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The split hypoglossal nerve versus the cross-face nerve graft to supply the free functional muscle transfer for facial reanimation: A comparative study

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KEYWORDS
Facial palsy;
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Summary Long-standing cases of facial paralysis are currently treated with free functional muscle transfer. Several nerves are mentioned in the literature to supply the free muscle transfer. The aim of this study is to compare the split hypoglossal nerve and the cross-face nerve graft to supply the free functional muscle transfer in facial reanimation.

Of 94 patients with long-standing, unilateral facial palsy, 49 were treated using the latissimus dorsi muscle supplied by the split hypoglossal nerve, and 45 patients were treated using the latissmus dorsi muscle supplied by healthy contralateral buccal branch of the facial nerve.

The excursion gained by the free muscle transfer supplied by the split hypoglossal nerve (mean 19.20 ± 6.321) was significantly higher (P value 0.001) than that obtained by the contralateral buccal branch of the facial nerve (mean 14.59 ± 6.245).

The split hypoglossal nerve appears to be a good possible option to supply the free vascularised muscle transfer in facial reanimation. It yields a stronger excursion in less time than the contralateral cross-face nerve graft.
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Introduction

Long-standing facial palsy still represents a difficult management challenge. Several options are available for treatment, but no single technique enables the restoration of ocular and oral sphincter control and natural smile. Free neurovascularised muscle transfer offers a dependable, dynamic reanimation of the mouth with adequate vector of pull of the oral commissure.[1] Several nerves are used to reinnervate the newly transferred muscle.[2-8] One of the most important goals of facial reanimation is to achieve adequate excursion on the paralysed side. The aim of this study is to

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evaluate and compare the excursion gained by free muscle transfer when supplied with the split hypoglossal nerve versus the healthy contralateral buccal branch of the facial nerve (through a nerve graft). The literature does not discuss any efforts to do so before.

Patients and methods

The study was registered with and approved by the Research Ethics Committee at Cairo University hospitals. The work complied with relevant aspects of the Declaration of Helsinki. Each patient was offered a range of surgical reanimation options, and all patients in this cohort chose to undergo free functional muscle transfer after providing a full informed consent. Data are expressed according to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Ninety-four patients with long-standing (more than one year), unilateral facial palsy were treated in the period from 2009 to 2014 by the first author, using the latissimus dorsi muscle at Cairo University hospitals. This study included only cases of free latissimus dorsi flap supplied by a single nerve (either the split hypoglossal or the cross-face nerve graft). Cases in which the author used the gracilis muscle, the masseteric nerve or dual innervation to supply the free muscle transfer were excluded from the study. Patients were divided into two nonrandomised groups according to the donor nerve supply. Group A contained 49 patients, who had one stage procedure with the thoracodorsal nerve directly coapted to the split hypoglossal nerve; Group B contained 45 patients, who had two stages of facial reanimation. In the first stage, a cross-face nerve graft was done and, in the second stage, the latissimus dorsi muscle was transplanted. Selection of the technique used was decided on individual bases. For patients refusing a longer waiting period for recovery or surgical procedure on the healthy side, the split hypoglossal nerve was offered. Conversely, for patients refusing to be innervated by a non-facial source, the cross-face nerve graft was offered.

Surgical technique

Group A (using the split hypoglossal nerve)

This technique was previously described in full detail by the author.[4] The whole procedure is done as a single stage. After preparation of the facial pocket and identification of the facial artery and vein, the hypoglossal nerve is identified by elevation and upward retraction of the submandibular gland to expose the digastric tendon. The digastric tendon is then elevated to identify the hypoglossal nerve. One of the terminal branches of the hypoglossal nerve is selected. The branch represents 25% of the hypoglossal nerve diameter. This branch is dissected (with inter-fascicular dissection) from the rest of the nerve. Dissection proceeds in a retrograde fashion for an appropriate distance to reach the thoracodorsal nerve without the need for a nerve graft. Finally, the distal end of the branch is transected, and the branch is rotated to reach the thoracodorsal nerve, leaving the rest of the hypoglossal nerve intact.

Group B (using the contralateral buccal branch of the facial nerve)

The standard two-stage procedure is employed. The first stage consists of a cross-face sural nerve graft sutured on the healthy side to the buccal branch of the facial nerve and left on the paralysed side over the zygomatic area and marked with Prolene 5-0. After 10 months, the second stage is performed, insetting the muscle and anastomosing the thoracodorsal vessels to the facial vessels and the thoracodorsal nerve to the end of the sural nerve graft.

