Fifteen-year survey of one-stage latissimus dorsi muscle transfer for treatment of longstanding facial paralysis

Akihiko Takushima [a],*, Kiyonori Harii [a], Hirotaka Asato [b], Masakazu Kurita [a], Tomohiro Shiraishi [a]

[a] Department of Plastic and Reconstructive Surgery, School of Medicine, Kyorin University, 6-20-2 Shinkawa, Mitaka-shi, Tokyo 181-8611, Japan
[b] Department of Plastic and Reconstructive Surgery, Dokkyo Medical University, Tokyo, Japan

Summary   *Background:* Neurovascular free muscle transfer is one of the main reconstructive options for established or long-standing facial paralysis. The two-stage gracilis muscle transfer combined with the cross-face nerve graft (two-stage method) has been supplanted by one-stage reconstruction using the latissimus dorsi muscle (LD) at our institution. This study retrospectively evaluated the results of one-stage LD transfer.
Methods: Between September 1993 and December 2008, 344 patients (133 males, 211 females; age range, 5—75 years) with unilateral facial paralysis underwent 351 one-stage LD transfers. Patients were evaluated with a custom grading scale. Differences in grading scale score were compared according to age, past surgical history and the duration from operation to neuromuscular recovery.
Results: Contraction of the transferred muscle was recognised in 305 (87.0%) transfers. The duration until neuromuscular recovery ranged from 3 to 16 months (average $\pm$ standard deviation: 6.48 ± 1.92 months). The grading scale was significantly lower in middle-age group than in younger and elder groups ($P < 0.01$). Duration until neuromuscular recovery was significantly different when comparing the younger group and the oldest group. There was no difference in grading scale score or in duration until neuromuscular recovery when comparing the patients with a past surgical history and those without. The grading scale negatively correlated with the duration until neuromuscular recovery.
Conclusions: The results are consistent and statistical analysis revealed the versatility of the one-stage LD transfer. Although we believe the two-stage method is still a good option for facial reanimation, the one-stage method is advantageous regarding the shorter period of recovery and little donor-site morbidity.

* Corresponding author. Tel.: +81 422 47 5511; fax: +81 422 46 6138.
  E-mail address: takushima-pla@umin.ac.jp (A. Takushima).

The motor source of the first neurovascular free muscle transfer for facial reanimation was the ipsilateral deep temporal nerve.[1] Although the results were encouraging, having resulted in the restoration of strong and powerful contraction upon smiling, these patients also showed involuntary muscle contraction with biting, most likely because the obturator nerve innervating the gracilis muscle was sutured to the ipsilateral deep temporal nerve that innervates the temporal muscle.

To overcome this problem, a two-stage operation combining the cross-facial nerve graft with the free-muscle transfer was developed.[2—4] This method enables the use of the contralateral facial nerve, which results in a significant probability of achieving spontaneous synchronous animation. Surgeons therefore apply this method using various kinds of free muscles, including the gracilis,[5,6] pectoralis minor,[4,7] rectus abdominis[8] and latissimus dorsi (LD).[9] However, the long recovery period associated with this strategy (up to 2 years) may dissuade patients from engaging in this therapy. Further, donor-site morbidities related to harvesting of the sural nerve, including lower leg scarring and the sensory disturbances of the foot, are not negligible.

One-stage reconstruction, in which the motor nerve is directly crossed through the face and sutured to the contralateral facial nerve branches, may result in shorter duration until recovery of motor function with minimum donor-site morbidities. In 1981, Mayou described 10 cases of one-stage reconstruction using the extensor digitorum brevis muscle.[10] However, the results were not as favourable as expected. One-stage LD transfer was first described by Wang et al.,[11,12] but the original article was published only in Chinese and was not widely recognised by the Western world. Our group has also used one-stage transfer of the neurovascular LD muscle with the contralateral facial nerve branches as a recipient nerve (one-stage LD transfer) since 1993, and, in 1998, we described our experience in 24 consecutive patients undergoing one-stage LD transfer.[13] Since then, we have accumulated additional cases. Thus, the goal of this study was to retrospectively evaluate the results of one-stage LD transfer.

Patients and methods

Between September 1993 and December 2008, 344 patients (133 males, 211 females; mean age, 41.2 years; age range, 5—75 years) with unilateral facial paralysis underwent 351 one-stage LD transfer. Facial paralysis was complete in 204 patients and was incomplete in 140 patients. The aetiologies of facial paralysis are summarised in Table 1.

Surgical procedures

The operative procedure for the one-stage LD transfer has been previously described.[13] First, a subcutaneous cheek pocket is made through a preauricular incision. When the paralysis is complete, dissection can be conducted using an electrocautery. However, when incomplete paralysis is present, the partially damaged facial nerve should not be damaged further when dissecting the subcutaneous plane for the pocket of the muscle. The nasolabial fold line is not

Table 1 Aetiology.

