Free Rectus Femoris Muscle Transfer for One-Stage Reconstruction of Established Facial Paralysis

Isao Koshima, M.D., Takahiko Moriguchi, M.D., Shugo Soeda, M.D., Takaomi Hamanaka, M.D., Hitoshi Tanaka, M.D., and Shigeo Ohta, M.D.

Okayama and Ibaraki, Japan

The free vascularized rectus femoris muscle graft with a long motor nerve was used for reconstruction of unilateral established facial paralysis in one stage. The pedicle vessels were anastomosed to the recipient vessels in the ipsilateral face, and the motor nerve of the muscle, which was led through the upper lip, was sutured to the contralateral facial nerve. The advantages of this one-stage reconstruction as compared with surgery involving second-stage reconstruction are that the reconstruction can be completed in one stage and that the period required for muscle refunctioning after surgery is short. The vascular supply of the rectus femoris muscle can emanate mainly from the lateral circumflex femoral artery. In our cadaveric study, five types of variation were found for origination of a nutrient artery of the muscle. The most common type was one in which the artery derived from the descending branch of the lateral circumflex femoral artery (39 percent). The motor nerve of the rectus femoris muscle is derived from the femoral nerve under the inguinal ligament and runs downward through the intermuscular space between the sartorius muscle and the iliopsoas muscle before entering the posteromedial part of the upper third of the rectus muscle. The advantages of using the rectus muscle are as follows: (1) safety and simplicity exist with one main large arterial supply for arterial anastomosis; (2) the length of the femoral nerve (more than 20 cm) is adequate for reaching the contralateral facial nerve for suturing; (3) a simultaneous operation by two teams is possible with the patient in the supine position; (4) the force and distance of contraction are appropriate to reanimate the face; (5) the rectus muscle can be separated as a segment with appropriate lengths, size, and power for replacing lost muscles in the face; (6) the tendinous fascia in both ends provides a reliable point for anchoring sutures, which provides firmer attachment; and (7) no loss of donor leg function occurs. (*Plast. Reconstr. Surg.* 94: 421, 1994.)

Treatment for facial paralysis should aim at achieving symmetry at rest, during voluntary motion, and during expression of emotion. Successful achievement of this aim has improved in the last 17 years by microsurgery and by the introduction of cross-facial nerve grafting. However, cross-facial nerve grafting has been found to be useful only for patients with some limited conditions. Harii et al.[1] first reported use of the gracilis muscle for reanimation of the paralyzed face by connecting a branch of the deep temporal nerve to the nerve of the transferred gracilis muscle. Thereafter, Harii[2] and O'Brien et al.[3] obtained successful results with a two-stage procedure using a cross-facial nerve graft in the first stage and a free gracilis muscle transfer in the second stage. An alternative involving refinement of the gracilis muscle by identifying independent neurovascular units within the gracilis and cutting it to fit the facial defect has also been offered by Manktelow.[4]

In another two-stage reconstruction with a muscle graft, Tolhurst and Bos[5] used a procedure consisting of the insertion of a cross-facial nerve graft followed by its anastomosis to a free vascularized extensor digitorum brevis muscle

From the Departments of Plastic and Reconstructive Surgery at Kawasaki Medical School, Okayama, Japan, and Tsukuba University, Ibaraki, Japan. Received for publication July 13, 1992; revised September 20, 1993.

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graft. Movement of the grafts, however, was somewhat disappointing, and the results were inconsistent. Harrison[6] used a cross-facial nerve graft and a free vascularized pectoralis minor muscle graft with successful results. The serratus anterior has also been described as potentially offering advantages because each of its muscles has separate slips of muscle and because these muscles have smaller mass.[7] A segmentally innervated latissimus dorsi muscle graft[8] and a vascularized rectus abdominis muscle transfer[9,10] have been used recently with satisfactory results.