Harvesting the flap, preparation of the facial pocket, site of muscle insertion and suturing were similar in both groups. In all cases, the recipient vessels were the facial vessels on the paralysed side.

Patients in both groups were strictly followed up at 3, 4, 5, 6, 8, 10, 12 and 18 months after the free muscle transfer. Measurements were taken by the second author without knowing which technique was used (single blind study). Measurements were taken from preoperative photos and at 18 months after the muscle transfer. We used the SMILE system of Bray et al[9] and Adobe Photoshop CS4 Extended v.11 (Adobe Systems Inc., San Jose, California) for measurements.

One modification was introduced by the first author to the SMILE system of Bray et al,[9] where the excursion is calculated as the change in distance from midline to commissure on smiling from the preoperative to postoperative situation.

The distance from where the midline crosses the lower vermilion border to the commissure is measured on maximum smiling (referred to as distance X). This distance is measured pre- and postoperatively on the paralysed side (X1 and X2, respectively). This distance is also measured on the healthy side postoperatively (X3). The excursion gained by the muscle is considered the difference between the preoperative and postoperative distances on the treated sides (X2–X1). Figure 1 indicates the nomenclature used (X1, X2 and X3).

Figure 1 The nomenclature used. (Left) Preoperative view on smiling. (Right) Postoperative view on smiling.

Statistical analysis

Data were statistically described in terms of mean, standard deviation (SD), median and range when appropriate. Comparison between the study groups was done using Student's *t*-test for independent samples. Within-group comparison between pre- and post-treatment as well as to the normal side was done using a paired *t*-test. For comparing sex, a Chi-squared test was used. P values less than 0.05 were considered statistically significant. All statistical calculations were done using SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA), release 15, for Microsoft Windows (2006).

Results

Ninety-four patients with long-standing, unilateral facial palsy were treated by the first author at the Cairo University hospitals, using the latissimus dorsi muscle, from 2009 to 2014. The muscle was innervated by the split hypoglossal nerve in 49 cases and by the contralateral healthy buccal branch of facial nerve in 45 cases. Table 1 shows the age, sex, duration of paralysis and muscle dimensions for patients in each group.

No vascular complication was observed in any of the cases; however, haematoma occurred in one case postoperatively (from the split hypoglossal group), necessitating re-exploration and evacuation of the haematoma.

Group A (the split hypoglossal group)

The distance on the paralysed side preoperatively (X1) ranged between 7 and 28 mm (mean 16.27 ± 5.954). A statistically significant increase in the distance postoperatively on the treated side (X2) was observed (P value <0 .001). The distance ranged between 26 and 45 (mean 35.47 ± 4.073) postoperatively on the treated side. On the healthy side, the distance (X3) ranged between 26 and 44 mm (mean 35.78 ± 4.278). There were no statistically significant differences between sides postoperatively (P value 0.235) despite the statistically significant difference that existed preoperatively between the paralysed side and the healthy side (P value < 0.001). The excursion gained by the free muscle transfer (X2–X1) ranged between 9 and 29 mm (mean 19.20 ± 6.321). Table 2 shows the smile parameters for Group (A).

Table 1 Age, sex, duration of paralysis and muscle dimensions for each group.

	Group (A)	Group (B)
N	49	45
Age (mean)	16–57 (36.8)	17–47 (33.07)
Sex (M/F)	24/25	20/25
Duration of paralysis (mean)	2–25 (4.86) years	2–27 (3.96) years
Muscle width	4–5 (4.22) cm	4–5 (4.13) cm
Muscle length	8–10 (8.16) cm	8–10 (8.21) cm

Group B (The cross-face nerve graft group)

The distance on the paralysed side preoperatively (X1) ranged between 8 and 29 mm (mean 16.03 ± 5.784). The distance postoperatively on the treated side (X2) ranged between 24 and 39 mm (mean 30.61 ± 3.384). On the healthy side, the distance (X3) ranged between 27 and 41 mm (mean 35.93 ± 3.681). Despite a statistically significant increase in the distance X postoperatively on the treated side compared to the preoperative measurements on the same side (P value < 0.001), there was still a significant difference between the treated and healthy sides postoperatively (P value < 0.001). The excursion gained by the muscle transfer (X2–X1) ranged between 5 and 28 mm (mean 14.59 ± 6.245). Table 3 shows the smile parameters for Group (B).

