining subcutaneously extends approximately 1 to 2 cm beyond the nasolabial fold to the upper and lower lips. The lateral portion of the atrophying orbicularis oris muscle and the site of insertion of the zygomaticus major and minor muscles into the orbicularis oris muscle (the so-called modiolus) are also exposed. Several stay sutures are then placed at the lateral border of the atrophying orbicularis oris muscle in the upper and lower lips and the modiolus.[16] A newly created nasolabial fold is visualized by pulling these stay sutures toward the zygomatic region, which should correspond to the contralateral nasolabial fold. Thus, the fixation position of the end of the transferred muscle segment at the nasolabial region is determined. To secure the muscle fixation to the appropriate position in the nasolabial and lateral lip regions, a pull-out suspension suture using 2-0 or 3-0 monofilament nylon is placed between the deep subcutaneous tissue at the corner of the mouth and the skin either behind the ear lobe or in the temporal region. A small portion of the subcutaneous tissue over the zygoma is excised to accommodate the bulkiness when the other end of the transferred muscle segment is anchored to the zygoma.

Another small incision, about 2 to 3 cm long, is also placed at the submandibular region to expose the facial artery and vein as the recipient vessels. Skin undermining through this incision also proceeds to connect to the undermined area through the preauricular incision. Both preauricular and submandibular skin incisions are sometimes connected together to obtain a wide elevation of the cheek skin flap, although postoperative skin edema may be increased. Finally, through a small, less than 2-cm-long incision placed at the anterior margin of the parotid gland in the nonparalyzed cheek, several zygomatic and buccal branches of the intact facial nerve are exposed (Fig. 2). Of these, a few adequate branches innervating mainly the zygomatic and levator labii muscles should be selected by a nerve stimulator and made ready for the recipient motor nerve. This procedure is more simple and efficient than the procedure exposing facial nerves through a preauricular incision, which requires wide dissection to reach the facial nerve branches in the buccal region. A small scar of the skin incision is usually not conspicuous.[11]

During preparation of the recipient cheek, the other team harvests the latissimus dorsi muscle segment. Through an incision along the posterior axillary line, the neurovascular pedicle of the latissimus dorsi muscle is first exposed. The thoracodorsal nerve is then separated from the thoracodorsal vessels and traced proximally toward its origin from the posterior cord of the brachial plexus. To obtain a sufficient length of the nerve to reach the contralateral facial nerve branches exposed just anteriorly to the parotid gland, the dissection of the thoracodorsal nerve should also proceed into the muscle. When a further elongation of the nerve is required, several proximal twigs of the thoracodorsal nerve to the muscle are divided, leaving the dominant terminal innervating branch(es), which should be confirmed by a nerve stimulator. The thoracodorsal nerve, more than 15 cm long, is thus prepared, being sufficiently long to cross through the upper lip and reach the facial nerve branches prepared in the nonparalyzed cheek (Fig. 3).

After complete dissection of the neurovascular pedicle, a muscle segment of the required size (usually 3 to 4 cm wide and 8 to 10 cm long in moderately stretched position of the muscle) is harvested with its neurovascular pedicle. The latissimus dorsi muscle is first split longitudinally along the muscle fibers, taking about a 3- to 4-cm-wide muscle belly from the anterior margin of the muscle. The length of the muscle required (8 to 10 cm) is then measured, and the split muscle belly is divided distally to the neurovascular hilus and then proximally with a disposable stapler.[17] The proximal end of the muscle should be divided closely to the neurovascular hilus, permitting the nerve to easily reach the contralateral facial nerve branches when the proximal end is placed into the lateral lip and the angle of the mouth. Most of the muscle segment is involved distally to the neurovascular pedicle. Appropriate trimming and thinning of the muscle are carried out in situ to secure hemostasis and avoid postoperative hematoma (Fig. 4). Finally, the neurovascular pedicle is divided and the muscle segment is harvested (Fig. 5).

FIG. 2. Exposure of the facial nerve branches in the intact cheek through a small incision (arrow I) at the anterior margin of the parotid gland. M, latissimus dorsi muscle segment; N, thoracodorsal nerve crossed through the upper lip.

FIG. 3. Intramuscular dissection of the thoracodorsal nerve for elongation. M, latissimus dorsi muscle; N, thoracodorsal nerve; P, thoracodorsal vessels; n, intramuscular branches of the thoracodorsal nerve.