Acoustic tumour	92
Bell's palsy	58
Parotid region tumour	48
Congenital	46
Hunt syndrome	26
Brain tumour	22
Otitis media	18
Temporal bone fracture	11
Trauma	9
Stroke	5
Others	9

incised to accept the subsequent LD segment, although it is sometimes incised in a subsequent revision procedure.[14] Dissection should extend approximately 1.5 cm beyond the nasolabial fold. The facial vessels are then dissected from a small submandibular incision for the recipient vessels. When the facial vessels are not available or are too small for vascular anastomoses, other vessels in the neck, such as the superior thyroid artery or the internal jugular vein, are employed. The long stalk and the large diameter of vascular pedicles of the LD enable selection of those alternative recipient vessels. On the other hand, the superficial temporal vessels, which are preferred for gracilis muscle transfer, are seldom used, mainly due to the diameter discrepancy between the superficial temporal vessels and the thoracodorsal vessels.

After the subcutaneous plane is dissected to pass the vascular pedicles between the cheek pocket and the submandibular incision, several stay sutures for the muscle fixation are hooked in the lateral edge of the orbicularis oris; this site corresponds with the new nasolabial fold line. When the cheek is severely drooped, especially among those with complete paralysis, a few stay sutures are fixed to the parotid fascia for the static suspension of the modiolus. Contralateral facial nerve branches are then dissected from a small incision, less than 2 cm long, placed at the anterior margin of the parotid gland in the healthy cheek. One or two branches that contract the nasolabial fold line are well secured by the nerve stimulator and selected as a motor source nerve. Preparation of the face is finished by passing the guide thread through the tunnel using the nerve passer between the cheek pocket in the paralysed side and the healthy side.

The LD segment is harvested simultaneous to preparation of the face. An incision (~8 cm long) is made along the anterior margin of the LD, and dissection is performed. After the dissection of the thoracodorsal vessels, the thoracodorsal nerve is traced proximally towards its origin from the posterior cord of the brachial plexus. Dissection of the thoracodorsal nerve from the posterior cord allows harvesting of a sufficient length of the nerve to reach from the cheek pocket to the contralateral cheek incision. Conversely, distal dissection of the nerve deep into the muscle is avoided to prevent damage to the nerve—muscle interaction. After the first ramification of the thoracodorsal nerve in the LD, the most lateral branch running longitudinally is selected and dissected. However, the dissection is terminated just before entering into the muscle fibres, as

noted above. After securing a sufficient length of the nerve (~15 cm long), the rectangular muscle belly is divided, taking care not to damage the neurovascular hilum. A disposable stapler is used to divide the proximal end, as it secures the muscle fixation to the nasolabial fold line.[15] The muscle segment required in the usual setting is about 3—4 cm wide and 8—10 cm long. When the thickness is >1 cm, the surface of the LD is thinned to avoid the cheek bulkiness after the transfer. Thinning is performed *in situ* before severing the vascular pedicles to allow for accurate haemostasis. When the paralysis is incomplete, a segment with slightly smaller dimension in width and thickness is sufficient to assist the original cheek movement.[16] As a result, cheek bulkiness can be avoided and a subsequent revision procedure may not be necessary. After the trimming is finished, the thoracodorsal nerve and vessels are severed, and the muscle segment is immediately transferred to the face.

First, the thoracodorsal nerve is tied to the guide thread and passed through the tunnel to midway to avoid loosening of the nerve. The proximal end of the muscle through which stay sutures are passed is pushed in the direction of the nasolabial fold line, and the guide thread tied to the thoracodorsal nerve is simultaneously pulled. After it is confirmed that the distal end of the nerve reaches the contralateral cheek incision, the proximal end of the muscle segment is tightly fixed to the nasolabial fold line. The thoracodorsal vessels are guided to the submandibular incision without twisting. The thoracodorsal vessels are anastomosed to the recipient vessels (almost facial vessels by end-to-end fashion), followed by placement of the nerve suture between the thoracodorsal nerve and the suitable facial nerve branches under microscopy. Finally, a stapler is used to cut any excess amount of the transferred muscle, and the distal end is fixed to the zygomatic arch.