Comparing both groups

There was no statistically significant difference between the groups regarding the age, sex or duration of paralysis (P values 0.068, 0.660, and 0.277, respectively), nor was there any statistically significant difference in the muscle width and length between both groups (P values 0.167 and 0.566, respectively).

Movement appeared after 3 to 6 months postoperatively (mean 4.6 months) in Group A and 14 to 17 months (mean 15.4 months) from the first surgery in Group (B).

There was no statistically significant difference in distance X1 or X3 in either group (P values 0.864 and 0.851, respectively). However, the distance on the treated side postoperatively (X2) and the excursion (X2–X1) were significantly higher in Group A than in Group B (P values < 0.001 and = 0.001, respectively). Figure 2 shows graphs for the mean values in both groups and results are shown in Figures 3 and 4.

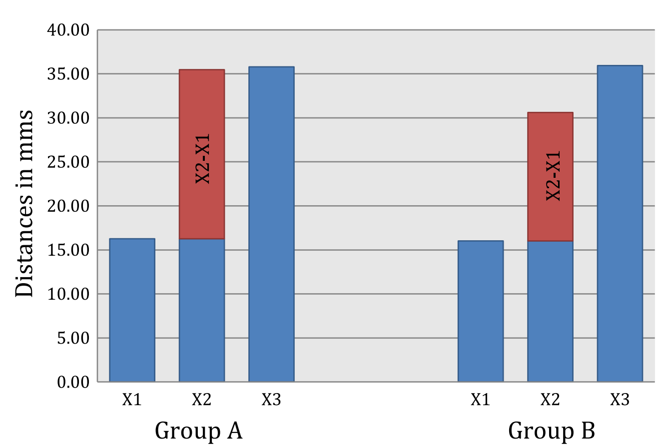

Figure 2 Mean values of distance from where the midline crosses the lower vermilion border to the commissure on maximum smiling (X1); on the treated side preoperatively (X2); on the treated side postoperatively (X3); on the healthy side postoperatively. X2–X1 represents the gained excursion by the muscle flap.

Table 2 Smile parameters in the split hypoglossal group.

Patient no.	Split hypoglossal Group (A)			
	Diseased side			Normal side
	Pre op distance X1	Post op distance X2	Actual excursion X2–X1	Normal side distance X3
1	16	37	21	30
2	25	44	19	43
3	28	38	10	37
4	12	35	23	39
5	22	35	13	37
6	18	35	17	36
7	20	39	19	36
8	15	31	16	30
9	16	28	12	29
10	12	39	27	40
11	11	38	27	40
12	12	26	14	26
13	17	32	15	31
14	15	30	15	32
15	7	36	29	39
16	27	38	11	39
17	27	36	9	39
18	24	37	13	38
19	19	34	15	34
20	27	38	11	38
21	9	34	25	39
22	12	41	29	39
23	20	39	19	39
24	7	35	28	36
25	8	36	28	36
26	18	37	19	38
27	22	35	13	35
28	17	33	16	34
29	14	29	15	29
30	10	39	29	39
31	25	45	20	44
32	18	27	9	26
33	10	37	27	36
34	20	39	19	40
35	10	28	18	28
36	10	39	29	39
37	11	38	27	39
38	18	37	19	37
39	26	36	10	37
40	14	29	15	29
41	16	32	16	31
42	14	34	20	34
43	16	36	20	35
44	10	34	24	34
45	11	40	29	41
46	10	38	28	39
47	19	37	18	38
48	10	33	23	33
49	22	35	13	36

X1 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the treated side at maximum smiling preoperatively; X2 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the treated side at maximum smiling postoperatively; X3 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the healthy side at maximum smiling postoperatively.

Table 3 Smile parameters in the cross-face group.

Patient no.	Cross face Group (B)			
	Diseased side			Normal side
	Pre op distance X1	Post op distance X2	Actual excursion X2−X1	Normal side distance X3
1	15	24	9	31
2	25	34	9	41
3	28	33	5	38
4	12	30	18	38
5	20	32	12	38
6	17	29	12	38
7	18	29	11	35
8	13	24	11	32
9	13	24	11	30
10	15	33	18	39
11	12	31	19	37
12	12	27	15	27
13	17	26	9	32
14	14	30	16	30
15	9	33	24	40
16	29	39	10	39
17	25	34	9	40
18	26	31	5	39
19	17	33	16	37
20	25	32	7	37
21	10	30	20	40
22	12	31	19	38
23	22	31	9	36
24	8	34	26	40
25	24	31	7	37
26	9	29	20	35
27	14	30	16	35
28	10	31	21	31
29	10	33	23	39
30	9	31	22	39
31	17	26	9	30
32	20	32	12	37
33	18	33	15	39
34	20	29	9	30
35	10	38	28	38
36	10	34	24	39
37	8	32	24	38
38	16	31	15	36
39	17	27	10	32
40	23	30	7	30
41	19	25	6	35
42	13	27	14	33
43	12	29	17	35
44	14	35	21	41
45	16	31	15	36

