J Plast Surg Hand Surg, 2012; 46: 25–31

ORIGINAL ARTICLE

Comparison of hemihypoglossal-facial nerve transposition with a cross-facial nerve graft and muscle transplant for the rehabilitation of facial paralysis using the Facial clima method

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Abstract

To compare quantitatively the results obtained after hemihypoglossal nerve transposition and microvascular gracilis transfer associated with a cross facial nerve graft (CFNG) for reanimation of a paralysed face, 66 patients underwent hemihypoglossal transposition (n = 25) or microvascular gracilis transfer and CFNG (n = 41). The commissural displacement (CD) and commissural contraction velocity (CCV) in the two groups were compared using the system known as Facial clima. There was no inter-group variability between the groups ($p > 0.10$) in either variable. However, intra-group variability was detected between the affected and healthy side in the transposition group ($p = 0.036$ and $p = 0.017$, respectively). The transfer group had greater symmetry in displacement of the commissure (CD) and commissural contraction velocity (CCV) than the transposition group and patients were more satisfied. However, the transposition group had correct symmetry at rest but more asymmetry of CCV and CD when smiling.

Key Words: *Hypoglossal nerve, facial nerve, muscle transplant*

Introduction

Various operations have been used in reconstructive surgery to solve functional and aesthetic disorders in patients with facial paralysis. These operations can be classified according to their purpose as static rehabilitation techniques that improve the facial symmetry in rest, and dynamic rehabilitation techniques that restore the normal tone and facial function. There are several surgical options for dynamic rehabilitation of facial paralysis, such as neurorrhaphy of the facial nerve [1], with the interposition of nerve grafts [2], cross-facial nerve grafts (CFNG) [3], nerve transpositions with the hypoglossal nerve [4], CFNG plus hypoglossal nerve as a "babysitter" procedure [5], local muscle transfers such as lengthening temporalis myoplasty [6], and finally free muscle transfers (gracilis [7] or latissimus dorsi [8]). The choice of one or other technique will depend on many factors, among which are the time that has passed since the paralysis set in, the patient's age, the facial morphotype, and the surgeon's preferred technique.

In cases of recent facial paralysis (usually less than 2 years), dynamic rehabilitation with hemihypoglossal transposition using a short nerve graft is a good option. The hemihypoglossal nerve provides correct muscle tone and symmetry at rest, as well as good commissural pulling. Many surgeons achieve excellent results [9].

In long-standing facial paralysis (usually more than 2 years), muscular denervation is associated with atrophy, so it is necessary to have a local or free muscle transplant. In these cases, a good choice for face reanimation is the gracilis muscle transplant combined with a CFNG [10].

Parallel to the development of surgical techniques, several qualitative and quantitative measurement systems were developed that have enabled us to classify

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(Accepted 29 August 2011)

ISSN 2000-656X print/ISSN 2000-6764 online
DOI: 10.3109/2000656X.2011.644716

Table I. Details of patients studied.

	Hemihypoglossal transposition (n = 25)	Gracilis transplant + CFNG (n = 41)	Total (n = 66)
Sex:			
Male	5	16	21
Female	20	25	45
Aetiology:			
Acoustic neuroma	14	25	39
Trauma	5	15	20
Herpes zoster	6	1	7
Side:			
Right	7	17	24
Left	18	24	42

CFNG = cross-facial nerve graft.

the degree of facial paralysis, and even to measure the results obtained with specific techniques used for facial rehabilitation. The traditional system used is the House-Brackmann scale [11], which allows us to assess the degree of facial paralysis in qualitative terms and is an observer-dependent method [12]. To resolve these deficiencies, computerised systems have been developed to provide quantitative measures based on analysis of photographs or video recording [13], by counting pixels [14], and by looking at variations in light reflections [15]. However, because of the complexity of analysis generated by these systems and the fact that they provide dynamic information limited to two dimensions of space, none of them has been accepted for clinical use. This type of method makes comparisons between different techniques and surgical centres almost impossible, as every centre uses its own system of measurement to quantify its results. We have developed an automatic, easy, fast, quantitative method called Facial clima [12], which provides dynamic three-dimensional information that allows us to compare and contrast the results obtained using different surgical techniques.