Evaluation

The results of the present series were all evaluated according to the grading scale illustrated in Table 2, which was based on a combination of clinical and electromyographic findings. Results were evaluated at least 2 years postoperatively. All patients were evaluated on clinical site by the senior author (KH). Differences in the grading scale score according to age and past surgical history were analysed statistically. Patients were classified into five age groups (group 1: <15 years old; group 2: from 15 years to <30 years; group 3: from 30 years to <45 years; group 4: from 45 years to <60 years; and group 5: ≥60 years), and the grading scale of each group was compared using the Kruskal—Wallis test, followed by a multiple comparison using the Bonferroni—Dunn method. Patients were divided into two groups, depending on the presence/absence of a past history of previous surgery in the parotid, face and neck area. The grading scale scores of these two groups were compared using the Mann—Whitney test.

The duration from the operation to the time of neuromuscular recovery was also assessed. The relationship between the presence/absence of past surgical history was evaluated using Mann—Whitney U test/non-paired t-test. One-way analysis of variance, followed by a multiple

Grade	Description
Table 2	**Evaluation criteria.**
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
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

comparison using the Tukey—Kramer method, was performed to test for statistically significant differences between age groups.

Finally, correlations between the duration until nerve recovery and the grading scale score were analysed nonparametrically using the Spearman rank-correlation coefficient.

Results

Contraction of the transferred muscle was recognised in 351 (87.0%) transfers. The beginning of the muscle
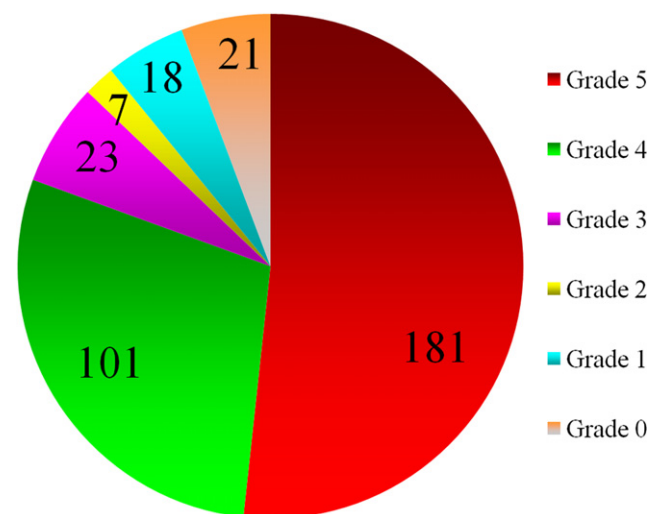

Figure 1 Postoperative results evaluated by the grading scale listed in Table 2.

movement ranged from 3 to 16 months, and the average ± standard deviation was 6.48 ± 1.92 months.

Smile results were evaluated as grade 5 in 181 (51.6%) transfers, grade 4 in 101 (28.8%) transfers, grade 3 in 23 (6.6%) transfers, grade 2 in seven (2.0%) transfers, grade 1 in 18 (5.1%) transfers and grade 0 in 21 (6.0%) transfers (Figures 1—4).

Grade 0 (n = 21) indicated that patients were not followed up for at least 2 years; thus, these patients were excluded from statistical evaluation of the grading scale score. Age comparison analysis included the grading scale score of 18 transfers in group 1, 95 transfers in group 2, 64 transfers in group 3, 101 transfers in group 4 and 59 transfers in group 5. The average ± standard deviation of the grading scale score was 4.06 ± 1.06 in group 1, 4.40 ± 0.49 in group 2, 3.91 ± 1.35 in group 3, 4.44 ± 0.94 in group 4 and 4.25 ± 1.04 in group 5. The grading scale score was significantly lower in group 3 than in group 2 ($P < 0.05$) or group 4 ($P < 0.01$) (Figure 5). Grading scale scores were also compared between 279 of 297 transfers with no past surgical history around the face and the neck and 51 of 54 transfers with a positive history of past surgical history around the face and the neck. The average ± standard deviation of the grading scale score was 4.29 ± 1.07 in transfers without a past surgical history and was 4.20 ± 1.04 in transfers with a past surgical history. There was no significant difference between these two groups.