The harvested muscle segment is immediately set into the recipient cheek pocket. Its proximal end is fixed to the nasolabial region with the previously placed stay sutures, placing the neurovascular pedicle proximally and in a reversed orientation. The thoracodorsal nerve is then passed through the upper lip by a specially designed nerve passer to the contralateral facial nerve branches, which have already been prepared at the anterior margin of the parotid gland. Epineurial sutures between the thoracodorsal nerve and the suitable facial nerve branches are accomplished under an operating microscope using 10-0 nylon sutures. Microvascular anastomoses are also carried out between the thoracodorsal vessels and the re-

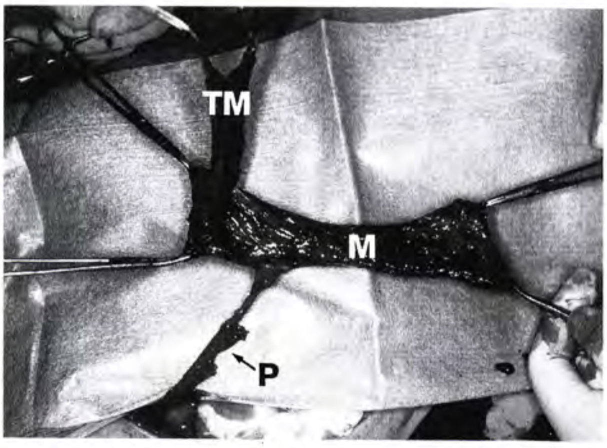

FIG. 4. Thinning of the muscle in situ to obtain an appropriate thickness. M, latissimus dorsi muscle; P, neurovascular pedicle; TM, removed segment of the muscle.

cipient facial artery and vein in an end-to-end fashion. Finally, the distal end of the muscle is fixed to the zygoma, giving a proper tension to the transferred muscle segment. Should the transferred muscle be too long, the distal muscle end is adequately shortened. The cheek skin is then closed with a suction drainage, and the end of the pull-out suspension suture previously placed is tightly fixed with a small pillow.

RESULTS

Between September of 1993 and May of 1996, this procedure was performed in 24 patients, ranging in age from 14 to 70 years (mean 41.5 years) at the time of surgery. The etiology of facial paralysis was as follows: postoperative in 16 (acoustic neuroma and cerebellopontine tumors, 10; otitis media, 4; parotid tumor, 2) (67 percent), unresolved Bell's palsy

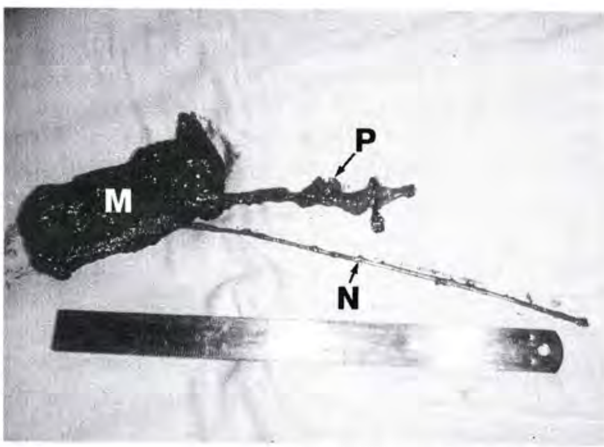

FIG. 5. Completely isolated segment of the latissimus dorsi muscle. M, muscle; P, thoracodorsal vessels; N, thoracodorsal nerve.

TABLE I
Evaluation Criteria

Grade	Description
5	Symmetric balance and good facial tone at rest Sufficient muscle power upon voluntary contraction Synchronous and natural expression upon emotional facial movements, especially upon smiling EMG demonstrating relatively high amplitudes with full interference patterns and high evoked potentials obtained upon stimulation of the contralateral facial nerve
4	Symmetric balance and good facial tone at rest Active muscle contraction acquired but not sufficiently synchronous (too strong or slightly weak) EMG demonstrating good interference patterns and evoked potentials Results well accepted by the patients
3	Symmetric balance and good facial tone at rest Insufficient contraction of the muscle Low volitional EMG spikes with discrete interference patterns
2	Reduced symmetric balance upon smiling No effective contraction of the muscle EMG with no interference patterns
1	No correction Electrically silent EMG
0	No follow-up

and Hunt syndrome in 4 (17 percent), congenital in 2 (8 percent), and others in 2 (8 percent). The duration of paralysis before surgery ranged from 4 months to 70 years (mean 13 years). The case in which the surgery was performed 4 months after the onset of the paralysis was the result of severe paralysis in a 63-year-old man following resection of an acoustic tumor. Conventional hypoglossal nerve crossover or cross-face nerve grafting would have been the first choice, but we used this proce-

