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FACIAL REANIMATION BY TRANSPLANTATION OF A MICRONEUROVASCULAR MUSCLE: LONG-TERM FOLLOW-UP

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Abstract. The two-stage operation for reanimation of long-standing facial paralysis by cross-facial nerve grafting and later free microneurovascular muscle transfer has been the treatment of choice for nearly 25 years. However, the functional outcome may be unpredictable. We therefore need to know more about the factors that influence the final result. We have recorded the long-term results of microneurovascular surgery in facial paralysis, and evaluated which factors influenced the functional outcome. Twenty-seven of 40 patients aged 7 to 65 years (mean 40) operated on at Helsinki University Hospital between 1986 and 2000 were available for interview and video recording. The gracilis, latissimus dorsi, and serratus anterior muscles were used for microneurovascular transfer in 11, 10, and 6 cases, respectively. The outcome of microneurovascular muscle transfer was graded on House's scale 1 to 6. The mean follow-up period was 8.5 years (range 2 to 15). Sixteen patients (59%) displayed only mild or moderate dysfunction (grades 2 to 3) after reconstruction. In 8 patients (30%) dysfunction was graded as moderately severe, and in 3 (11%) as severe. There was a correlation between final functional outcome and the follow-up time after microneurovascular facial reanimation. The longer the follow-up time after muscle transplantation the poorer the functional result ($p = 0.003$). Twenty-one patients (78%) considered that their quality of life was better or much better after facial reanimation. Patients' satisfaction correlated with a good functional result.

Key words: facial reanimation, microneurovascular muscle transfer, facial paralysis.

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Long-standing facial paralysis is a serious functional and aesthetic problem for a patient, and treatment often requires several operations (26). The treatment should aim to achieve symmetry at rest, during voluntary movement, and during expression of emotions (26). It should also improve speech and mastication (26).

In the past many procedures have been used to restore facial function. Cross-facial nerve grafting was first reported by Scaramella and Tobias (21) and Smith (23) in 1971, and was publicised by Anderl (1) in 1973. The problem with this technique was that the operation had to be done within 6 months of the onset of paralysis (1), and the results were inconsistent. Harii et al. (11) first reported free-muscle transplantation for reanimation of a paralysed face using microvascular techniques in 1976. In 1979, Harii (9) recommended a two-stage procedure that combined cross-facial nerve grafting and microneurovascular muscle transfer, and this became a standard procedure as described by Terzis and Noah (24) and Wells and Manktelow (26).

The muscle is transferred when the presence of outgrowing axons is indicated by a positive Tinel's sign at the free end of the grafted nerve on the paralysed side (peripheral tingling on percussion over the site of the damaged nerve), usually 9–12 months after transfer of the nerve (9). Recently, single-stage facial reanimation has also been used as an alternative to the standard technique (10, 14).

Twenty years of surgical experience in facial reanimation has contributed to our knowledge of the factors that influence functional and aesthetic outcome. Restoration of the original resting tension of the muscle graft (7, 25) and meticulous coaptation of the nerve (15) between the donor nerve and the motor nerve of the muscle graft have proved to be of great importance. Nevertheless, many questions remain unanswered.

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The aim of this study was to report the long-term results of facial reanimation using three different donor muscles, and to find out which preoperative, operative, and postoperative factors influenced the final result. Functional outcome and patients' satisfaction were also compared.

PATIENTS AND METHODS

The study comprised 40 patients who presented with complete, long-lasting unilateral facial paralysis between 1986 and 2000. Twenty-seven of the 40 patients responded to an invitation to attend a late clinical evaluation including an interview and a video recording. The aetiology of the paralysis is shown in Table I.

All patients were operated on by a single senior surgeon using a standard two-stage method. In the first stage, an 18–20 cm long sural nerve graft was harvested and transplanted under the chin to connect the healthy side to the preauricular area on the paralysed side. Large buccal branches of the facial nerve (8–12 axons) on the healthy side were sacrificed, and the nerve graft was coapted epineurally with 10/0 sutures. About eight months after the nerve transplantation, the microneurovascular muscle bundle was grafted. The size, length, and total volume of the graft were carefully planned. Blood vessels were anastomosed to the facial artery and vein under the chin. The nerve was coapted with epineural sutures. From 6 to 8 months later, patients started to train the facial muscle. They were advised to train their mimic muscles in front of the mirror several times a day.

To evaluate which demographic and clinical factors influenced the final functional outcome of facial reanimation the patients' hospital charts were reviewed retrospectively. Table II shows characteristics of the patients and their operations.

The duration of the facial paralysis preoperatively ranged from 1 to 41 years (mean 8). At the time of operation, the mean age of the patients was 41 years (range 7 to 65). Only one patient was a child, a girl aged 7 years.

The sural nerve was used as a cross-facial nerve graft in every case. Three muscles were used: the gracilis ($n = 11$), the latissimus dorsi ($n = 10$), and the serratus anterior ($n = 6$). The gracilis was used in 1986, 1989, and 1995, and from 1997 to 2000. The latissimus dorsi was used in 1989, 1990, 1991, 1993, 1998, and 1999. The serratus muscle was used in the beginning of the follow-up period, from 1987 to 1989.