For analysis of grading scale score according to duration until neuromuscular recovery, grade 0, 1 and 2 patients were excluded from the statistical evaluation, because these patients did not have muscle contraction.
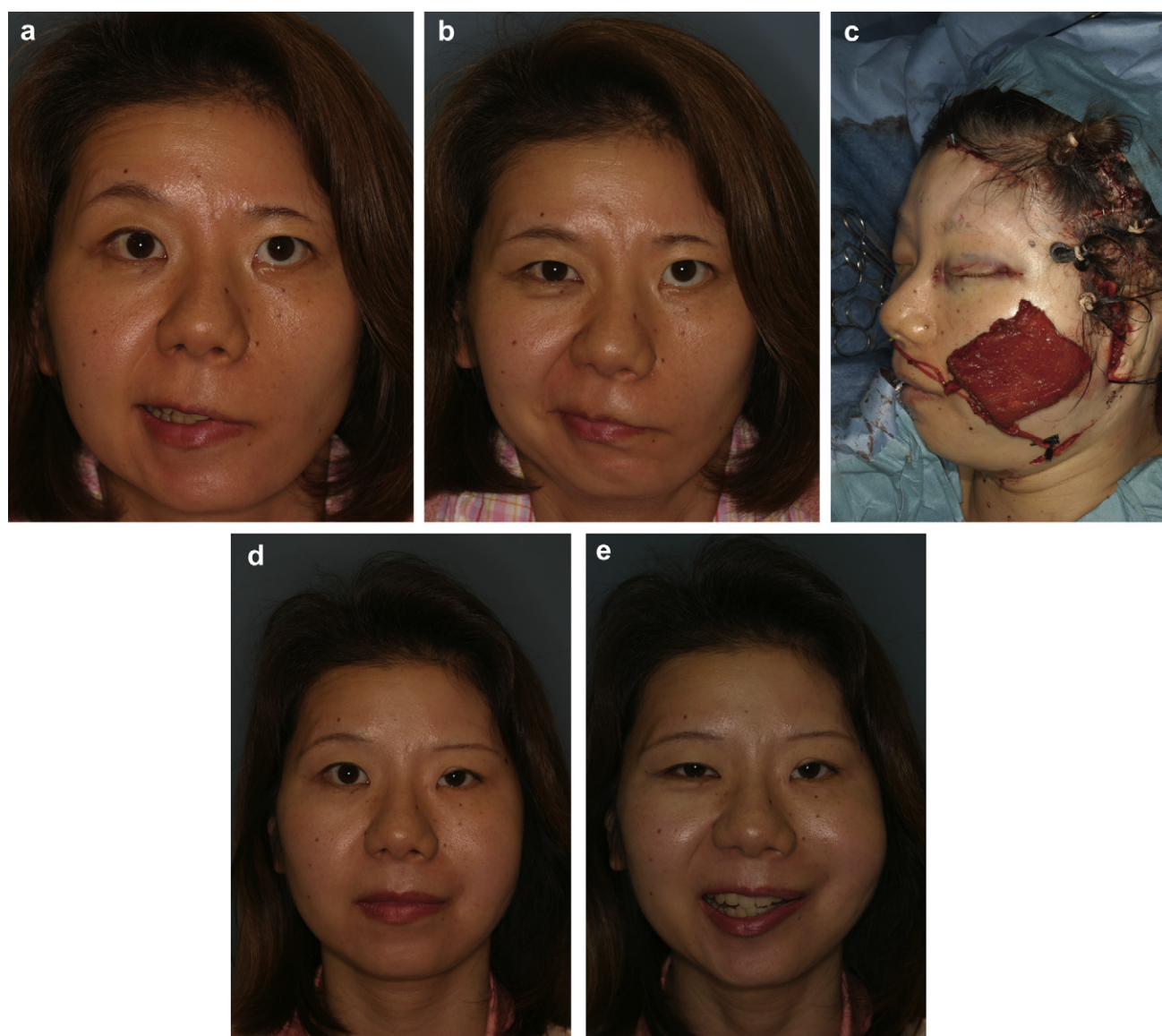

Figure 2   a. Case 1. A 40-year-old woman with a congenital left complete paralysis due to hemifacial microsomia seen preoperatively at rest. b. The same patient smiling preoperatively. c. A neurovascular LD was transferred. Simultaneously, the paralysed eyebrow was elevated and the temporal muscle was used for complete eye closure. d. One year after a LD transfer at rest. e. The patient show a near-natural smile with a grade 5.
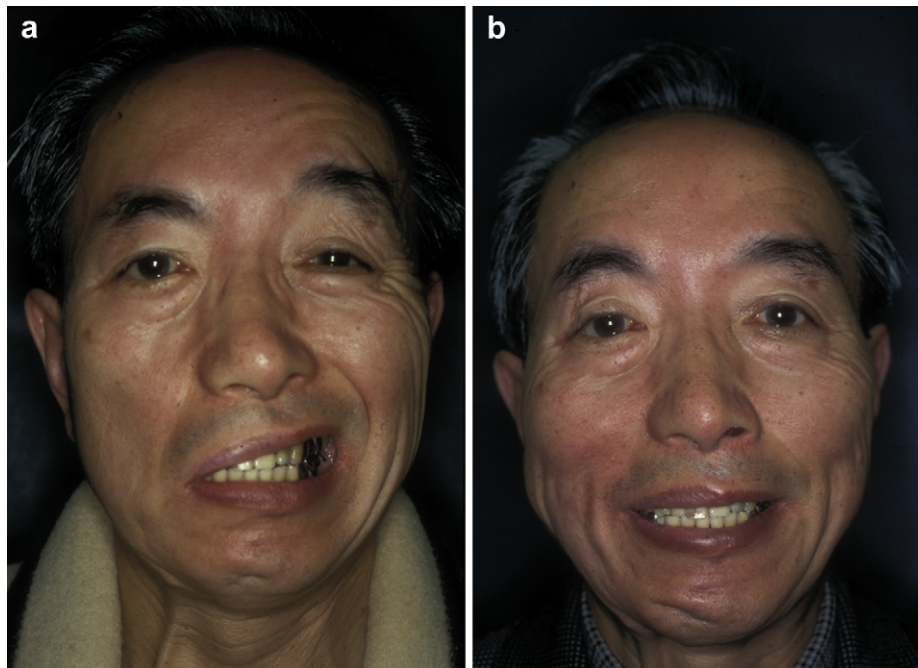
Figure 3 a. Case 2. A 66-year-old man with an established left complete Bell's palsy seen preoperatively while smiling. b. Four years after LD transfer and blepharoplasty, seen while smiling.