X1 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the treated side at maximum smiling preoperatively; X2 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the treated side at maximum smiling postoperatively; X3 is the distance from the intersecting point of the midline and lower vermilion border to the commissure on the healthy side at maximum smiling postoperatively.

Discussion

Despite that free muscle transfer is now considered the cornerstone in the management of long-standing facial nerve paralysis,[1] there is no universal agreement on the donor nerve supplying this free functional muscle transfer. Several nerves are used, including the contralateral healthy facial nerve,[2,3] the masseteric nerve[5] and the hypoglossal

Figure 3 Right facial paralysis patient who underwent reconstruction, using a split hypoglossal nerve and latissimus dorsi muscle flap. Above, left: preoperative appearance at rest; above, right: preoperative appearance during smiling. Below, left: postoperative appearance at rest; below, right: postoperative appearance during smiling.

nerve.[4,10] Other nerves are used to less extent, including the spinal accessory[7] and c7 root.[8]

Among all these nerves, there is no single nerve that can achieve the full goals of facial reanimation. The search for different nerves to supply the free muscle flap came from the fact that no donor nerve is without flaws. The contralateral buccal branch of the facial nerve usually requires a two-stage procedure with a nerve graft. It also requires a longer period to function. Some authors advised a single-stage procedure to shorten the recovery period and eliminate the need for a nerve graft.[11,12] This single-stage procedure has the drawback of leaving the muscle uninnervated for a long period, thus affecting the final outcome, and the choice of the contralateral healthy branch may not achieve a quantitatively symmetrical smile. Makentlow reported fewer movements on the treated side than on the healthy side and, in some cases, even very little movement on using the contralateral healthy facial nerve branch.[5] Faria et al used the healthy contralateral buccal nerve to supply the free muscle transfer. They found that the naturalness of facial expression was reduced in all cases by variable degree of cross-synkinesia while speaking or when

Figure 4 Right facial paralysis patient who underwent reconstruction, using a cross-face nerve graft and latissimus dorsi muscle flap. Above, left: preoperative appearance at rest; above, right: preoperative appearance during smiling. Below, left: postoperative appearance at rest; below, right: postoperative appearance during smiling.

the patient is asked to pucker the lips. Two cases were identified in which contractions of the muscle were introduced with eye closure on the non-paralysed side.[13]

Regarding the masseteric nerve, parotid fistula is a possible complication of exposing the nerve, and in cases of partial facial paralysis, there is a possibility of injuring the upper facial branches when exposing the masseteric nerve.[13] Rozen and Harrison stated that all patients undergoing facial reanimation with a free tissue transfer supplied by the masseteric nerve should be informed that they would universally have involuntary animation during mastication.[14] Chuang et al stopped using the masseteric nerve because it does not show completely independent movement, and persistent involuntary movement of the cheek during eating and biting occurred.[7]

We strongly believe that several studies should be conducted to detect the most appropriate nerve to supply the flap or to tailor the selection of the nerve according to the need of the patient. These nerves may differ dramatically in several factors, such as the onset of return of movement, amount of axonal supply and, hence, power of muscle contraction and excursion and of degree of brain orientation that helps the patient mimic a natural smile. In this study, we compared the amount of muscle excursion using two nerve sources, the healthy contralateral buccal nerve and the ipsilateral split hypoglossal nerve. In all cases, we used a segment of the latissimus dorsi muscle. To eliminate any variables, cases in which we used gracilis muscle or dual innervation were excluded from the study.

We used the SMILE system advocated by Bray et al[9] with one modification. Bray et al considered the distance from where the midline crosses the lower vermilion border to the commissure as the excursion. We disagree with this point in our work. The actual excursion gained by the muscle is the difference in this distance on comparing post- and preoperative results.