Primary complications included five haematomas that were treated conservatively. One wound infection was cured with antibiotics, and one wound developed minimal necrosis.

Table I. *Aetiology of facial palsy*

Removal of acoustic neuroma	11
Parotidectomy	4
Trauma	4
Intra-acoustic diseases	2
Removal of intracranial tumours	2
Congenital	2
Not known	2
Total	27

Table II. *Characteristics of patients and operations*

Sex:	
Male	8
Female	19
Mean duration of palsy (years)	8
Range	1–41
Side of the palsy:	
Right	14
Left	13
Mean age at time of free muscle transfer (years)	41
Range	7–65
Mean body mass index at time of free muscle transfer	24
Range	18–37
Smoking:	
Yes	7
No	20
Alcohol consumption:	
Heavy	3
Moderate	12
None	12
Mean time between nerve cross-over and microneurovascular muscle transplantation (months)	8
Range	4–20
Muscle:	
Gracilis	11
Latissimus dorsi	10
Serratus anterior	6
Mean weight of muscle (g) ($n = 14$)	53
Range	20–110
Mean duration of microneurovascular muscle transplantation (min)	306
Range	240–410
Mean intraoperative ischaemia time of free muscle (min)	84
Range	59–153
Number of primary complications	7/27
Mean number of secondary procedures	2
Range	0–8
Mean duration of follow-up (years)	8.5
Range	2–15

After transplantation of the muscle, other procedures including tarsorraphies ($n = 16$) and forehead procedures ($n = 4$) were needed 53 times in 21 patients. Secondary operations involving the transplanted muscle totalled 32 facial lifts including raising of the muscle in 19 patients during follow-up.

Written consent was obtained from each patient and the study was approved by the Ethics Committee of Helsinki University Hospital.

Video recording and interview

The patients were videoed at rest, while speaking, and while making a number of voluntary movements to show mimic muscle function.

In interviews, their satisfaction was measured by asking them how the operations had affected their quality of life. The answers were graded on a scale from 1 (quality of life considerably better after the operations) to 4 (quality of life poorer than before the operations). They were also asked to estimate how much time they spent practicing facial movements after they had been asked to train their facial function. The amount of practice was graded on a scale from 1 (none) to 4 (several times a day).

Scoring techniques

The functional outcome of the operation was illustrated by the amount of facial dysfunction remaining. It was graded objectively during the interview by a single physician on a scale from 1 to 6 as described by House (12). These grades were later combined with those obtained from the videotapes. The House scale was modified by disregarding the function of the forehead, as in these operations no muscle was transferred to the forehead area. The House scale is shown in Table III.

Statistical analysis

Ordinal regression was fitted with the Statistical Package for the Social Sciences (SPSS) Polytomous Universal Model (PLUM). For univariate analysis we used the Kruskal-Wallis test. In multivariate analysis the most appropriate link function was found to be complementary log-log-function. Probabilities of less than 0.05 were accepted as significant.

RESULTS

The long-term functional outcome measured as the state of mimic function is summarised in Table III. Nearly two thirds of the patients achieved a result defined as only mild or moderate dysfunction (grades 2–3) of facial movement. In one-third of the patients, dysfunction was graded as moderately severe and in 10% as severe (grade 5). None of the patients had retained total facial paralysis postoperatively (grade 6).

In statistical analysis, the period after facial reanimation had an effect on the final functional outcome, the longer the follow-up time after the muscle transplantation the weaker was the muscle function ($p = 0.003$) (Fig. 1).

In addition, correlations were studied between functional outcome and patients' age and sex, body mass index (BMI), smoking habits, alcohol consumption, dominant hand, aetiology and side of the palsy, duration of palsy, time interval between the two operations, duration of operation and intraoperative ischaemia, number of primary complications, and number of secondary procedures. None of these factors correlated with the functional result. None of the different donor muscles had any significant effect on final functional outcome.

The patients estimated the amount of time they had spent on mimic practice after the muscle had been transplanted; the amount of practice did not correlate with the final functional result. Twenty-one patients (78%) thought that their quality of life had improved after the microneurovascular muscle transplantation but six (22%) considered that the reanimation had had

Table III. *Functional outcome as the postoperative state of mimic function graded according to House (12)*

Grade of dysfunction	Number of patients
I Normal	0
II Mild	5
III Moderate	11
IV Moderately severe	8
V Severe	3
VI Total paralysis	0
Total	27

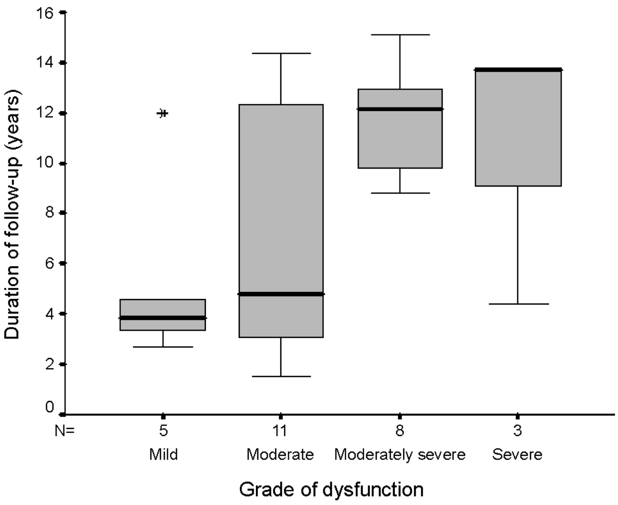

Fig. 1. Box plot showing the relation between the duration of follow-up time (years) and the grading of patients' facial dysfunction. The solid bars indicate the median and the error bars the range.

no effect. The degree of satisfaction correlated with a good final functional result ($p = 0.008$).