Comparisons according to age was conducted in 17 transfers in group 1, 87 transfers in group 2, 56 transfers in group 3, 97 transfers in group 4 and 55 transfers in group 5. The average $\pm$ standard deviation duration until nerve recovery was 6.65 ± 2.01 months in group 1, 6.16 ± 1.59 months in group 2, 6.68 ± 1.82 months in group 3, 6.90 ± 2.23 months in group 4 and 7.35 ± 2.12 months in group 5. Duration until neuromuscular recovery was significantly shorter in group 2 than in group 5 ($P < 0.01$) (Figure 6). The duration until neuromuscular recovery was also compared among 263 of 297 transfers with no past surgical history around the face and the neck with 48 of 54 transfers with a past surgical history around the face and the neck. The average $\pm$ standard deviation of duration until neuromuscular recovery was 6.80 ± 2.09 months in transfers without a past surgical history and was 6.25 ± 1.33 months in transfers with a past surgical history. There was no significant difference between these two groups.

Grading scale score negatively correlated with the duration until neuromuscular recovery (Figure 7). This indicates that patients who experience earlier recovery of muscle contraction tended to achieve better results.

Discussion

Selection of the optimal donor muscle and the motor source nerve has been a controversial topic ever since the neurovascular free-muscle transfer was first developed for the treatment of facial paralysis. Other than the length and stability of the vascular pedicle and donor-site morbidity, types and proportions of muscle fibres are very important factors when selecting the most appropriate donor muscle. Essentially, the parallel muscle fibre can bring the long excursion length. By contrast, the pennate muscle fibre is

associated with stronger muscle power with shorter excursion length. The gracilis and the LD, both of which are composed by the parallel fibres, are advantageous from this point. We always check the muscle contraction by electrically stimulating the donor nerve just before muscle harvest. Our experience reveals that the contraction length of the gracilis muscle is longer than that of the LD. The gracilis muscle, therefore, may be better suited for facial reanimation when compared with the LD muscle from the standpoint of muscle fibre quality. Thus, we always transfer the gracilis muscle when the ipsilateral facial nerve branch is available. However, the gracilis muscle transfer in the usual setting requires the precedent cross-face nerve graft when the contralateral facial nerve is selected as a motor source. In this situation, two nerve suture points are required, resulting in a decrease of the axons that can innervate the grafted muscle.[17] As a result, we did not find any difference in the results of the muscle transfer when comparing the two-stage operation using the gracilis combined with the cross-face nerve graft and the one-stage LD transfer. Nevertheless, the one-stage LD transfer is the strategy of choice due to the shorter recovery period and the minimal donor-site morbidity.