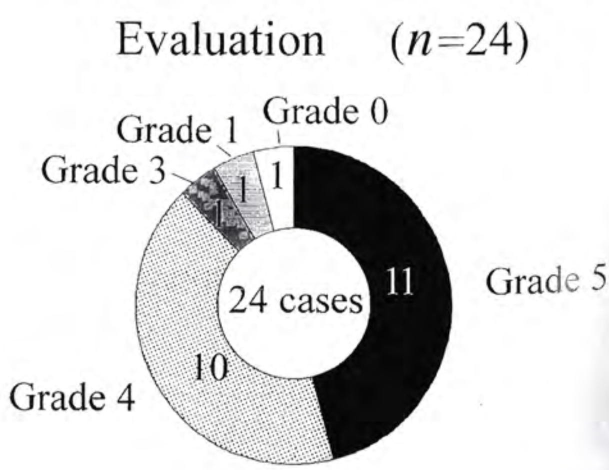

FIG. 6. Postoperative evaluation of the patients according to the grading scale listed in Table I.

FIG. 7. Case 1. A 22-year-old woman with incomplete left facial paralysis following parotidectomy, more than 10 years previously, owing to a parotid gland metastasis of a medulloepithelioma of the left orbit. (*Above, left* and *center*) Preoperative views. Impaired elevation of the upper lip and little movements on the nasolabial region cause asymmetric facial deformity upon smiling. Smile reconstruction was accomplished with one-stage transfer of the latissimus dorsi muscle segment. (*Above, right*) The harvested latissimus dorsi segment transferred to the cheek is shown. M, muscle; N, thoracodorsal nerve crossing the face; P, thoracodorsal vessels anastomosing to the facial artery and vein. (*Below, left* and *center*) Three and a half years postoperatively. Good results (grade 5) are obtained without any revisional operations. (*Below, right*) No visible scar remains at the contralateral cheek for nerve suturing.

dure as the atrophy of the mimetic muscles was so severe in this case and the patient wanted to have an early and certain recovery from cheek drooping. There were 17 complete and 7 incomplete paralysis patients. The latter chiefly complained of severe asymmetry or diminished movements of the face upon smiling. Of a total 24 latissimus dorsi muscles transferred in 24 patients, there were no vascular complications and no obvious signs of muscle necrosis such as unusual swelling, infection, or discharge.

Because this procedure was principally focused on reconstruction of the ability to provide a natural or near-natural smile, the results in the present series were evaluated according to the grading scales illustrated in Table I. The patients were followed up for more than 1 year, except for one case (Fig. 6). The majority of

FIG. 8. Case 2. A 24-year-old woman with complete left facial paralysis after an otitis media operation 2 years previously. (*Above, left* and *center*) Preoperative views: static and smiling. Completely diminished movement of the left cheek is seen. (*Above, right,* and *below*) One and a half years postoperatively. Near-natural movements upon smiling (grade 4) are obtained without conspicuous scar at the contralateral anterior cheek.

patients (>87 percent) felt that their results were excellent (grade 5) or satisfactory (grade 4) (Figs. 7 through 11), whereas in four patients (17 percent), the acquired muscle contraction was insufficient (three patients) (grade 3) or not present (one patient) (grade 1).

DISCUSSION

The first report of the one-stage muscle transplantation innervating through the contralateral facial nerve for the treatment of facial paralysis was made by Thompson[18] using the extensor digitorum brevis muscle. He crossed, through the upper lip, the long anterior tibial nerve of the extensor digitorum brevis muscle to the contralateral facial nerve branches. This idea seemed to be superb, but the result was not satisfactory because his procedure did not vascularize the muscle. A similar procedure involving vascularization of the extensor digitorum brevis muscle was thereafter reported by Mayou et al. in 1981.[19] Their results, however, were also unsatisfactory, because of diminished excursion and weak force of the transferred extensor digitorum brevis muscle.

