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Facial animation in patients with Moebius and Moebius-like syndromes

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Abstract. Moebius syndrome, a rare congenital disorder of varying severity, involves multiple cranial nerves and is characterised predominantly by bilateral or unilateral paralysis of the facial and abducens nerves. Facial paralysis causes inability to smile and bilabial incompetence with speech difficulties, oral incompetence, problems with eating and drinking, including pocketing of food in the cheek and dribbling, as well as severe drooling. Other relevant clinical findings are incomplete eye closure and convergent strabismus. The authors report on 48 patients with Moebius and Moebius-like syndromes seen from 2003 to September 2007 (23 males and 25 females, mean age 13.9 years). In 20 cases a reinnervated gracilis transplant was performed to re-animate the impaired sides of the face. In this series, all free-muscle transplantations survived the transfer, and no flap was lost. In 19 patients complete reinnervation of the muscle was observed with an excellent or good facial symmetry at rest in all patients and whilst smiling in 87% of cases. In conclusion, according to the literature, the gracilis muscle free transfer can be considered a safe and reliable technique for facial reanimation with good aesthetic and functional results.

Keywords: Moebius syndrome; paralysis; animation; face.

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Moebius syndrome/sequence is a rare congenital disorder of varying severity characterised by bilateral or unilateral paralysis of the facial and abducens nerves[1,3,4,7,14,17,19,20]. Its aetiology is unknown, but environmental and genetic factors have been implicated. Recent studies suggest the occurrence of a vascular disruption causing a hypoxic/ischaemic insult to the brain stem during the first trimester, which could affect some of the cranial nerves[4,5,7,14,19,20]. The hypoxic/ischaemic insult might result from uterine contractions due to a variety of causes. An abortifaciant drug, misoprostol, has been linked to self-induced but unsuccessful abortions that result in some subjects with the clinical findings of Moebius sequence[14]. Although evidence of a genetic mechanism has been noted in a few subjects, most cases of Moebius sequence appear to be sporadic[14].

Paralysis of the VI and VII cranial nerves leads to lack of function in the muscles they supply. Lateral gaze and facial animation are absent. When the paralysis is bilateral, it can be asymmetric, and facial movement, when present, is always located in the lower face with platysmal activity or depressor anguli oris activity. Effective lower-lip support, lower-lip elevation for bilabial speech production and commissure movement and upper-lip elevation for smiling and emotional expression are absent, and the inability of these patients to smile often leads to the mistaken impression that they are dull and disinterested. Speech difficulties are complex and multifaceted, and facial paralysis often leads to bilabial incompetence, which causes the characteristic speech pattern of flaccid dysarthria consisting of substitution, distortion or omission of the bilabial phonemes/p/,/b/ and/m/and the alveolar phonemes/t/,/d/

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and/n/[1,4,17,19]. Paralysis of the lower face often causes problems with eating and drinking, including pocketing of food in the cheek, dribbling and severe drooling[1,6,12]. Other relevant clinical findings are incomplete eye closure and convergent strabismus. In addition to the abducens and facial nerves, the hypoglossal nerve is the most commonly involved cranial nerve, being affected in 25% of cases[1,6]. This manifests with further problems of articulation, primarily with vowels. Velopharyngeal incompetence is present in about 11% of patients because of glossopharyngeal nerve palsy, which results in a hypernasal voice, glottal substitutions and increased nasal air emission[6]. Mental disability is overdiagnosed and is only present in 14% of patients[6]. This mistake is often due to the frequent inability of people to understand what these patients are saying or feeling. When these patients begin school, they are often teased by other children, which can cause them to become withdrawn and reluctant to speak, despite normal intelligence. The inability to show happiness, sadness or anger frequently results in severe introversion and a reclusive personality with low self-esteem[17]. Impairments of the II, V, X and XI cranial nerves have also been observed in rare instances[1,6,17,20].

Patients with Moebius syndrome have been associated with additional deformities that include limb malformation (clubfeet and agenesis, rudimentary fingers or toes and syndactyly or brachydactyly), malformations of the orofacial structures (bifid uvula, micrognathia, cleft palate, small palpebral fissures, epicanthic folds, ocular hypertelorism, microstomia, external ear deformity with occasional hearing loss and airway problems with aspiration), musculoskeletal malformations (absence of the sternal head of the pectoralis major muscle, rib defects and arthrogryposis; cases with dextrocardia have been described) and dysfunction of the cerebrum (mental retardation and epilepsy)[13,17]. Moebius syndrome may also be associated with Poland syndrome, Klippel–Feil anomaly, Kallmann syndrome and Hanhart syndrome[17].