The ipsilateral masseteric nerve can be used as an alternative motor source.[18,19] The masseteric nerve is a powerful motor source and can drive the transferred muscle well. However, the smile driven by the deep temporal nerve is limited in that patients can smile only when the jaws are clenched and because patients cannot control unnatural movements when chewing food. Thus, facial reanimation using a non-facial motor source may preclude spontaneous movement. In contrast to this established theory, Lifchez et al. described three children with bilateral paralysis in whom the ipsilateral trigeminal nerve was selected as a motor source and suggested that
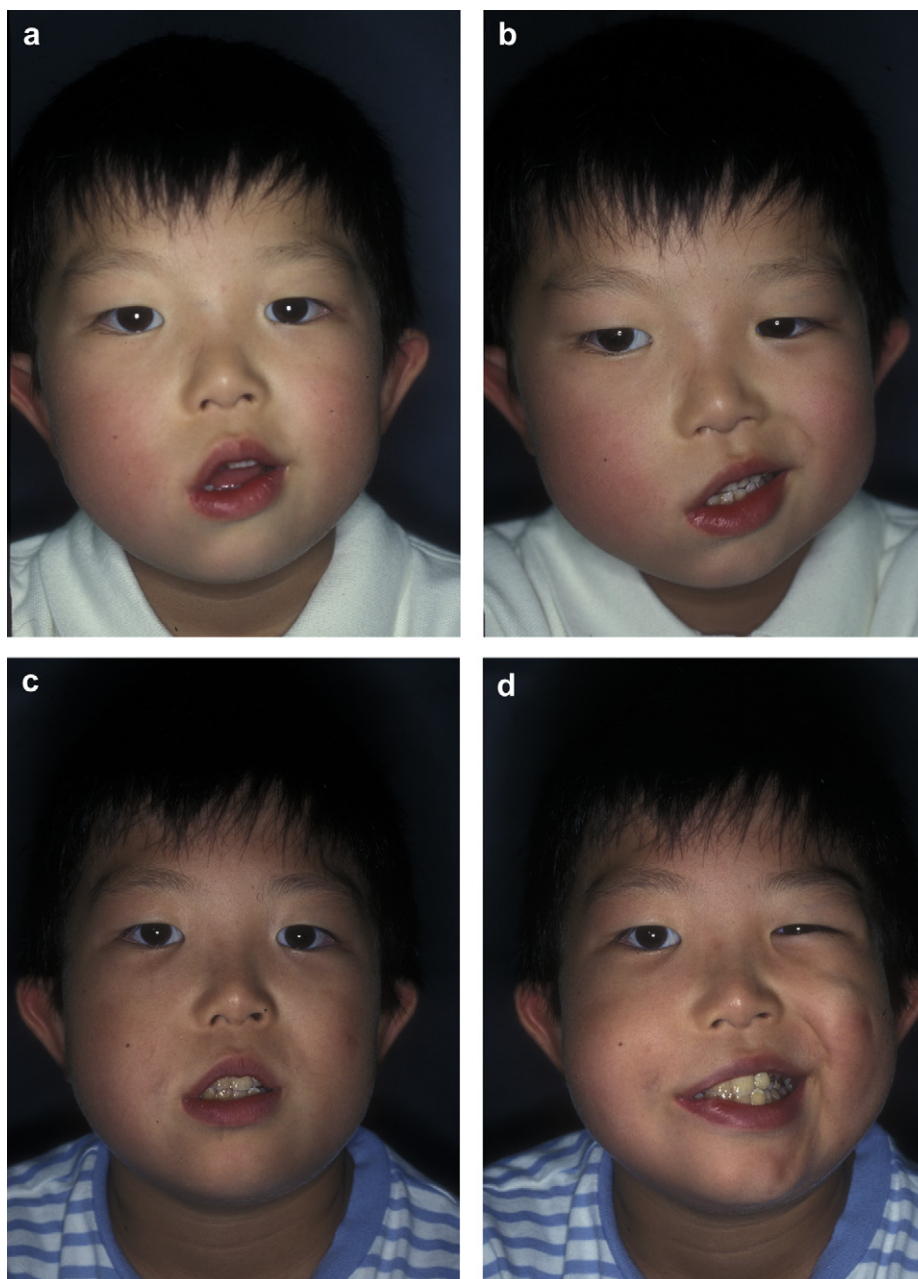
Figure 4   a. Case 3. A 8-year-old boy with a congenital right complete paralysis seen preoperatively at rest. b. The same patient smiling preoperatively. c. Two years after a LD transfer at rest. d. Spontaneous smile is achieved with a grade 5.

cortical adaptation can occur to coordinate the motor activity of smiling, especially when patients undergo the operation at a young age.[18] Manktelow et al. agreed with this cerebral plasticity theory, although they reported that age did not affect the degree of spontaneity of smiling without biting.[19] We have used the pedicled temporal muscle transfer for eye closure and found that some patients can close their eyes without consciously thinking of clenching. While cerebral adaptation probably occurs in some patients, the clinical challenge is to predict which patients will experience this phenomenon. Manktelow et al. suggested that this procedure is suitable for older patients, those who have a heavy face or rest asymmetry and those who have a very powerful smile on their normal

side. Statistical analysis in our series revealed that the grading scale score was significantly lower in group 3 (30—45 years) than in group 2 (15—30 years) or group 4 (45—60 years) (Figure 5). We feel that the power produced by the one-stage LD transfer can sometimes be weak, especially among middle-aged male patients with a fatty and heavy cheek. The use of the ipsilateral trigeminal nerve may be better than the contralateral facial nerve branch in such patients. Thus, there may be specific indications for each method rather than one universally optimal method.