Thompson[11] pioneered a one-stage reconstruction using a muscle transfer, with the treatment of incomplete facial paralysis by a free nonvascularized extensor digitorum brevis muscle transfer in which the muscle survival was enhanced by denervation 2 weeks before transfer. Thereafter, Thompson and Gustavson[12] extended the use of free muscle grafting to cases of complete paralysis by including a motor nerve to the muscle, the deep peroneal nerve, and taking it across the upper lip and suturing it to branches of the normal contralateral facial nerve. Mayou et al.[13] modified this method by adding immediate vascularization to the muscle graft by anastomosis of the vascular pedicle of the muscle, the tibialis anterior muscle, to the vessels in the face. They failed to produce consistent symmetrical movement of the muscle, however. Recently, successful one-stage reconstruction with the use of several muscles has been reported by Nakajima,[14] O'Brien,[15] and Jiang and Kuo.[16] The present report describes an anatomic study and clinical experience that suggest that the rectus femoris muscle can be used for one-stage reconstruction of established facial paralysis.

Anatomic Study

Materials and Methods

In the present study, dissection was performed on four legs of cadavers to confirm grossly the anatomy of the neurovascular bundle of the rectus femoris muscle. A total of 23 clear stereoscopic arteriograms of the lower legs were also made after barium was injected into the femoral arteries of the cadavers with the arterial embalming method. Three-dimensional analyses of the pedicle artery of the rectus femoris muscle were then carried out on these arteriograms with a stereoscope.

Results

The double heads of the rectus femoris muscle arise from the inferior anterior iliac spine and the superior margin of the acetabulum and descend into a spindle muscle. The muscle fibers run downward into a flat tendon that inserts through the patella into the tuberosity of tibia. The rectus muscle has thick fascia in its posterior aspect.

The vascular supply of the rectus femoris muscle mainly emanates from the lateral circumflex femoral artery. In this cadaveric study, five types of variations at the site of origin of a nutrient artery of the muscle were found. In type 1, the nutrient artery originated from the descending branch of the lateral circumflex femoral artery (39 percent). In type 2, it originated from the main trunk of the lateral circumflex femoral artery (30 percent). In type 3, the artery originated from the proximal side of the deep femoral artery (17 percent). In type 4, it originated from the distal side of the deep femoral artery (9 percent). In type 5, the artery originated directly from the superficial femoral artery (5 percent) (Figs. 1 and 2). These arteries were finally divided into a few branches to create muscle hila with motor nerve, and they terminated into the muscle. The concomitant veins of these arteries provided venous drainage.

The femoral nerve emerges from the retroperitoneum of the pelvic cavity and runs downward under the inguinal ligament to divide into some branches of the extensor muscle of the thigh. The motor nerve of the rectus femoris muscle is derived from the femoral nerve under the inguinal ligament, and it descends through the intermuscular space between the sartorius muscle and the iliopsoas muscle. It is divided into several branches before it enters the posteromedial part of the upper one-third of the rectus muscle. When the branches of motor nerve enter the muscle, they create a few neurovascular hila with the vessels that enter parallel into the muscle (Fig. 1).

Operative Technique

Subcutaneous dissection to create subcutaneous pockets in the upper and lower eyelids and the malar regions was performed through a preauricular hockey-type incision in the paralyzed side. To reconstruct the paralyzed orbicularis oculi muscle, we elevated the anterior one-third of the temporal muscle on the paralyzed