Preoperatively, in both groups, there were statistically significant differences between the healthy and the paralysed sides, and there was no statistically significant difference on the paralysed side between both groups. However, postoperatively, the situation differed completely. In both groups, significant improvement in excursion occurred postoperatively on the treated side compared to the preoperative data. In the buccal branch group, despite the significant increase in excursion in the treated side, comparing postoperative to preoperative results, there was still a statistically significant difference between the normal and treated sides. In the split hypoglossal group, there were no statistically significant differences between the healthy and treated sides postoperatively.

Despite that, preoperatively, on the paralysed side, there were no statistically significant differences between the groups; postoperatively, the distance and excursion on the treated side were significantly higher in the split hypoglossal group. The excursion gained with the split hypoglossal nerve was more than that achieved with a cross-face nerve graft and is equal to the healthy contralateral side.

The decreased excursion by the contralateral buccal branch in comparison to the split hypoglossal nerve can be explained by several factors. In all our cases, we used a cross-face nerve graft. The axons have to travel two anastomotic sites and a longer distance to reach the target muscle affecting the final outcome. Furthermore, the motor drive obtained from the hypoglossal nerve is definitely larger than that obtained from the contralateral buccal branch. Taking a bigger segment of the hypoglossal nerve if needed can easily increase the axonal load of the split hypoglossal nerve, an advantage that is definitely not available with the contralateral buccal nerve.

Snyder-Warwick et al found that the degree of facial movement following free muscle transfer in paediatric facial reanimation depends on donor nerve axonal density. They compared the contralateral facial nerve (by a nerve graft) to the masseteric nerve. The downstream, cross-face nerve graft had a 76% reduction in the myelinated fibres from the donor facial nerve. The masseteric nerve provided a more robust innervation, resulting in a greater commissure excursion.[15]

The hypoglossal nerve was used as a whole to reanimate the face a long time ago.[16,17] The main concern was tongue atrophy with its subsequent complications. Several authors attempted to use the hypoglossal nerve while minimising the drawbacks.[4,18–22] None of our patients suffered from any weakness on the healthy side in the buccal group, and none of them suffered from speech or mastication problems in the split hypoglossal group. Mori et al reported using one-third of the hypoglossal nerve with minimal tongue dysfunction.[22] Terzis and Tzafetta studied tongue effect after mini-hypoglossal nerve transfer to restore lower lip function and for baby sitting procedure. They found that in all cases, full electrogenesis of the tongue occurred after two years on electromyography. They also found no measurable intraoral defect.[19,23]

The first contraction was observed after 3 to 6 months (mean 4.6 months) in the split hypoglossal group and after 14 to 17 months from the first procedure (mean 15.4 months) in the cross-face group. The split hypoglossal nerve was able to achieve an earlier smile than the cross-face nerve group. The earlier return of movement, using the split hypoglossal nerve, can be easily explained by the shorter distance the axons have to travel to reach the target muscle.

The onset of movement in the split hypoglossal group was achieved by pushing the tongue against the teeth; however, after 3 to 6 months, all the patients were able to smile without moving the tongue.

The increased excursion and the faster onset of movement on using the split hypoglossal nerve rather than the contralateral buccal nerve have many advantages. First of all, it achieves a more symmetrical smile and achieves this symmetrical smile in less time. The more powerful excursion is a great advantage in cases of scarred face, where more power is needed to move the face.

Bae et al compared the contralateral buccal branch to a non-facial nerve source (the masseteric nerve). There were no differences in either side in the masseteric group; however, the excursion was less on the treated side in the contralateral buccal nerve group. The excursion on the treated side in the buccal nerve group was also less than on the treated side in the masseteric group.[24] Hontanilla et al concluded that use of the masseteric nerve yielded a better symmetry and a higher recovery than the contralateral facial nerve achieved.[25]

Several authors used the contralateral facial nerve based on the theoretical advantage of producing a spontaneous smile. However, this did not prove to be totally true. Faria et al noticed that when the contralateral facial nerve was used directly or through a nerve graft, it produced spontaneity only in 45% and 34% of the cases, respectively.[13] Using a non-facial donor source (namely the masseteric nerve), Hontanilla and Cabello were able to achieve spontaneity in 55.55% of cases.[26]

The split hypoglossal nerve is a good possible option to supply the free vascularised muscle transfer in facial reanimation. It yields a stronger excursion in less time than the contralateral cross-face nerve graft. We believe that several studies should be conducted to compare different nerve sources for facial reanimation. In addition, the choice of nerve should be tailored according to the patient situation and need.

Conflict of interest

The authors report no conflict of interest.

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