The one-stage LD transfer was first developed by Wang et al. and was published in a Chinese-language journal.[11] They harvested the thoracodorsal nerve as a vascularised nerve by dissecting the vascular stalk and the nerve as
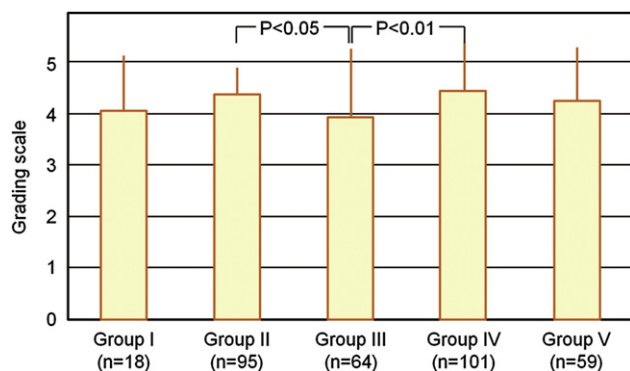
Figure 5 Age-dependent comparison of grading scale score. The grading scale is significantly lower in Group 3 than in Group 2 or Group 4.

Figure 7 Grading scale score negatively correlated with the duration until nerve recovery.

a whole.[12] In our method, the thoracodorsal vessels and nerve are dissected separately, and the thoracodorsal vessels are sutured to the ipsilateral facial vessels. Therefore, the thoracodorsal nerve is not likely to be vascularised. However, the superiority of the vascularised nerve graft has not been well demonstrated when the recipient bed is well vascularised. Further, the tunnel through which the thoracodorsal nerve passes is surrounded by the subcutaneous fat tissue with good vascularisation. As a result, we propose that there is no need for the thoracodorsal nerve to be vascularised by the thoracodorsal vessels.

Statistical analysis in this series revealed that the duration until neuromuscular recovery increased in proportion to patient age. Although the duration until neuromuscular recovery was longer in the youngest group (group 1) relative to group 2 or 3, this difference did not reach the level of statistical significance. Harvesting a nerve with sufficient length to reach the contralateral face in children requires a sophisticated technique. Furthermore, the tip of the thoracodorsal nerve is so small that the number of the sprouting axons through the nerve suture may be fewer than that in adults. In cases in which these are the main reasons of delayed nerve recovery in children, a two-stage operation using the cross-face nerve graft should be used. At present, the number of paediatric
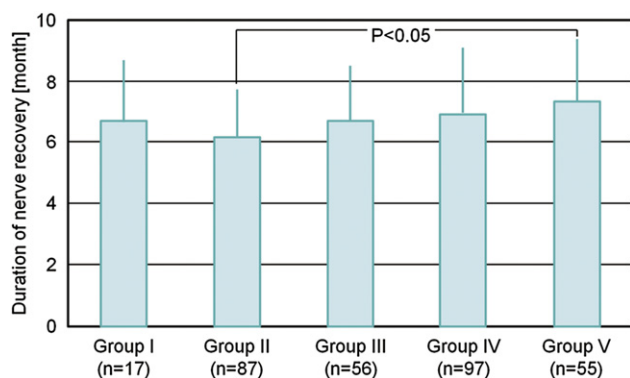
cases is relatively small when compared with other age groups. Thus, accumulation of a greater number of paediatric cases is required to make a definitive determination as to the optimal method in these patients.

A prior history of surgery around the parotid area did not affect the results of the grading scale or the duration of the nerve recovery. Among patients with a prior history of surgery, fewer vessels are suitable for microvascular anastomoses because of radical resection and chemotherapy.[20] In this situation, use of the LD, which has a long vascular stalk, is preferable from the perspective of the potential recipient vessels. Moreover, when the soft tissue is deformed due to ablative surgery, a soft-tissue flap combined with the LD flap, such as the LD perforator flap and the serratus anterior musculocutaneous flap, can restore the tissue defect, resulting in the possibility of a superior grading scale score.[21] These characteristics indicate the versatility of the one-stage LD transfer.

Disclosure

The authors of this article have no financial interests to disclose.

Ethical approval

The study was conducted under protocols as approved by our institutional review board and in accordance with ethical treatment of human subjects.

Funding

None.

Conflict of interest

None.

References

1. Harii K, Ohmori K, Torii S. Free gracilis muscle transplantation, with microneurovascular anastomoses for the treatment of facial paralysis. A preliminary report. *Plast Reconstr Surg* 1976; **57**:133—43.