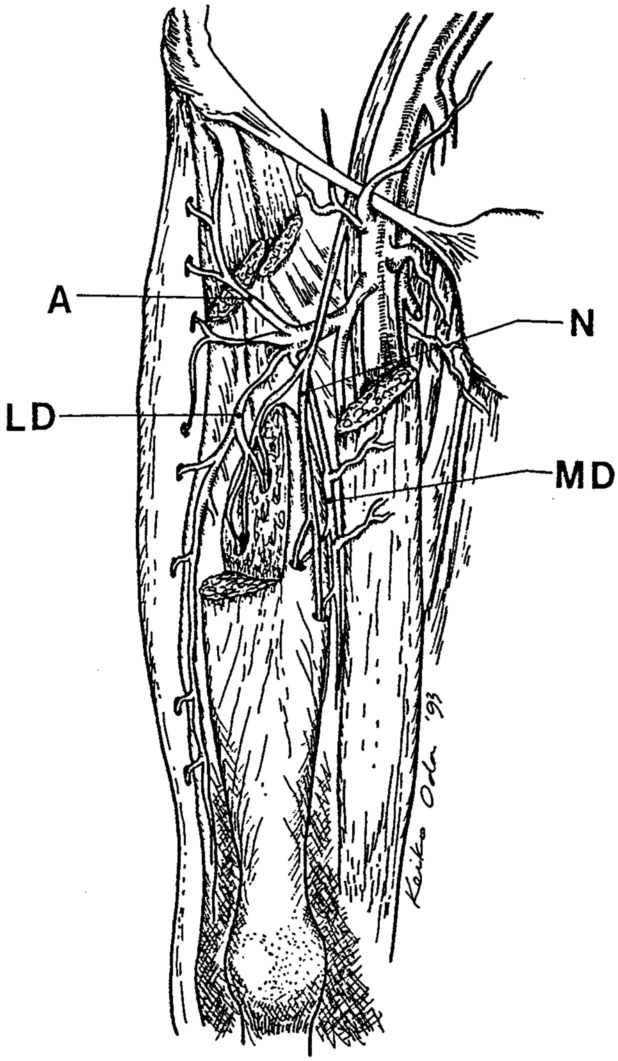

FIG. 1. Schematic drawing of the neurovascular anatomy of the rectus femoris muscle. *N*, femoral nerve; *A*, ascending branch of the lateral circumflex femoral artery; *LD*, lateral descending branch of the lateral circumflex femoral system; *MD*, medial descending branch of the system.

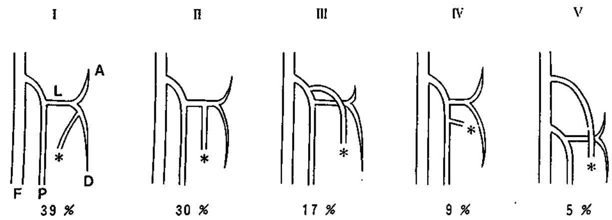

FIG. 2. Anatomic variation of the origin of the nutrient artery of the rectus femoris muscle. Nutrient artery of the rectus muscle is indicated by the asterisk. *L*, transverse branch of the lateral circumflex femoral system; *A*, ascending branch of the system; *D*, descending branch of the system; *F*, femoral artery; *P*, deep femoral artery.

side and fixed its fascia strip to the distal portion of the muscle. After the temporal muscle flap was anteriorly transferred, the distal ends of longitudinally divided fascia that were passed through the subcutaneous pockets of the eyelids were fixed to the inner canthal ligament under tension.

To prepare the recipient vessels and nerve, we dissected the facial vessels on the mandibular body of the ipsilateral side. Because the motor nerve was to be joined to that of the rectus femoris muscle flap, the buccal branches of the facial nerve on the nonparalyzed side were exposed and dissected along the anterior border of the parotid gland through a small longitudinal incision in the contralateral malar region. Among these branches, two branches of the major zygomatic muscle usually could be selected as the recipient nerve. This was confirmed by an intraoperative electrostimulating method.

The ipsilateral rectus femoris muscle was usually used for transfer. The muscle was exposed by a hockey-type incision that was made through the inguinal ligament to the longitudinal line on the anterior middle thigh. This line corresponds to the medial margin of the rectus femoris muscle. A few hila of the neurovascular bundle of the rectus muscle usually exist in the proximal one-third of the posteromedial edge of the muscle. With a pair of retractors, a vascular pedicle of one of the muscle hilum was proximally traced and skeletonized up to the superomedial side of the rectus muscle, where its pedicle joins the lateral circumflex femoral vessels. A medial part of the muscle that included the neurovascular hilum was split longitudinally and mobilized. Both ends of the muscle graft and all vascular branches in the muscle were cut. The motor funiculi of the same hilum was traced upward and dissected from the femoral nerve up to the retroperitoneal region through the previous incision in the groin. As a result of this neurovascular dissection, a vascular pedicle of more than 5 cm and a motor nerve of more than 20 cm usually could be included with the free rectus muscle graft (Fig. 3).