Our aim was to find out using the Facial clima system, whether dynamic rehabilitation of facial paralysis using muscle transplants (microvascular free transposition of gracilis muscle associated with a CFNG) is better than nerve transfers (hemihypoglossal nerve transposition) in terms of commissural movement and velocity of muscle contraction.

Patients and methods

From December 2000-February 2008, 66 patients had their faces reanimated. In the transposition group (n = 25), patients underwent hypoglossal-facial transfer, and in the transfer group (n = 41), patients had two-stage free tissue transfer. All the operations were done by the senior author. All patients had developed complete unilateral facial paralysis over a minimum time of 12 months with no signs of recovery. The mean age in the hemihypoglossal nerve transposition group was 49.5 years and that in the group that had free transposition of gracilis muscle was 55.8 years. Most of patients presented with secondary facial paralysis as a result of excision of a tumour (Table I). Hemihypoglossal transpositions were done within two years of the onset of facial paralysis whereas CFNG/gracilis transplant was done at least two years after the onset. The patients were assigned to the two treatment groups according to the surgical technique used.

Operative technique

Hemihypoglossal transposition to facial nerve with a nerve graft. Through a preauricular incision on the paralysed side, a cheek flap was raised through a supra-SMAS dissection until the anterior margin of the parotid gland was identified, in which the zygomatic-facial trunk was located. To locate the hypoglossal nerve, a 1–2 cm incision was made parallel to the lower mandibular line. Then, the sub-mandibular gland was retracted and the digastric muscle tendon displaced. Once the digastric muscle had been raised, the hypoglossal nerve could be seen. The sural nerve was used as the donor nerve graft, the mean length of wich was 8 cm (range 6–10 cm). It was harvested by means of two small horizontal incisions in the posterolateral leg. After the hypoglossal nerve had been identified, the sural nerve graft was interposed between the hypoglossal nerve and zygomatic trunk of the facial nerve using a tendon stripper to introduce the graft through a subcutaneous tunnel. One third of the diameter of the hypoglossal nerve was opened and was anastomosed end-to-side to the nerve graft. The distal stump of the nerve graft was connected end-to-end to the zygomatic trunk of the facial nerve by using a 10/0 monofilament polyamide (Ethilon®, Johnson & Johnson) [16].

Free microvascular muscle transfer associated with cross-facial nerve graft. The operation is a two-stage reconstruction. The first step consists of a cross-facial nerve graft to connect the normal side to the paralysed side, locating the distal stump of the nerve under the paralysed upper lip [10]. The sural nerve was used in the cross-face nerve procedure as an interposition nerve graft. The mean length was 20 cm (range 18–22 cm). Through a preauricular incision on the normal side with an infra-auricular extension, a cheek flap was raised with a supra-SMAS dissection to identify the anterior margin of the parotid gland in which the branches of the facial nerve are located. It is important to select the appropriate branch on the normal side to produce raising of the commissure. Using the nerve stimulator (Aesculap Surgical Instrument, Group B. Braun, Spain) we identified and transected two zygomatic branches. The nerve graft was tunnelled across the midline as far as a subcutaneous level and was left of the opposite upper lip. We then did an end-to-end nerve coaptation with a 10/0 monofilament suture, suturing the distal stump of the sural nerve and the two selected zygomatic branches.

Once six months had passed, we did the second procedure. It consisted of the microvascular free transposition of gracilis muscle to the paralysed side. We chose the gracilis muscle as the donor muscle because of its constant vascular pedicle and nervous anatomy. It also has contractile ability and enough strength to offset the gravity and resistance of the tissues [7].