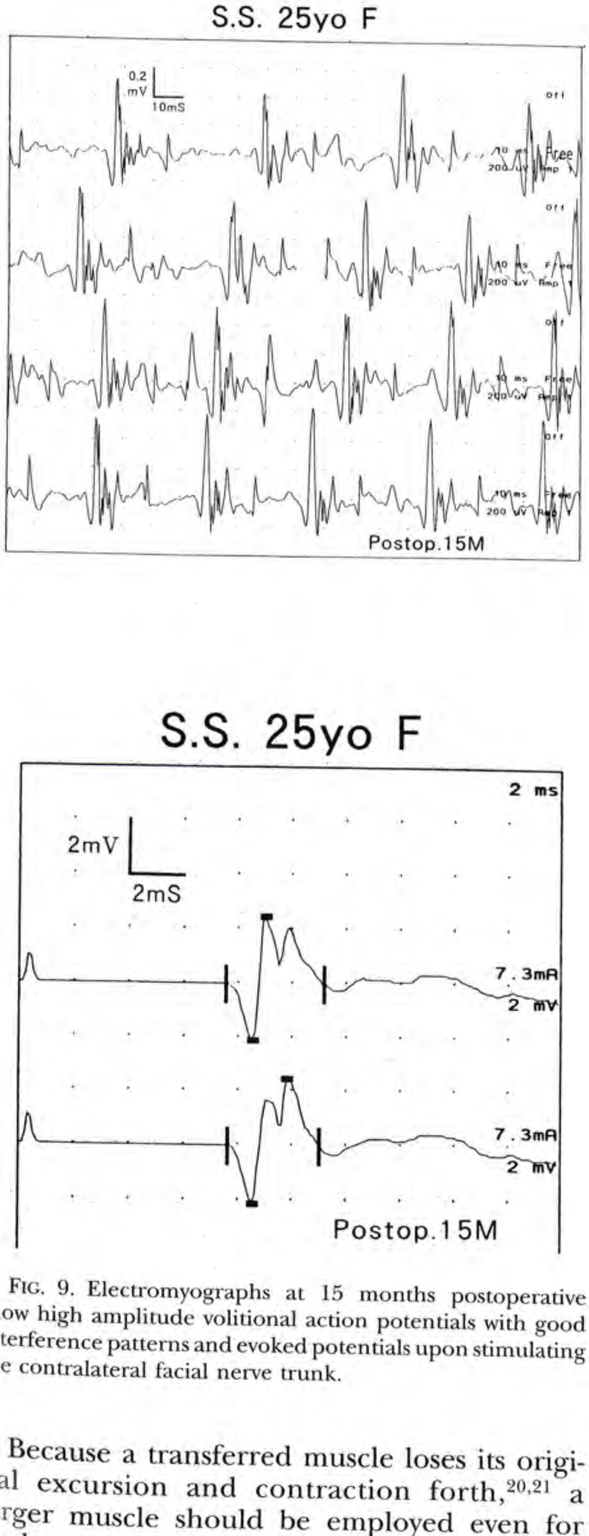

FIG. 9. Electromyographs at 15 months postoperative show high amplitude volitional action potentials with good interference patterns and evoked potentials upon stimulating the contralateral facial nerve trunk.

Because a transferred muscle loses its original excursion and contraction forth,[20,21] a larger muscle should be employed even for replacement of fine and thin mimetic muscles. To date, such large muscles as the gracilis, pectoralis minor, serratus anterior, rectus abdominis, or latissimus dorsi muscles are recommended as good candidates for the two-stage method combining with cross-face nerve grafting.[3–8] However, it takes at the earliest almost 2 years after the first cross-face nerve-grafting operation before a transferred muscle acquires its contraction. Sacrifice of the sural nerve produces such sequelae as hypoesthesia and conspicuous scars in the donor foot, although endoscopic harvest of the sural nerve has been developed and leaves a minimal scar.

To overcome such drawbacks of the two-stage method, several authors have recently reconsidered the one-stage method using vascularized free-muscle transfer in which the motor nerve is crossed through the face and sutured to the contralateral facial nerve branches.[13–15] Of these, however, the gracilis muscle reported by Kumar[13] in 1995 and the rectus femoris muscle reported by Koshima et al. in 1994[14] only would be considerable, although they could not sufficiently demonstrate satisfactory results as compared with results of the two-stage method. Numbers of patients involved in their series were also small.