The rectus muscle was transferred to the prepared malar pocket of the affected face, and the long motor nerve of the muscle was led through the subcutaneous tunnel of the upper lip to the contralateral intact buccal branches. For lower face reanimation, the distal end of the transferred muscle was divided into two seg-

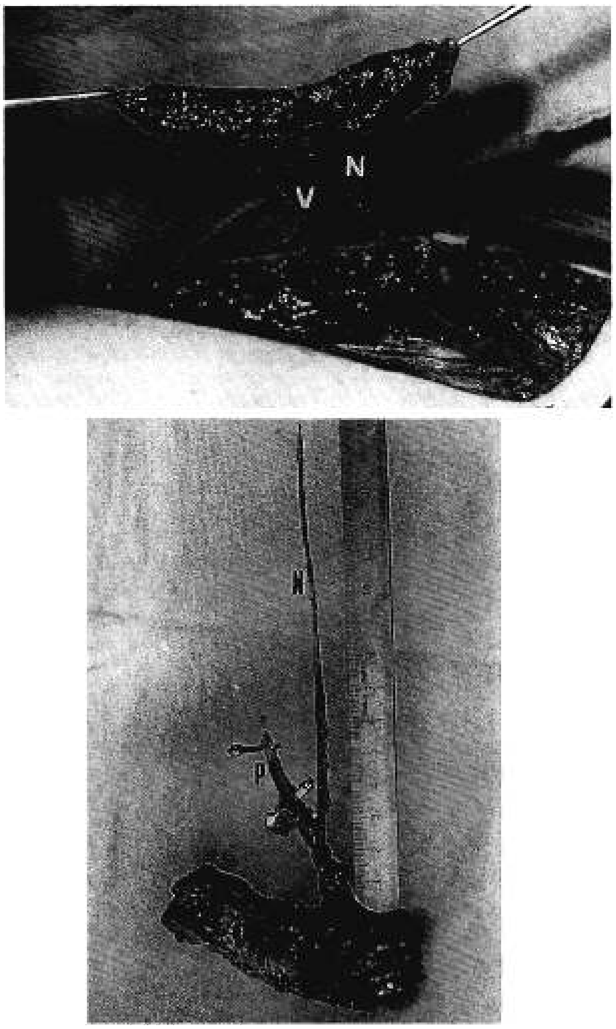

FIG. 3. (*Above*) Through a longitudinal incision on the anterior thigh, a segmented rectus femoris muscle was elevated with a neurovascular pedicle. *V*, vascular pedicle; *N*, motor nerve of the muscle (*Below*). A partial segment of the rectus femoris muscle was obtained with a long motor nerve more than 15 cm. *P*, vascular pedicle; *N*, motor nerve.