The restoration of even a small degree of volitional facial movement can be rewarding in terms of verbal and nonverbal communication. In this study, the authors report on patients with Moebius and Moebius-like syndromes seen and treated surgically from 2003 to September 2007. The authors evaluate the effectiveness of gracilis transplant to restore facial movement and indications and results in the use of the controlateral facial nerve or of the masseter motor nerve in providing adequate innervation to the muscle transfer. The complications and the outcomes of the different techniques, focusing on functional and aesthetic issues such as oral competence, speech and the degree of movement and its impact on these patients, is analysed.

Table 1. Patient classification.

	n	%
Moebius	19	39.6
Moebius incomplete	8	16.7
Moebius-like	21	43.7
Total	48	100

Table 2. Associated findings in patients with Moebius syndrome.

	n
Poland syndrome	2
GERD	2
Cleft palate	3
Syndactyly	2
Bifid uvula	1
Clubfeet	3
Micrognathia	3
Testicle anomalies	2
Pituitary dysfunction	1
Angel wing	1
Mental retardation	2
Persistent ductus arteriosus	1
Hearing reduction	1
Epicanthic fold	2

Materials and methods

The authors reviewed the records of 48 patients with Moebius and Moebius-like syndromes seen between 2003 and September 2007. They comprised 23 males and 25 females with a mean age, when first seen, of 13.9 years (range 1–48 years). 27 patients had bilateral Moebius syndrome, a monolateral form was present in 21 patients with involvement of the right side in 8 and the left side in 13. The patients were classified (Table 1), following the classification proposed by Terzis et al.[16,17,23]: Moebius (complete bilateral facial and abducens nerve paralysis); Moebius incomplete (clinical picture of Moebius with the exception that some residual motor function was noted on one side of the face); Moebius-like (unilateral facial paralysis, but additional cranial nerve palsies present).

In those with the Moebius incomplete form, some facial movements were evident, which were always located in the lower face with platysmal activity or depressor anguli oris activity. The abducens nerve was involved in 70% of the patients. In 13 patients, additional cranial nerves were involved, of which the hypoglossal nerve was impaired in 25% and the motor branches of the fifth cranial nerve in 4%.

A standardised neurological and logopaedic examination was performed in all cases. Facial expression, oral motor function and speech were evaluated clinically, and most patients underwent electromyographic examinations during their first visit. Special attention was directed toward the identification of possible motor donor nerves. Examination of the facial nerve included needle electromyography of the facial musculature, including the upper, middle and lower facial territories. The temporalis and masseter muscles were tested clinically. All patients were videotaped and photographed with particular attention to facial expression, oral motor function and speech.

The logopaedic evaluation showed alterations of speech patterns with articulation difficulties and substitution or distortion of the bilabial phonemes/p/,/b/and/m/in 40% of the patients. Speech was severely altered in 10%. The associated findings are shown in Table 2.

Patients satisfying the following criteria were excluded from 'smile surgery': age less than 6 years; low collaboration due to mental retardation; good functional repair of the residual motor units; anomalies in walking; absence of a collaborating family.

Twenty patients underwent microsurgical reconstruction to re-animate the impaired sides of the face. A segment of the gracilis muscle was transplanted in all cases. The facial artery and vein were used as recipient vessels in most of the procedures. In one patient, the facial vein was not found so the transverse facial vein was used. Ten patients underwent a bilateral free-muscle transplantation, with a total of 30 gracilis free flaps. The contralateral facial nerve was used as a motor donor nerve in 7 procedures, the motor nerve to the masseter muscle in 13 patients, 10 with bilateral and 3 with monolateral facial paralysis.

Cross-facial nerve graft

On the normal side through a preauricular incision, the branches of the facial nerve are identified as they exit the anterior portion of the parotid fascia. With the aid of a nerve stimulator, a map of the muscles they innervate can be made, identifying the buccal and zygomatic branches. Segments of these branches can be sacrificed as their activity is dupli-

Fig. 1. Sural nerve graft tunnelled across the face with the aid of nasal vestibule incisions.