When the muscle is transferred as a segment, not as a whole, the muscle fiber types, either parallel-fibered or bipennate, are especially significant. The fiber length and the angle of pennation would determine a total cross-sectional area of fibers in the transferred muscle, which gives a maximum isometric tetanic force of the muscle. It is also confirmed experimentally that tetanic force is higher in parallel-fibered muscles than in bipennate muscles when they are freely transferred with neurovascular repair.[22] Because a muscle employed in facial reanimation should obtain the most effective contraction force when it is fabricated to a thin and small segment, a parallel-fibered muscle would be a better choice than a bipennate muscle. The gracilis muscle employed by Kumar[13] therefore would be better than the rectus femoris muscle employed by Koshima et al.[14] The maximum length of the motor nerve of the gracilis muscle, however, is not as long (less than 12 cm), which makes it difficult to suture to large branches of the contralateral facial nerve without tension. Kumar exposed facial nerve branches in the anterior cheek, leaving a relatively long conspicuous scar on the face because of difficulty in obtaining sufficient facial nerve branches through a small incision in the anterior cheek.

The latissimus dorsi muscle, on the other hand, is a representative parallel-fibered muscle, and its dominant nutrient vessels, the thoracodorsal vessels, are long-stalked and sizable. The thoracodorsal nerve originates from the

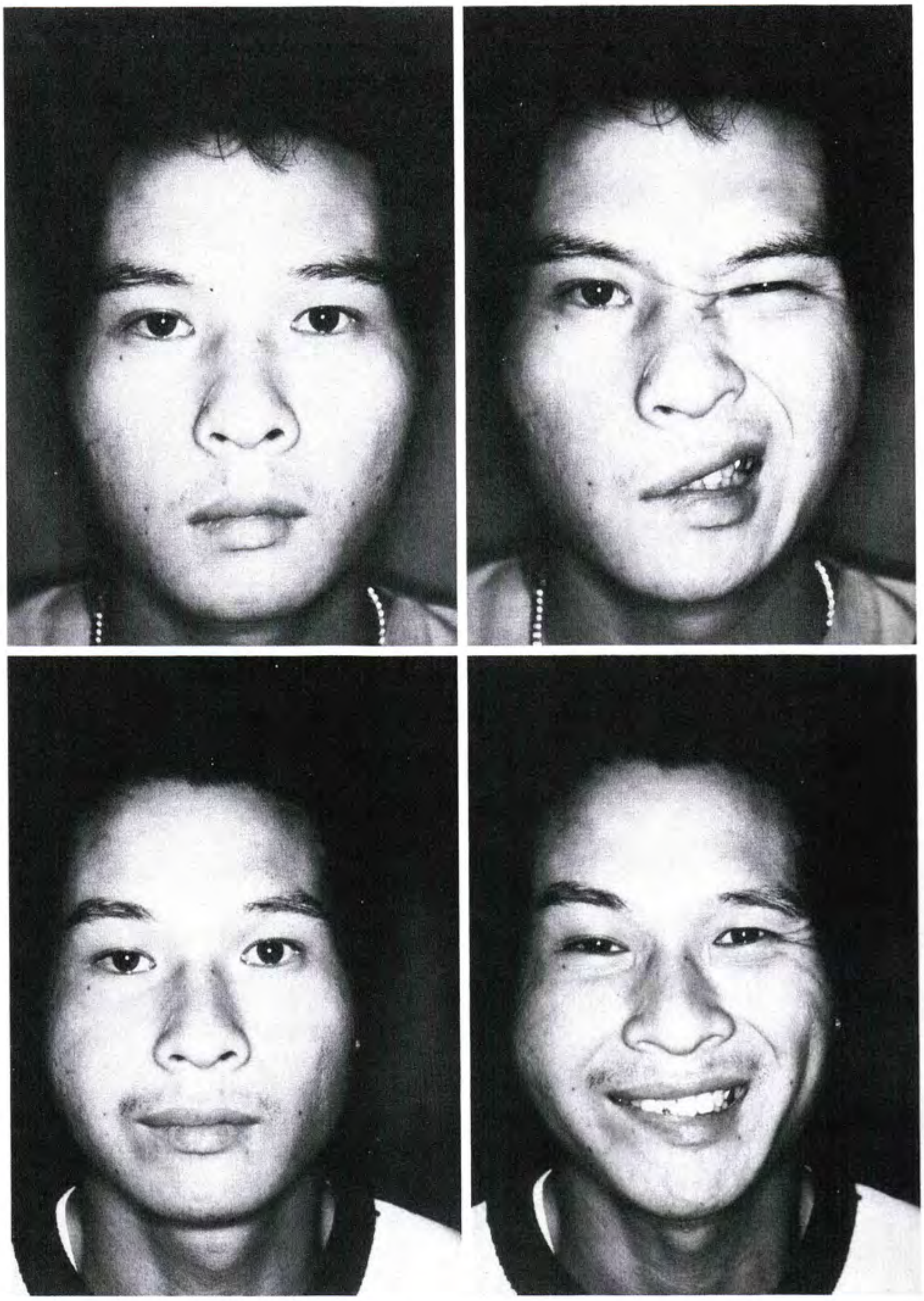

FIG. 10. Case 3. A 26-year-old man with complete right facial paralysis after a car accident. A sural nerve graft had once been placed between the facial nerve stump exposed in the facial nerve canal and the intraparotid trunk but failed. (*Above*) Preoperative views of the right complete paralysis. The latissimus dorsi muscle transfer was achieved 1 year after the accident because the patient wanted an earlier recovery from the paralysis. (*Below*) Good results with symmetric involuntary movements upon smiling (grade 5) are obtained.