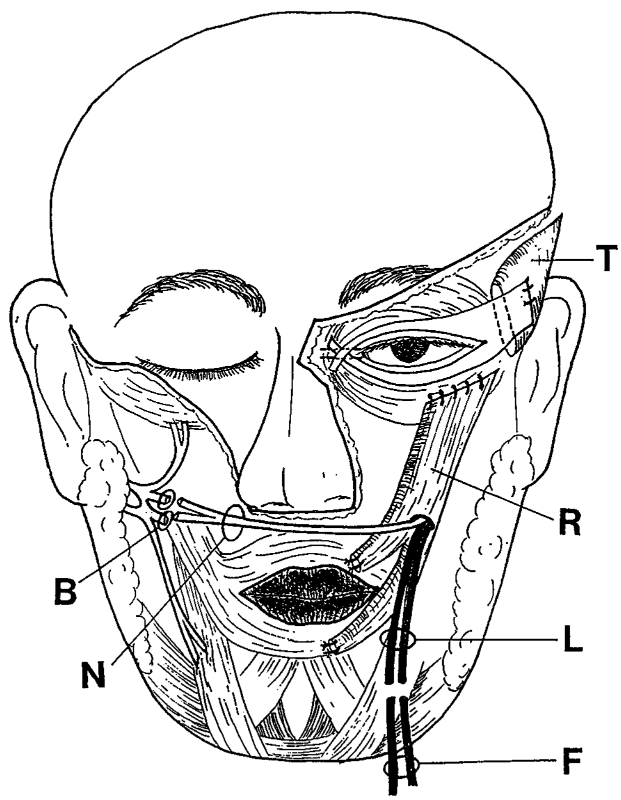

FIG. 4. Schematic drawing of the one-stage reconstruction of established facial paralysis. After the muscle (*R*) is transferred to the prepared face, its motor nerve (*N*), which is led through a subcutaneous tunnel in the upper lip to the contralateral side, is sutured to the buccal branches (*B*) of the nonparalyzed facial nerve. The vascular pedicle of the muscle (*L*) is anastomosed to the ipsilateral facial vessels (*F*). A part of the temporal muscle (*T*) is simultaneously transferred.

ments and sutured to the muscles of the lateral aspects of the upper and lower lip. The proximal muscle was fixed to the periostium of the zygomatic prominence to provide a more vertical lift to the paralyzed lip. The muscle was sutured under tension to overcorrect the deformity slightly. The vascular pedicle of the transferred muscle was anastomosed to the prepared facial vessels at the mandibular region of the paralyzed side, and the motor nerve of the muscle was joined to the contralateral intact buccal branches in the contralateral nonparalyzed malar region (Fig. 4). Finally, skin closure of the donor thigh and face with suction drains was made in layers.

PATIENT SUMMARIES

A total of seven patients with facial paralysis were treated with rectus femoris muscle grafts. The facial paralyses of these patients were caused by resection for acoustic neuromas, Bell's palsy, and resection for arteriovenous malformations. The age of patients ranged from 17 to 59 years of age, and the duration of palsy until muscle transfer ranged from 6 to 308 (average, 104.7 ± 98.2) mo. The period required for initial voluntary movement of the transferred muscles ranged from 5 to 12 (average, 8.6 ± 3.2) mo after operations. The period of postoperative follow-up ranged from 4 to 43 (average, 23.7 ± 15.3) mo, and the subjective assessment of facial reanimation showed good recovery in almost all cases. Also, no postoperative functional limitation in donor legs was observed (Table I).

TABLE I
Patient Summaries

Patient	Age	Sex	Cause	Paralyzed (mo)	Degree	First Movement after Operation (mo)	Follow-up (mo)	Subjective Assessment of Recovery
1	51	F	Bell's palsy	120	Incomplete	5	43	Very good
2*	53	M	Acoustic neuroma	72	Complete	7	37	Very good
3	42	M	Arteriovenous malformation	6	Complete	12	32	Good
4*	59	M	Bell's palsy	120	Complete	12	28	Good
5*	17	M	Arteriovenous malformation	308	Incomplete	7	16	Very good
6	19	M	Acoustic neuroma	54	Complete		6	
7	49	F	Acoustic neuroma	53	Incomplete		4	
Average	41.4 ± 15.5			104.7 ± 98.2		8.6 ± 3.2	23.7 ± 15.3	

* The patients presented in this paper.

Case Reports

Case 2

A 53-year-old man had undergone resection of a right acoustic neuroma involving the facial nerves and had right complete facial paralysis (Fig. 5, *left*). Six years after the surgery, a one-stage reconstruction with a muscle transfer was planned. A free rectus femoris muscle with a motor nerve of 16 cm from the right thigh was transferred to the paralyzed face. The motor nerve of the muscle was anastomosed to two buccal branches of the left intact facial nerve, and the vessels of the muscle were anastomosed to the right superficial temporal vessels with vein grafts of 3 cm length because of loss of the facial vein. A temporalis muscle transfer was simultaneously performed to repair the paralyzed right orbicular oculi muscle.