The gracilis muscle transplant was carried out by two teams. One team harvested the muscle while the other team prepared the face. The cheek flap was raised by means of a supra-SMAS dissection through the preauricular incision with a submandibular extension. The upper portion of the dissection extends to the body of the zygoma. During the dissection, the facial vessels were identified and isolated, and the dissection continued anteriorly to the commissure and upper lip. Depending on the type of smile of the patient, three or five traction sutures were placed using 2/0 braided nylon (Ethibond®, Johnson & Johnson) anchorage sutures in the orbicularis oris muscle and modiolus to recreate, as naturally as possible, the nasolabial fold and angle of a smile. Through an upper medial thigh incision just posterior to the anterior border of the gracilis, the muscle was dissected circumferentially, taking care not to damage the neurovascular pedicle. A suitable amount of the circumference and length of the muscle was harvested (a mean of 9 cm long and 3 cm wide). It was then transplanted with its motor nerve and its vascular pedicle. The ends of the gracilis muscle were fixed with horizontal mattress sutures using 2/0 braided nylon, with the aim of leaving the muscle fibres intact. The distal end of the gracilis muscle transplant was attached to the corner of the mouth and upper lip according to the previously placed anchorage sutures in the orbicularis oris muscle and modiolus. The largest vena comitantes was sutured to the facial vein and the facial artery was anastomosed to the artery of the gracilis. The motor nerve was tunnelled to the upper lip of the paralysed side, where the nerve graft was coapted end-to-end to the cross-facial nerve graft.

Description of the capture system: Facial clima

Facial clima is an automatic optical system to capture facial movements, which involves placing special reflecting dots on the subject's face after a predetermined configuration. A system of video recording with three infrared cameras captures the subject making various facial movements such as smiling, puckering of the mouth, closing the eyes, and raising the forehead. Images from the cameras are automatically processed with a software program that generates customised information such as three-dimensional data on velocities, distances, and areas. The accuracy of the measurement is between 0.13 mm and 0.41°. This system has been tested in normal patients and found to have a reliability of 99%. More information about intrarater and inter-rater accuracy, and exact functioning of this system, is available [12].

Data analysis

We compared the two dynamic rehabilitation techniques, evaluating the following variables in each patient using the Facial clima system: the commissural contraction velocity (CCV) (mean of maximum velocity of contraction) and the oral commissure displacement (CD) (mean difference between the minimum and maximum commissural displacement at rest and when contracted) in the healthy and paralysed side. Both groups were analysed two years after the operation.

The data obtained were coded to maintain anonymity. To compare results on one side of the face with those on the other side we used a paired Student's t test. To compare results between the two treatment groups we used the independent Student's t test. To assist with the analysis we used the Statistical

Package for the Social Sciences (SPSS Inc, version 15, Chicago IL, USA). Probabilities of less than 0.05 were accepted as significant.

Results

As we have selected complete facial paralysis, all preoperative measurements of the paralysed sides showed no movement of the oral commissure.

In the transposition group the mean (SD) oral CD on the paralysed side was 7.7 (3.9) mm and on the healthy side 9.3 (3.9) mm. The percentage difference between the two sides was 27.5% (Figure 1). The mean CCV on the paralysed side was 35.3 (16.7) mm/second and on the healthy side 48.7 (19.0) mm/second. The percentage difference between the two sides was 21.5%.

In the transfer group the mean (SD) oral CD on the paralysed side was 5.8 (2.9) and on the healthy side 6.4 (2.9) mm. The percentage difference between the two sides was 12.2%. The mean CCV on the paralysed side was 25 (12.1) mm/second and on the healthy side 28.5 (11.9) mm/second. The percentage difference between the two sides was 8.2% (Figure 1).

Inter-group variability did not differ significantly for the variables studied: CD on the paralysed side ($p = 0.15$) and on the healthy side ($p = 0.98$); CCV on the paralysed side ($p = 0.31$) and on the healthy side ($p = 0.69$).

Intra-group variability differed significantly in the transposition group between the paralysed side and the healthy side with respect to CD ($p = 0.02$) and CCV ($p = 0.04$). However, there were no significant differences in the transfer group between the paralysed side and the healthy side regarding CD ($p = 0.2$) or CCV ($p = 0.4$) (Figures 2, 3).

Discussion

Nerve transfer surgery uses ipsilateral motor nerves as potential fibre donors to acquire voluntary facial movement. These nerves have been used in cases of irreversible damage to the facial nerve, when a cross facial nerve graft is ruled out (more than six months after onset of the facial paralysis and a strong smile on the healthy side) and the facial muscles are still available. The main nerves used for this purpose are the hypoglossal and spinal accessory nerve [17]. In 1991, May et al. [18] described a modified technique, based on the original operation devised by Terzis and Tzafetta [16], in which the facial and hypoglossal nerve were connected by a nerve graft forming a terminoterminal nerve coaptation and terminolateral nerve coaptation, respectively. The use of the hemihypoglossal nerve (30%–40% of its total diameter) avoids the hemiatrophy of tongue and difficulties in biting, speech, and swallowing.