posterior cord of the brachial plexus and can be harvested in an average length of 15 cm when it is maximally dissected. This facilitates reaching the contralateral facial nerve branches exposed through a small incision, less than 2 cm long, at the anterior parotid margin, leaving a minimal scar. Despite such advantages, the latissimus dorsi muscle was considered unsuitable for facial reanimation owing to its size and bulk. However, according to its intramuscular neurovascular anatomy, Tobin et al.[23] and Dellon and Mackinnon[4]

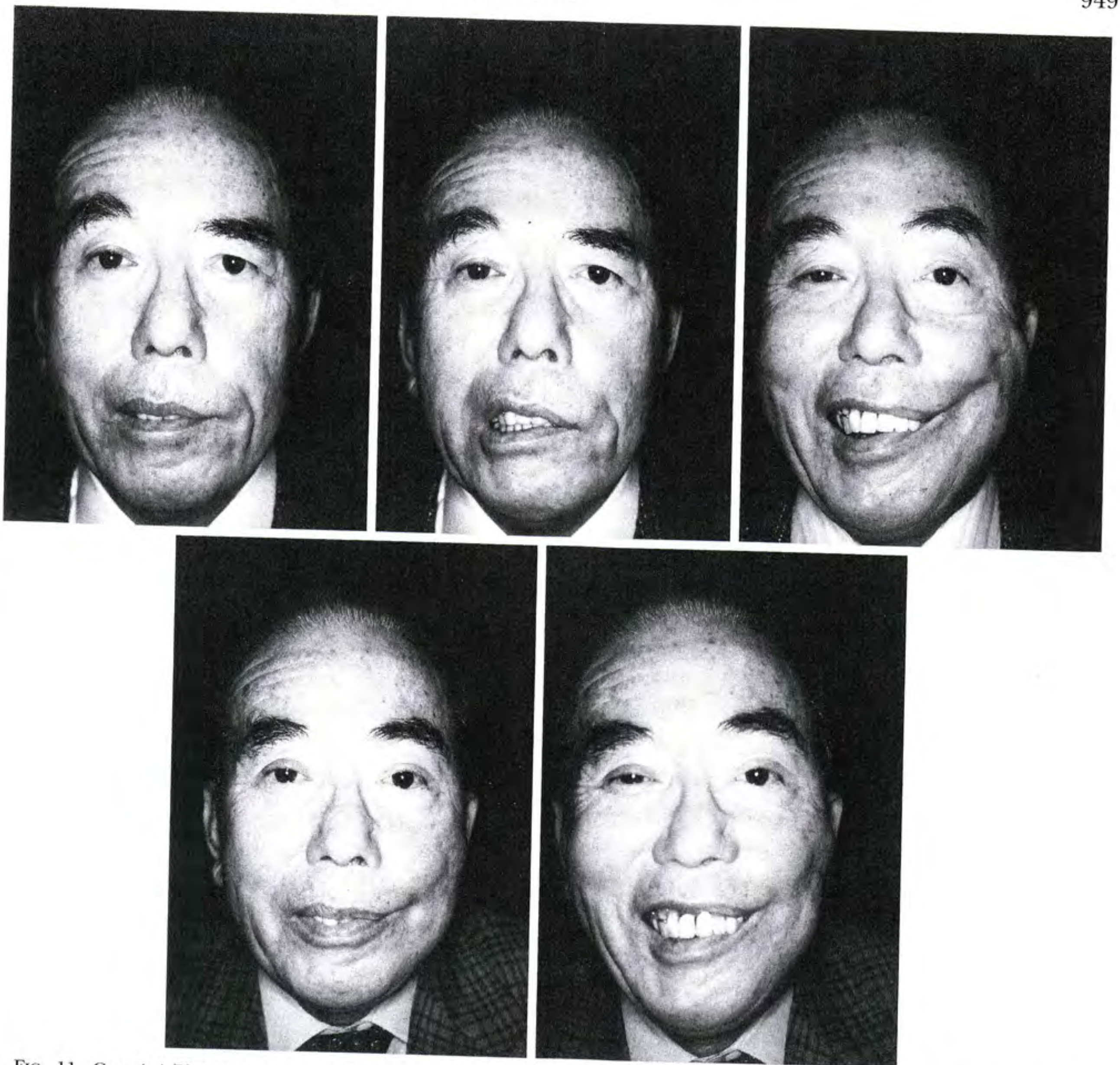

FIG. 11. Case 4. A 70-year-old man with incomplete left facial paralysis caused by an unresolved Bell's palsy attack in his infancy. (*Above, left* and *center*) Preoperative views. Although he showed symmetric facial balance at rest, left facial palsy became evident on full expression. He therefore took care against smiling for a long time. Brow lift and the temporal muscle sling transfer for eye closure were simultaneously achieved. (*Above, right*) One year postoperatively, the transferred latissimus dorsi muscle showed good contraction, but an unnatural tethering and rather strong contraction were problems (grade 4). (*Below*) After secondary corrective operation, good results (grade 5) are obtained with natural facial animation upon smiling.

proved the feasibility of splitting it into small muscle bellies. The excessive size and bulk of the latissimus dorsi muscle can be accommodated to the face when it is carefully split and thinned along the muscle surface.

First signs of reinnervation of the transferred latissimus dorsi muscle such as slight twitch or contraction and low amplitude volitional spikes of EMG were observed at the 7.4 ± 1.8 postoperative month. This seems slightly faster than those of the two-stage method combining cross-face nerve grafting (8.2 ± 3.2 postoperative month). There were no statistically significant differences between the present method ($n = 20$) and the two-stage method ($n = 127$) in adult patients more than 