Nine months after the surgery, the right oral angle started to show voluntary movement, and 2 years after the operation the muscle had contracted with satisfactory results (Fig. 5, *center* and *right*). The patient had no disability of the donor leg.

Case 4

A 59-year-old man had right complete facial paralysis caused by Bell's palsy for 10 years (Fig. 6, *above, left* and *above, right*). With a temporalis muscle transfer, a free rectus femoris muscle transfer with a motor nerve of 15 cm from the

FIG. 5. Case 2. (*Left*) A 53-year-old man with right facial paralysis caused by resection of an acoustic neuroma. Preoperative facial asymmetry was observed at smiling. (*Center*) Two years after surgery. A symmetric face was seen at rest. (*Right*) Two years after surgery with the patient smiling. The contractile power of the muscle has increased.

FIG. 6. Case 4. (*Above, left*) A 59-year-old man with right complete facial paralysis resulted from Bell's palsy. Preoperative static facial appearance. (*Above, right*) Preoperative smiling. (*Below, left*) Static appearance at 1 ½ years after the operation. (*Below, right*) Smiling 1 ½ years after surgery.

right thigh was performed. The motor nerve was anastomosed to contralateral buccal branches, and the vascular pedicles were joined to right facial vessels.

One year after the surgery, the patient felt voluntary movement of the transferred muscle, and 1 ½ years after the operation, the muscle obtained good contraction (Fig. 6, *below, left* and *below, right*). No functional limitation of the donor leg was observed.

Case 5

A 17-year-old boy had right incomplete facial paralysis caused by a wide resection for infraauricular arteriovenous malformation in his childhood. Although the patient was treated by a masseter muscle transfer with temporal muscle transfer at 7 years after the resection, he was not satisfied with his facial appearance because of the disability seen when smiling naturally (Fig. 7, *above, left* and *above, center*). About 17 years after the resection, a free rectus femoris muscle with a long motor nerve obtained from the left thigh was transferred to the paralyzed face. The motor nerve was connected to contralateral buccal branches, and the pedicle vessels were anastomosed to right submental vessels because right facial vessels had been resected with the arteriovenous malformation.

Postoperative initial contraction of the transferred muscle was 7 mo after the transfer, and 1 ½ years after the surgery the patient had smiling that looked natural (Fig. 7, *above, right* and *below, left*). No functional difficulty in donor leg was observed. The patient had no difficulty when he climb up and down steps, and he could lift up the leg while in a spine position (Fig. 7, *below, right*).

Discussion

The advantages of this one-stage reconstruction for established facial paralysis compared with two-stage reconstruction are that it can be completed in one stage and that the period required for muscle contraction is both theoretically and actually shorter.

Regarding selection of the muscle for repair of facial paralysis, although the extensor digitorum brevis muscle was used initially, it has