The use of the hemihypoglossal nerve allows correct tone of facial muscles at rest when there is no muscle atrophy. With this technique, the whole nasolabial fold is clearly defined compared with the use of muscle transplants in facial reanimation. With muscle transplants, the upper portion of the nasolabial fold is poorly defined. The more proximally the hypoglossal nerve is coapted to the facial nerve, the more effective is the amount of raising of the lower eyelid, which steadily improves the correction of ptosis, ephyphora, and ectropion. Many surgeons obtain excellent results [9], but this procedure does not achieve coordinated and spontaneous facial movements. In addition, there have been cases of aberrant reinnervation, which produces synkinesias and global facial movements. Better results were achieved when the nerve was transferred during the first year after the onset of the facial paralysis, because the function of the facial

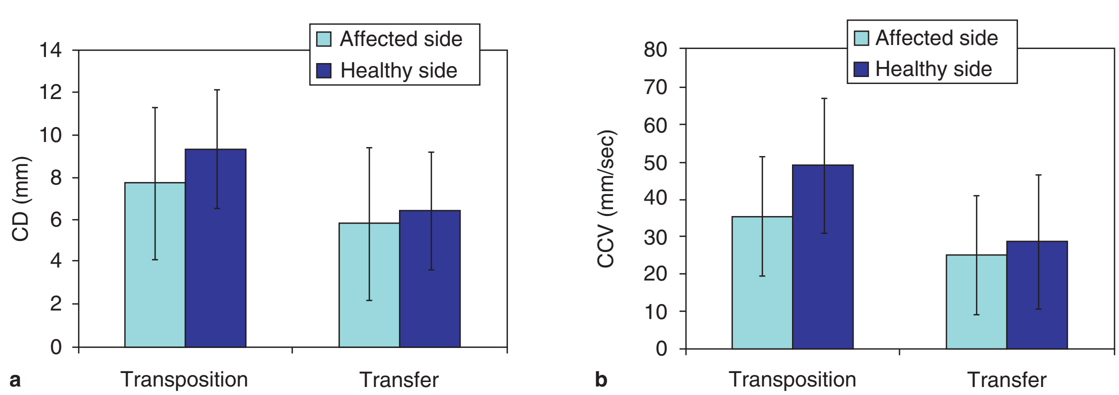

Figure 1. Graph showing the data obtained concerning (*a*) commissural displacement (CD) and (*b*) commissural contraction velocity (CCV) in the two groups.

Figure 2. (*a*) A 32-year-old patient smiling, after short lasting facial paralysis (8 months) caused by resection of an acoustic neurinoma. (*b*) The same patient smiling after a hemihypoglossal nerve transposition two years postoperatively. (*c*) The same patient recorded with the Facial clima.

muscles decreases gradually, although several cases of good facial reinnervation are described even after more than three years of facial denervation [19].

In cases of long-standing facial paralysis, there is muscular denervation associated with atrophy and loss of function, so that a local or free muscle transplant is necessary [17]. In 1980, O'Brien et al. [20] first described the gracilis muscle transfer to a cross facial nerve. Several muscles have been used as donors, for instance, the latissimus dorsi muscle [8], the serratus anterior muscle [21], the pectoralis minor muscle [22], and the gracilis muscle [23]. The last one is the preferred muscle because of its length, contractility, and constant vascular and nervous anatomy [7]. In long standing facial paralysis, therefore, our preference was to rehabilitate the smile in a two-step surgical procedure: a cross facial nerve graft, associated with a free muscle flap six months later. Using this technique the facial movement achieved is more physiological. We also had the clinical feeling that commissural movement after a gracilis transplant with a CFNG was better obtained in terms of symmetry and intensity compared with the hemihypoglossal transpositions. To find out whether this is the case we compared the commissural excursion and the contraction velocity of the zygomatic-commissural vector using the Facial clima system.

The Facial clima system has advantages over the other systems described above. The calibration process requires just a few seconds, training is easy, and static-dynamic quantitative information is provided about all kinds of facial movements on all three axes in only 20 seconds [12].