15 years old (Wilcoxon's test). However, it is interesting that reinnervation through the long thoracodorsal nerve, 14 to 15 cm long between the nerve suture site and the nerve entrance to the muscle, was faster than that of the two-stage method in which the secondary nerve suture is usually achieved close to (less than 3 cm from) the nerve entrance to the muscle.

The major concern with the one-stage muscle transfer is whether the transferred muscle undergoes denervation atrophy or not before reinnervation, because the sprouting axons through the nerve suture should run a long way before they reach the muscle. However, nerve recovery in our present series, confirmed in other reports,[13,14] was faster than we expected and reached the muscle before it had become severely atrophied. This early axonal recovery could be explained by the following reasons. The motor nerve of the muscle probably maintains its blood supply through reversed flow from the muscle for most of its length or at least some proximal length, which may facilitate axon transfer as a vascularized nerve graft.[14] Numbers of sprouting axons through one suture line can rapidly reach the muscle without other obstacles while axons regenerating through a cross-face nerve graft in the two-stage method have to surmount the scar barrier of another suture line to reach the muscle. Number and size of regenerating axons through a cross-face nerve graft are also not many (less than 30 to 40 percent of the original sural nerve axons[24]). Thus, the one-stage transfer of the latissimus dorsi muscle can obtain good results. It compares well with the two-stage method combining free-muscle transfer with cross-face nerve grafting, which has long been championed in reconstruction of long-standing facial paralysis. The most remarkable advantage of this method is the shorter period in recovery from the paralysis.

Kiyonori Harii
Department of Plastic and Reconstructive Surgery
Graduate School of Medicine
The University of Tokyo
7-3-1 Hongo, Bunkyo-Ku
Tokyo 113, Japan