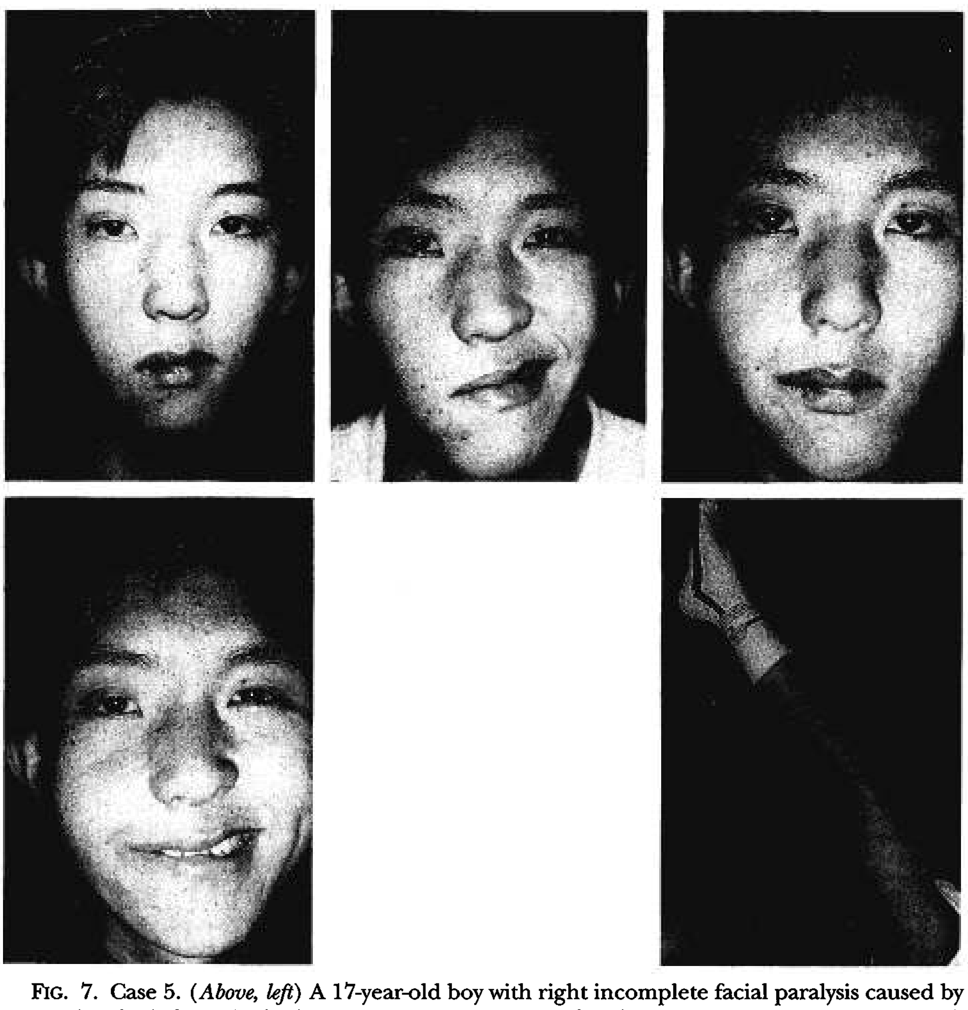

FIG. 7. Case 5. (*Above, left*) A 17-year-old boy with right incomplete facial paralysis caused by a resection for infraauricular hemangioma. Preoperative facial appearance at rest. (*Above, center*) Preoperative smiling. (*Above, right*) One year after the operation. Appearance at rest. (*Below, left*) Smiling 1 year after surgery. (*Below, right*) Two months after surgery in a supine position. There was no functional limitation in the donor leg.

been replaced by the gracilis muscle because results with the former muscle were inconsistent.[17] Mayou et al.,[13] who used the extensor digutorum brevis muscle, suggested that the treatment of facial paralysis could be dealt with better by transfer of a vascularized muscle with greater excursion and power than the extensor digitorum brevis muscle. They also suggested that a portion of the long neural pedicle of the latissimus dorsi muscle was suitable for transfer in one stage. Ferreira,[16] who at first used the extensor digitorum brevis with disappointing results, also attempted to use the latissimus dorsi, but the muscle did not seem to have enough excursion to reaminate the face. Other muscles, such as the pectoralis minor and the serratus anterior, have also been used for reconstruction of established paralysis by several authors.[6,7] In summary, to date the gracilis has been considered to be the most favorable muscle for two-stage reconstruction of facial animation.[17,19]

One of the most important aspects of successful clinical application of muscle transfer is selection of the donor muscle. Regarding selection of the muscle, it must be possible to remove it from the donor site without any residual functional disability,[1] and it must be large enough for the work required. When selecting a muscle for smile reconstruction, the muscle should be easy to prepare and distant from the face so that muscle preparation can be done simultaneously with the preparation of the face. The shape and size of the muscle must fit the cheek, have appropriate neurovascular anatomy, and provide 1 cm or more of movement to the mouth.[20]