Figure 6 Age-dependent comparison. The beginning of the muscle movement was significantly earlier in Group 2 than in Group 5.
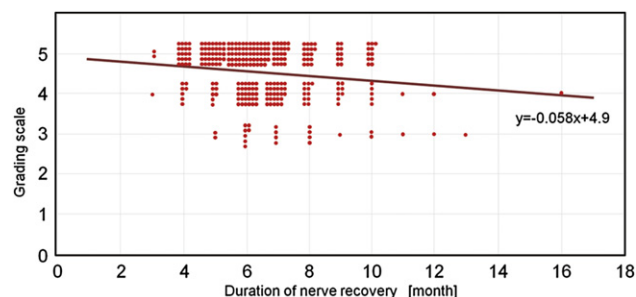
2. O'Brien BM, Franklin JD, Morrison WA. Cross-facial nerve grafts and microneurovascular free muscle transfer for long established facial palsy. *Br J Plast Surg* 1980;**33**:202—15.

3. Harii K. Microneurovascular free muscle transplantation for reanimation of facial paralysis. *Clin Plast Surg* 1979;**6**:361—75.

4. Harrison DH. The pectoralis minor vascularized muscle graft for the treatment of unilateral facial palsy. *Plast Reconstr Surg* 1985;**75**:206—13.

5. O'Brien BM, Pederson WC, Khazanchi RK, et al. Results of management of facial palsy with microvascular free-muscle transfer. *Plast Reconstr Surg* 1990;**86**:12—22.

6. Harii K. Refined microneurovascular free muscle transplantation for reanimation of paralyzed face. *Microsurgery* 1988;**9**:169—76.

7. Terzis JK. Pectoralis minor: a unique muscle for correction of facial palsy. *Plast Reconstr Surg* 1989;**83**:767—76.

8. Hata Y, Yano K, Matsuka K, et al. Treatment of chronic facial palsy by transplantation of the neurovascularized free rectus abdominis muscle. *Plast Reconstr Surg* 1990;**86**:1178—87.

9. Dellon A, LMackinnon SE. Segmentally innervated latissimus dorsi muscle. Microsurgical transfer for facial reanimation. *J Reconstr Microsurg* 1985;**2**:7—12.

10. Mayou BJ, Watson JS, Harrison DH, Parry CB. Free microvascular and microneural transfer of the extensor digitorum brevis muscle for the treatment of unilateral facial palsy. *Br J Plast Surg* 1981;**34**:362—7.

11. Wang W, Chang T, Yang C, et al. Cross-face neurovascular latissimus dorsi for facial reanimating in one stage. *Chin J Microsurg* 1989;**12**:155.

12. Wei W, Zuoliang Q, Xiaoxi L, et al. Free split and segmental latissimus dorsi muscle transfer in one stage for facial reanimation. *Plast Reconstr Surg* 1999;**103**:473—80.

13. Harii K, Asato H, Yoshimura K, et al. One-stage transfer of the latissimus dorsi muscle for reanimation of a paralyzed face: a new alternative. *Plast Reconstr Surg* 1998;**102**:941—51.

14. Takushima A, Harii K, Asato H, et al. Revisional operations improve results of neurovascular free muscle transfer for treatment of facial paralysis. *Plast Reconstr Surg* 2005;**116**:371—80.

15. Asato H, Harii K, Nakatsuka T, et al. Use of the disposable stapler to insure proper fixation of a transferred muscle in treatment of facial paralysis. *J Reconstr Microsurg* 1998;**14**:199—204.

16. Takushima A, Harii K, Okazaki M, et al. Availability of latissimus dorsi minigraft in smile reconstruction for incomplete facial paralysis: quantitative assessment based on the optical flow method. *Plast Reconstr Surg* 2009;**123**:1198—208.

17. Harii K. Experimental and clinical studies of nerve and muscle grafts for the treatment of facial paralysis. *J Jpn Plast Reconstr Surg* 1987;**7**:347—72.

18. Lifchez SD, Matloub HS, Gosain AK. Cortical adaptation to restoration of smiling after free muscle transfer innervated by the nerve to the masseter. *Plast Reconstr Surg* 2005;**115**:1472—9.

19. Manktelow RT, Tomat LR, Zuker RM, Chang M. Smile reconstruction in adults with free muscle transfer innervated by the masseter nerve: effectiveness and cerebral adaptation. *Plast Reconstr Surg* 2006;**118**:885—99.

20. Takushima A, Harii K, Asato H, et al. Neurovascular free-muscle transfer for the treatment of established facial paralysis following ablative surgery in the parotid region. *Plast Reconstr Surg* 2004;**113**:1563—72.

21. Takushima A, Harii K, Asato H, et al. One-stage reconstruction of facial paralysis associated with skin/soft tissue defects using latissimus dorsi compound flap. *J Plast Reconstr Aesthet Surg* 2006;**59**:465—73.