DISCUSSION

Nearly two thirds of our patients achieved adequate mimic function after microneurovascular reconstruction. The longer the duration of follow-up, the poorer the function.

Several outstanding studies on facial reanimation have been published (14, 17, 20, 24). When we compare the results of different papers, factors such as the great variation in duration of follow-up must be taken into account. O'Brien et al. had a follow-up period ranging from 9 months to 11.3 years (mean 4.1 years) (17) and Kumar and Hassan from 7 months to 6.5 years (mean 3.5 years) (14). In the analysis of 100 patients by Terzis and Noah, the follow-up time was 2 years (24). Our study was retrospective, so the different patients were assessed at different time points after muscle transplantation. However, the mean follow-up period covered nearly 9 years, and was up to 15 years for some patients. This may be of great importance when judging the outcome, as there was a clear correlation between recent muscle transplantation and a good functional result.

As noted before, the older the transplant, the weaker was the muscle function. The better outcome achieved in more recent cases may have been the result of increased experience and improved technical skills on the part of the surgical team. We also want to know if lack of muscle adaptation after the transfer could influence the long-term result. Experimental studies have shown that both muscle transfer and denervation damage muscle tissue (5). If there are no contractile stimuli or innervation is incomplete, the repeated attempts at regeneration will eventually exhaust satellite cells (22, 27). Depletion of satellite cells impairs contractile function and the ability to repair tissue is lost (13). Studies on the regenerative state of microneurovascular muscle transfers and the contractile protein expression may provide some new insights into this subject.

Another factor that may be of importance for the final result is the extent of the facial paralysis that has been treated. In our study, all the patients had complete facial palsy. In this respect our series differs from that of other studies, such as the large study of Terzis and Noah, in which only 34% of the patients had complete facial palsy (24), and that of O'Brien et al.'s study, in which 68% of the patients had complete palsy (17). We suggest that there may be greater potential for a favourable functional outcome of the reanimation when patients with incomplete palsies are treated.

The correlation between age and recovery of muscles is a subject of investigation (4, 24). In our series, the mean age of the patients at the time of surgery was 41 years. As most of them were middle-aged (only one was a child), we could not show the effect of age on recovery of muscle function and final functional outcome. A recent study on patients with a mean age of 22 years, however, reported a tendency for younger patients to achieve earlier functional recovery (24). Experimental studies confirm that the youth of an animal given a graft is an important determinant of the success of regeneration of skeletal muscle (4). The comparably older age of our patients must therefore be considered when evaluating our results.

Numerous grading systems have been developed to quantify the extent of facial paralysis and the outcome of microneurovascular reanimation of the face (3, 12, 16). Promising computer-assisted methods for assessing mimic function are also being developed, and some of them are already available (6, 8, 19). In our study, facial dysfunction was measured by House's well-established standard grading system (12). The degree of dysfunction is clearly defined on a scale from 1 to 6. The patients were assessed both live during the interview and from video-recorded tapes illustrating mimic function at different sessions. Every face has a range of dimensions (18), and a human observer can recognise the dimensions of a smile not measurable in millimeters or action potentials. It is not easy to compare studies using different grading systems. Nevertheless, in the study by Terzis and Noah, which used a scale from 1 to 5, about 80% of patients had results ranging from moderate to excellent and about 42% were considered to have good or excellent results (24). In O'Brien et al.'s study, which used a scale from 1 to 4, 51% of the patients had good or excellent final results (17).

In our study, 59% of the patients had mild or moderate dysfunction at the time of evaluation, implying a quality of results similar to that of other studies.

Most of our patients (78%) were satisfied with the result of their facial reanimation. Other studies have reported similar figures for satisfaction among patients (14, 17).

The choice of muscle for microneurovascular transfer is still a matter of debate (2, 17, 24, 26), and at least seven different muscles have been used during the search for the most appropriate one (2). In the present study three different muscles were used. The poorest long-term results were obtained with the serratus anterior muscle, which was used in the late 1980s. However, whether this outcome was the result of the type of muscle or the duration of follow-up remains uncertain.

In summary, we report good functional results for two-thirds of patients treated by facial reanimation. The mean age of our patients was higher than that in other studies, and our series included only cases of complete facial palsy. Attention should focus on the length of follow-up, because the outcome got worse with prolonged follow-up. The question remains whether our surgical techniques have improved since the early days or whether the transplanted muscle becomes exhausted. Further work is under way to shed light on the state of muscle reinnervation after microneurovascular muscle transfer in humans.

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