Several authors have proposed the use of the rhomboid major muscle with the dorsal scapular nerve,[14] the gracilis muscle with the obturatory nerve,[15] and the abductor hallucis muscle with the motor nerve dissected from the posterior tibialis nerve.[16] As muscles with a long motor nerve for one-stage reconstruction of facial reanimation. On the basis of the abovementioned criteria for muscle selection, even for one-stage reconstruction of facial reanimation, the gracilis muscle should be considered the most suitable muscle if it has a long obturatory nerve that can reach the contralateral intact facial nerve. However, based on our clinical experience, it is impossible to use this because it is difficult to obtain a motor nerve of adequate length (more than 10 cm) beyond the inguinal ligament. Therefore, we used the rectus femoris muscle for one-stage repair of facial paralysis.

According to our cadaveric results, the rectus femoris muscle is nourished by a few vascular pedicles whose diameters are large enough for microvascular anastomosis. The advantages of using the rectus femoris muscle are as follows: (1) safety and simplicity exist in using one main large arterial supply for arterial anastomosis in its recipient site; (2) a femoral nerve is long enough (more than 20 cm) to reach the contralateral facial nerve for suturing; (3) it is possible to have simultaneous operations by two teams with the patient in the supine position (this implies that one-stage reconstruction can be completed within 5 hours); (4) the force and distance of contraction are appropriate to reanimate the face; (5) it can be separated as a segment with appropriate lengths, size, and power to replace lost muscles in the face; (6) the tendinous fascia in both ends provide a reliable point for anchoring sutures to the mouth and zygoma, which provides firmer attachment of the muscle; and (7) as Schneck[21] has reported, no loss of leg function occurs, with full strong knee and hip extensions in the donor leg from the remaining quadriceps portions. Thus, the rectus femoris muscle fulfills the requirements of a muscle for smile reconstruction.

Regarding the disadvantages of using this muscle, the entire rectus femoris muscle is too large to replace the facial muscles and consists of oblique muscle fibers. Therefore, segmentation of the muscle is required to use smaller pieces of it, splitting it longitudinally during the harvesting. This additional procedure with the risk of vascular damage is rendered easier if the muscle is segmented for use before transection at its point of origin and insertion. Another disadvantage of using this muscle is the shortness of the vascular pedicle. This disadvantage is often overcome with vascular anastomoses to the facial vessels, which are generally located closer to the pedicle than the temporal vessels. When a longer vascular pedicle is required, the descending branch of the lateral circumflex femoral vessels, which can be dissected downward more, might be used as a reverse-flow muscle graft.

The progress of regenerating axons is monitored by Tinel's sign on percussion along the course of the motor nerve. This usually takes about 10 to 12 mo after cross-facial sural nerve transfer. On the basis of our cases, it takes a shorter period of time, less than 6 mo, for passage throughout a cross-facial femoral nerve of the rectus muscle. This faster sprouting may have occurred because the femoral nerve, which was close to the rectus muscle, had a reverse blood supply from the revascularized muscle. Although the distant portion of the femoral nerve, which could not be reached by the reverse blood flow, was a free nerve graft, it might have been vascularized within a short time after surgery because of the small caliber of the nerve as compared with that of the sural nerve. These rich and early postoperative vascularizations of the femoral nerve might accelerate axonal sprouting through the cross-facial femoral nerve.

Finally, the major concern of this method is a possibility of postoperative dysfunction of the donor leg because of the loss of the rectus femoris muscle. To minimize this dysfunction, as a pedicle of the muscle, only one of several neurovascular hila of rectus femoris muscle was given up with segmentation of the rectus muscle. Motor nerves of the other hila might still be effective and could innervate the remaining rectus femoris muscle. Some of our patients had temporary scar contracture on the anterior thigh in the early postoperative stage, nobody, however, had major functional limitation of the donor leg, such as hindrance of walking or running, lower leg edema, or limited range of motion of the leg joints. However, a few patients had hypesthesia on the small area in the distal anterior aspect of the thigh.

Isao Koshima, M.D.
Plastic and Reconstructive Surgery
Kawasaki Medical School
577 Matsushima
Kurashiki City
Okayama, 701-01, Japan

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