Previously, Erni et al. [24] in 1999 compared temporary transposition with the free muscle transfer associated with the CFNG technique following the Frey protocol [25]. They concluded that there was greater excursion and more satisfactory symmetry in the commissure in patiens in whom muscle was transferred. Subsequently, Bae et al. [10] in 2006 compared the

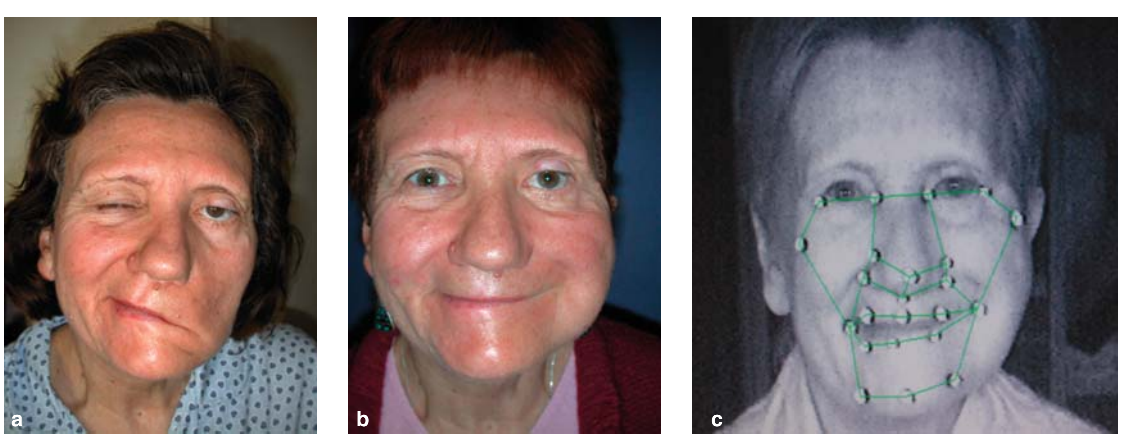

Figure 3. (*a*) A 59-year-old patient smiling, after long standing facial paralysis (6 years) caused by resection of an acoustic neurinoma. (*b*) The same patient smiling two years postoperatively after a gracilis transplant and CFNG six months before. (*c*) The same patient recorded with the Facial clima.

commissure excursion that resulted from a muscle transfer using a CFNG compared with the masseter nerve. They concluded that better results were obtained when a masseter nerve was used as the donor. However, there are no published reports of comparisons of nerve transfers and muscle transplants using a quantitative three-dimensional measurement system.

When we compared the results obtained with both surgical techniques, two years postoperatively we found that CD and CCV were similar in both groups. However, when we compared the results obtained within the groups (affected side compared with healthy side), we found significant differences in both measures in the transposition group. This indicates that there is a more asymmetrical commissural movement when the hemihypoglossal transposition is used. However, we found no significant differences in the transfer group (affected side compared with healthy side) in either variable, which in turn means that there is better symmetrical commissural movement when compared with cases of hemihypoglossal transposition.

Facial movements in the transposition group depend on two different nerves: the facial nerve (healthy side) and the hypoglossal nerve (affected side). This could have an adverse influence during the achievement of symmetry of both sides of the patient face. When the patient smiles, we see a strong but uncoordinated commissural movement that could explain the differences between the sides of the face (CD difference of 27.5% and CCV difference of 21.5% between the affected side and the healthy side).

On the other hand, in the transfer group after the gracilis transplant and a CFNG is performed, there is only one nerve (the healthy facial nerve) that activates both sides of the patient's face. Patients in this group could therefore have been taught to adapt both facial movements to obtain greater symmetry by a minor contraction of the healthy side (CD difference of 12.2% and CCV difference 8.20% between the affected side and healthy side). Patients in this group reported more balanced movement and more satisfactory results compared with those from patients in the transposition group.

In conclusion, although we found no inter-rater variability between groups in CD and CCV, the transfer group showed more symmetry in the CD and CCV and gave more satisfaction to patients. However, hemihypoglossal transpositions present correct symmetry at rest but more asymmetry of CD and CCV when smiling, while other benefits are present.

Declaration of interest: The authors have no financial interest in the subject matter or materials discussed in this work.

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