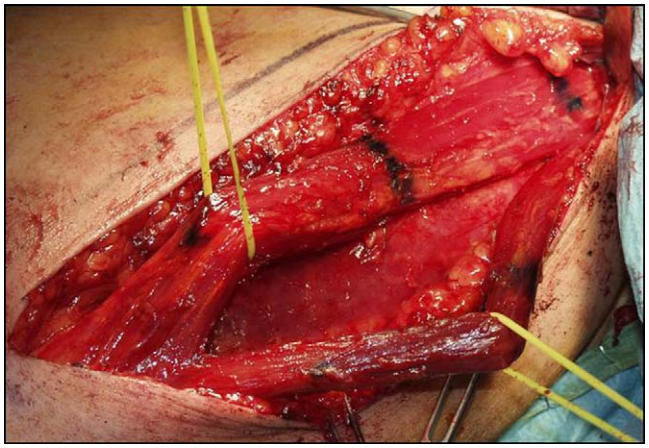

Fig. 2. Taking off the gracilis muscle. Only a part is used, usually the anterior third.

cated. Three to five fascicles are selected for division and routed into a sural nerve graft, which is tunnelled across the face with the aid of nasal vestibule incisions (Fig. 1). On the involved side, the nerve is placed high on the maxilla and zygoma to ease the dissection of this area at the time of muscle transplantation and to keep the nerve graft from being damaged. The regeneration of the graft can be followed by Tinel's sign. After 9–12 months, sufficient neural regeneration has occurred in the graft, and the nerve is capable of innervating a muscle transplant. Before the second surgical stage, a piece of the previously placed cross-facial nerve graft is taken under local anaesthesia and studied histologically. This allows better evaluation of neural regeneration and selection of the best fascicles of the graft to reinnervate the transplant.

Microvascular muscle transfer

The procedure begins with two teams operating simultaneously to elevate the muscle and prepare the face. The ispilateral gracilis is usually used for transfer. The gracilis is approached through a short medial thigh incision, posterior to the line joining the adductor tubercle to the medial condyle. The vascular pedicle is identified on the anterior border of the gracilis at the junction of the upper-quarter and lower three-quarters. The nerve to the gracilis from the anterior branch of the obturator nerve is traced to the obturator foramen. Only a segment of the muscle is needed; the use of the entire muscle leads to excess bulk. Approximately one-third to half of the muscle is needed to produce the appropriate amount of movement and to avoid excess bulk. The anterior third of the muscle is usually selected, and the fascicle that innervates this segment is identified and labelled (Fig. 2).

Facial dissection is performed simultaneously while harvesting the gracilis. The facial incision is begun in the scalp near the upper pole of the ear, courses downward through the preauricular area, and then, after a small posterior curve, courses anteriorly in the neck with submandibular extension. The cheek flap is elevated below the fat but above the parotid fascia. The plane of the dissection is carried anteriorly to the anterior border of the masseter muscle. Superiorly, the dissection extends up onto the body of the zygoma and the temple. The facial vessels are identified at the level of the anterior border of the masseter. Once the vessels are identified, the dissection continues anteriorly just above the vessels to the commissure and upper lip. Three to five sutures are placed for secure anchorage and careful positioning of the muscle. The first suture is placed in the oral commissure, the second is placed in the lower lip, and the third to fifth sutures are placed in the upper lip. They are positioned so that they do not produce eversion or inversion. With traction, they should produce a nasolabial crease that looks as natural as pos-

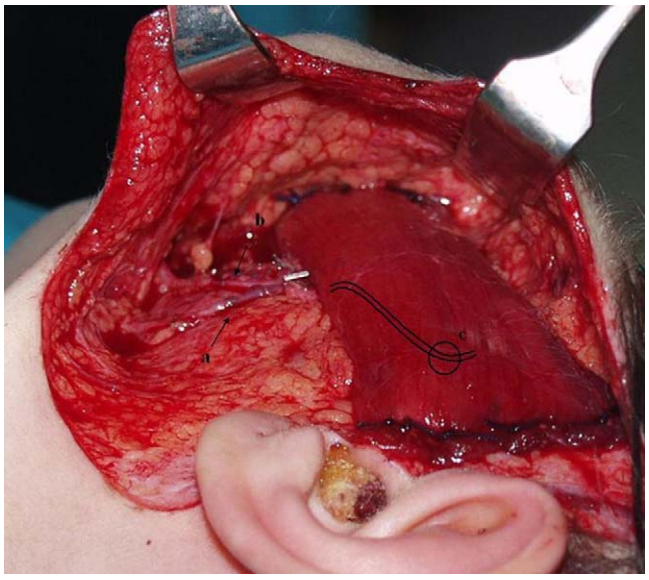

Fig. 3. Muscle position in the subcutaneous pocket with venous (a) and arterious (b) repair; design of the site of anastomosis with the masseteric nerve (c).