REFERENCES

1. Harii, K., Ohmori, K., and Torii, S. Free gracilis muscle transplantation with microneurovascular anastomoses for the treatment of facial paralysis: A preliminary report. *Plast. Reconstr. Surg.* 57: 133, 1976.
2. Harii, K. Microneurovascular free muscle transplantation for reanimation of facial paralysis. *Clin. Plast. Surg.* 6: 361, 1979.
3. O'Brien, B. McC., Franklin, J. D., and Morrison, W. A. Cross-facial nerve grafts and microneurovascular free muscle transfer for long established facial palsy. *Br. J. Plast. Surg.* 33: 202, 1980.
4. Dellon, A. L., and Mackinnon, S. Segmentally innervated latissimus dorsi muscle. *J. Reconstr. Microsurg.* 2: 7, 1985.
5. Harrison, D. H. The pectoralis minor vascularized muscle graft for the treatment of unilateral facial palsy. *Plast. Reconstr. Surg.* 75: 206, 1985.
6. Terzis, J. K. Pectoralis minor: A unique muscle for correction of facial palsy. *Plast. Reconstr. Surg.* 83: 767, 1989.
7. Whitney, T. M., Buncke, H. J., Alpert, B. S., Buncke, G. M., and Lineaweaver, W. C. The serratus anterior free-muscle flaps: Experience with 100 consecutive cases. *Plast. Reconstr. Surg.* 86: 481, 1990.
8. Hata, Y., Yano, K., Matsuka, K., Ito, O., Matsuda, H., and Hosokawa, K. Treatment of chronic facial palsy by transplantation of the neurovascularized free rectus abdominis muscle. *Plast. Reconstr. Surg.* 86: 1178, 1990.
9. Chuang, D. C. C., Devaraj, V. S., and Wei, F. C. Irreversible muscle contracture after functioning free muscle transplantation using the ipsilateral facial nerve reinnervation. *Br. J. Plast. Surg.* 48: 1, 1995.
10. O'Brien, B. McC., Pederson, W. C., Khazanchi, R. K., Morrison, W. A., MacLeod, A. M., and Kumar, V. Results of management of facial palsy with microvascular free-muscle transfer. *Plast. Reconstr. Surg.* 86: 12, 1990.
11. Harii, K. Refined microneurovascular free muscle transplantation for reanimation of paralyzed face. *Microsurgery* 9: 169, 1988.
12. Vedung, S., Hakelius, L., and Stalberg, E. Cross-face nerve grafting followed by free muscle transplantation in young patients with long-standing facial paralysis: Reanimation of the cheek and the angle of the mouth. *Scand. J. Plast. Reconstr. Surg.* 17: 201, 1984.
13. Kumar, P. A. V. Cross-face reanimation of the paralyzed face, with a single stage microneurovascular gracilis transfer without nerve graft: A preliminary report. *Br. J. Plast. Surg.* 48: 83, 1995.
14. Koshima, I., Moriguchi, T., Soeda, S., Hamanaka, T., Tanaka, H., and Ohta, S. Free rectus femoris muscle transfer for one-stage reconstruction of established facial paralysis. *Plast. Reconstr. Surg.* 94: 421, 1994.
15. Jiang, H., Guo, E. T., Ji, Z. L., Zhang, M. L., and Lu, V. One-stage microneurovascular free abductor hallucis muscle transplantation for reanimation of facial paralysis. *Plast. Reconstr. Surg.* 96: 78, 1995.
16. Harii, K. Microneurovascular Free Muscle Transplantation. In L. R. Rubin (Ed.), *The Paralyzed Face.* St. Louis: Mosby, 1991. Pp. 178–200.
17. Asato, H., Harii, K., Nakatsuka, T., and Yoshimura, K. Use of a disposable stapler to ensure proper fixation of a transferred muscle for treatment of facial paralysis. *J. Reconstr. Microsurg.* 14: 199, 1998.
18. Thompson, N. A review of autogeneous skeletal muscle grafts and their clinical applications. *Clin. Plast. Surg.* 1: 349, 1974.
19. Mayou, B. J., Watson, J. S., Harrison, D. H., and Parry, C. B. W. Free microvascular and microneural transfer of the extensor digitorum brevis muscle for the treatment of unilateral facial palsy. *Br. J. Plast. Surg.* 34: 362, 1981.
20. Yamada, A. Experimental study on free muscle transplantation with microneurovascular anastomosis in rabbits. *J. Jpn. Plast. Reconstr. Surg.* 2: 147, 1982.
21. Terzis, J. K., Sweet, R. C., and Dyke, R. W. Recovery of function in free muscle transplants using microneurovascular anastomoses. *J. Hand Surg.* 3: 37, 1978.

22. Guelinckx, P. J., and Faulkner, J. A. Parallel-fibered muscles transplanted with neurovascular repair into bipennate muscle sites in rabbits. *Plast. Reconstr. Surg.* 89: 290, 1992.
23. Tobin, G. R., Schusterman, B. A., Peterson, G. H., Nichols, G., and Bland, K. I. The intramuscular neurovascular anatomy of the latissimus dorsi muscle: The basis for splitting the flap. *Plast. Reconstr. Surg.* 67: 637, 1981.
24. Harii, K. Experimental and clinical studies of nerve and muscle grafts for the treatment of facial paralysis. *J. Jpn. Plast. Reconstr. Surg.* 7: 347, 1987.