Table 3. Clinical results.

	%			
Parameters	1. Excellent	2. Good	3. Fair	4. Poor
Symmetry at rest 1. No asymmetry at rest 2. Mild asymmetry of oral commissure 3. Facial asymmetry of commissures but midline in place 4. Marked asymmetry	60.0	40.0	0	0
Symmetry smiling 1. No asymmetry 2. Minimal asymmetry 3. Asymmetry of commissure 4. Marked asymmetry	53.3	33.3	6.7	6.7
Muscle action 1. Strong contraction 2. Good muscle contraction 3. Minimal visible muscle contraction 4. No muscle contraction	60	26.6	6.7	6.7
Muscle bulk 1. No increase in bulk 2. Slight increase in bulk 3. Moderate increase in bulk 4. Marked increase in bulk	53.3	46.7	0	0
Independent action 1. Good independent motion of affected side 2. Strong contraction requires some movement of normal side 3. Partial contraction of muscle requires marked contraction of normal side 4. No muscle contraction	46.7	33.3	15.3	6.7
Commissure elevation 1. Normal or nearly normal 2. Reasonable motion, not level with normal side 3. Flicker of movement at commissure 4. No movement of commissure	60	26.6	6.7	6.7
Mouth closure 1. Near normal 2. Close mouth; asymmetry 3. Incomplete closure 4. Oral incontinence	73.3	6.7	15.3	6.7
Involuntary movement 1. No noticeable 2. Minimal, only with strong contraction of other side 3. Some involuntary movement of muscle 4. Dyskinesias or mass movements of face	60	26.6	6.7	6.7
Overall final results	60	26.6	6.7	6.7

sible. When the motor nerve to the masseter is selected to reinnervate the muscle transplant, it can be identified on the undersurface of the masseter muscle. It is usually found coursing vertically downward at the posterior margin of the muscle just below the zygomatic arch. Occasionally it may be seen coursing obliquely downward and anteriorly or even transversely parallel to the arch. A nerve stimulator is helpful in identifying the motor nerve to the masseter. Once the nerve is identified, it is cleared of its fibrous connections and traced inferiorly, superficially and anteriorly into the muscle.

The gracilis muscle is transferred to the face with the neurovascular pedicle on the deep surface, enabling subsequent debulking if necessary. The distal end of the muscle is fixed to the lips and oral commissure through the previously positioned sutures. Anastomoses are carried out between the facial vessels and the artery and the larger of the paired venae comitantes of the gracilis. In 20–25% of patients, the facial vein cannot be found; in these cases, the transverse facial vein is isolated. Once vascularisation is ensured, a fasicular nerve repair unites the recipient nerve in the face to the selected fascicle of the motor nerve in the gracilis (Fig. 3).

After the neurovascular repairs, the muscle origin is secure. It is sutured with a slight degree of tension at the corner of the mouth and anchored to the temporal fascia and preauricular fascia. Tension at the insertion may be relieved by a prefabricated hook. Reinnervation of the muscle usually appears 3–6 months post-transfer.

Study design

To evaluate the results of the technique described, the authors only considered patients with a minimum follow-up of 12 months. Through the study of the clinical and surgical reports they reviewed the surgical procedure with attention to: characteristics of the flap, fat removed from the cheek, flap survival, early and late com-

Fig. 4. Nine-year-old female patient with complete Moebius syndrome (a). The clinical examination revealed the impairment of the VI cranial nerve bilaterally. In October 2006 she underwent transplant of the gracilis muscle on the left side and on June 2007 transplant of the gracilis muscle on the right side. During both the operations 6 g of fat were removed from the cheeks. Postoperative appearance while at rest (b) and while smiling (c).

plications and time of reinnervation. The functional and aesthetic results were analysed using patient response, clinical examination and preoperative and postoperative videotaping of patients filmed at rest and performing several standard facial movements to show muscle action, spontaneity, independence and fine facial movements during speech and smile.

A speech therapist evaluated the speech changes and the results on the impaired phonemes. The degree of deformity and the effectiveness of surgery was identified by comparing the paralyzed side with the normal side or the two treated sides in bilateral paralysis.

The smile was evaluated from the functional and aesthetic point of view using the evaluation criteria proposed by O'Brien et al.[13]: symmetry at rest and smiling, muscle action and bulk, independent action, commissure elevation, mouth closure and presence of involuntary movements.

Dynamic (smile movement) measurements were performed on each side evaluating the commissure movements. As reported by Mankтelow et al.[12] the commissure movement is considered the distance moved by the commissure from the rest position to a maximum smile as measured in the plane of movement of this point.

Results

In this series, all free-muscle transplantations survived the transfer, and no flap was lost. The segment of the muscle transplanted weighed an average of 29 g, with a range of 20–44 g, and had an average length of 11.8 cm. During the operation, all patients had fat removed from the cheek area. One seroma was seen at the inner thigh after the gracilis muscle harvest, which was treated by aspiration and pressure wrapping, and one patient developed a facial abscess that was drained. Three patients developed hypertrophic scars at the site of the neck incision. The mean time for the reinnervation of the gracilis muscle was 3.5 months (3–5 months). Only in one patient the muscle was well vascularised but did not show signs of reinnervation despite a new operation to revise the nervous anastomosis. In one case dyskinesias was observed and one patient required a new surgical operation to improve the muscle position and the smile direction.

Through direct questioning regarding functional problems, all patients with preoperative difficulties regarding oral competence reported a significant improvement with no spontaneous drool-

Fig. 5. Twenty-year-old male patient with a Moebius incomplete form. Some facial movements were observed, which were located in the lower face bilaterally with depressor anguli oris activity. Clinical examination revealed an impairment of the VI cranial nerve bilaterally and of the XII nerve on the left side. Preoperative view at rest (a) and smiling (b). The reconstruction was achieved by performing two free microneurovascular transfers of gracilis muscle flaps to the right and left cheeks in July 2004 and August 2005, respectively. During both the operations, 2 g of fat were removed from the cheeks. Postoperative appearance while smiling (c) and with independent bilateral contractions (d and e).

ing and with adequate capability to control oral fluid. The seven patients with preoperative abnormalities in speech had an improvement in articulation and in pronunciation of bilabial phonemes reported by the speech therapist.

Based on the evaluation criteria previously proposed by O'Brien et al.[13], the results shown in Table 3 were obtained. Facial symmetry at rest was excellent or good in all patients, and 87% maintained good symmetry whilst smiling, although one patient did not have any muscle movement. Excellent–good elevation of the commissure was observed in 87% of patients, and the ability to close the mouth was fair–poor in 20% of patients due either to drooping of the lower lip or the presence of micrognathia. Involuntary movements and dyskinesias were observed in two patients. The overall final results were excellent–good in 87% of patients and fair–poor in 15%. In all, 80% of the subjects reported improvement in self-esteem and stated that they would undergo the surgery again.

The mean commissural movement measured on the treated sides was 14 mm (range 11–20 mm): 16 mm when the masseteric nerve was used and 13 mm in patients treated with a cross facial nerve graft. The mean difference between the treated and the healthy side was 3.3 mm in the masseteric nerve group and – 4.2 mm in the cross facial nerve graft group. In patients treated bilaterally, the mean difference between the two sides was 2.5 mm (range 2–3 mm).

Four patients with a Moebius syndrome form treated with facial re-animation through a reinnervated gracilis muscle free-flap are presented in Figs. 4–7.

Discussion

The lack of facial animation in patients with Moebius syndrome poses a major barrier to interpersonal communication and creates severe aesthetic and functional problems. Several procedures to restore facial function have been advocated: neural reconstructions with accessory to facial nerve transfer, hypoglossal to facial nerve crossover or local muscle transfer[17]. None of these approaches has produced satisfactory functional and aesthetic results. Microneurovascular transfer of a free-muscle transplant is the procedure of choice for facial paralysis, and the benefits of using free-functioning muscle transplantation for facial paralysis are numerous[9,15,17,18]. Without the restrictions of the pedicle, the muscle can be placed precisely in the desired location and direction with improved outcomes[23]. Greater active excursion of the oral commissure can be obtained, and the muscle can be sculpted to the desired size and shape, avoiding the earlier drawbacks of excess bulk[21,23]. The gracilis muscle represents the first choice for facial animation, having the advantages of easy access, dispensability and appropriate vasculature for free transfer[9,13] and the authors' experience confirms these qualities.

Despite the advances made over the last few years with this surgical approach, problems associated with orientation, bulk and excursion remain[22,23]. It is difficult to obtain accurate symmetry of movement and consistently produce a nasolabial crease because of the imprecise nature of the muscle excursion, growth and reinnervation. This can be overcome through a careful preoperative study of the patient, precise selection of the motor nerve, good positioning of the muscle and continuous postoperative smile and speech training[22,23].

Preoperative planning is important, and detailed assessment of the location and direction of desired movement should be made[22]. Before the free-muscle transplant, the authors usually draw lines on the patient corresponding to the nasolabial crease and to the vector of the smile from the oral commissure toward the tragus. These lines direct the positioning sutures on the oral commissure and lips and aid in orienting the gracilis muscle. With traction, the sutures should produce a nasolabial crease that looks as natural as possible. It is important to ensure that the direction of contracture of the muscle produces movement that will simulate a normal smile, or in monolateral forms, the contralateral side. Lack of accuracy in muscle positioning will lead to asymmetrical movement, and the most common fault is placing the muscle too transversely.

Excessive bulk at the site of the transplant should be avoided. According to Zuker et al.[23] during dissection the

Fig. 6. Twelve-year-old female patient with a Moebius-like form on the left side. Preoperative appearance at rest (a) and while attempting to smile (b). In November 2005 a microsurgical reconstruction with the gracilis muscle was performed. The innervation of the muscle transfer was provided by the ipsilateral motor nerve to the masseter muscle. Postoperative appearance at rest (c) and while smiling (d).

Fig. 7. Thirteen-year-old female patient with a Moebius-like form on the left side. Preoperative appearance at rest (a) and while attempting to smile (b). Clinical examination revealed impairment of the XII nerve ipsilaterally. The reconstruction was achieved with a cross-facial nerve graft from the right facial nerve in June 2003, and subsequently, a gracilis muscle transplantation in February 2004. Postoperative appearance at rest (c) and while smiling (d).

authors removed 2–6 g of fat from the subcutaneous tissue of the cheeks and Bichat's fat-pad. They used approximately one-third of the width of the normal gracilis, and fixed the origin of the muscle on the inferior surface of the zygomatic arch and zygoma, thus avoiding the problem of muscle protuberance. If the muscle origin is placed on the superficial aspect of the zygomatic arch and zygoma, excess bulk will be apparent. In some patients, the authors also spread the proximal end of the muscle before anchoring it to the temporal and preauricular fascia.

The selection of a motor nerve is critical to the success of the procedure. Sufficient innervation must be present to power the muscle, and this innervation must be specific to the desired activity to achieve spontaneity, synchronicity and symmetry. The contralateral seventh nerve, by means of a cross-facial nerve graft, provides the preferred innervation for a muscle transfer in unilateral facial paralysis reconstruction[2,8,10,12,18,22,23]. When the VII nerve is not adequate in a person who has a very powerful smile on their normal side or in patients with bilateral forms, the authors used the motor nerve to the masseter muscle. As in earlier reports, they noted that in the cross-facial nerve graft group, the extent of oral commissure movement on the side that was operated on was much less than that of the masseteric group[2,12]. The commissure movements measured were similar to those reported by Bae[2]. The cross-facial nerve graft procedure provides a spontaneous movement that cannot be provided by the motor nerve to the masseter muscle[2,10]. In children, this spontaneity is crucial in producing a normal appearing smile. Nevertheless, the excursion produced by the motor nerve to the masseter is in the normal range and certainly superior to that provided by a cross-facial graft input from the opposite side[2,10,23]. Although it does not provide true spontaneity of activity, these children can achieve a good appearance of a smile. In the authors' experience, as in other studies,[11,12,21] most of these patients are able to develop facial movement independent of jaw motion and no longer have to think about moving their face whilst laughing.

To achieve a spontaneous and symmetrical smile, postoperative smile training by a speech–language pathologist using mirror exercises and biofeedback plays an important role. When reinnervation of the muscle appears 3–6 months post-transfer, an active exercise programme must be started, so that progress in strength, excursion and most importantly, symmetry, can be achieved. The age of the patient when undergoing surgery did not influence the results from an aesthetic or functional point of view. In adults, reinnervation takes longer (5–6 months) than in children (3.5 months).

The degree of patient satisfaction and the functional results in terms of drooling, drinking and speech were similar to those reported by Zuker et al.[21–23].

Competing interests

None declared

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Ethical approval

Not required.

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