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Dual innervation of free gracilis muscle for facial reanimation: What we know so far

Q1 Thanapoom Boonipat[a,*], Carrie E. Robertson[b], Jesse D. Meaike[a], Krishna S. Vyas[a], Malke Asaad[a], Samir Mardini[a]

[a] *Division of Plastic Surgery, Department of Surgery, Mayo Clinic, 200 First Street SW, Rochester, MN*
Q2 *55905, United States*
Q3 [b] *Department of Neurology, Mayo Clinic, Rochester, MN, United States*

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Abstract
Background: In the last decade, some institutions have begun combining the CFNG and masseteric nerve to provide dual innervation to the gracilis muscle for dynamic facial reanimation in facial paralysis patients. We reviewed the various ways that these two nerves have been coapted to provide dual innervation, and summarized the functional outcome for these methods.
Methods: A search of the Ovid EMBASE, MEDLINE, Cochrane, and Scopus databases was performed from 1946 to May 2019 for dual innervation of gracilis muscle using CFNG plus masseteric nerve for facial reanimation.
Results: A total of 184 articles were identified in the initial search, of which seven met our inclusion criteria. Three additional abstracts with 43 patients were identified but the level of details was not sufficient to include the results in the analysis. A total of 57 patients were reviewed (mean age of 42.1 years (6–79 years)). The majority of dual innervation procedures were performed using the ipsilateral masseteric nerve sutured end-to-end to the obturator nerve, and an additional CFNG connected end-to-side to the obturator nerve. In the 26 patients with Terzis scores available, there were no differences between masseteric nerve coapted end-to-end and CFNG as end-to-side to the obturator, or the reverse coaptation. All but two patients achieved function of the gracilis activated by the masseteric nerve within 2–5 months.
Conclusions: This review shows that dual innervation of the gracilis is safe; and in some cases, does appear to provide early onset gracilis activation as well as an eventual spontaneous smile.

* Corresponding author.
E-mail address: boonipat.thanapoom@mayo.edu (T. Boonipat).

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Introduction

In 1976, Harii et al. pioneered the use of a free functional gracilis muscle transfer innervated by the deep temporal nerve for facial reanimation.[1] At many institutions including ours, the gracilis is now the muscle of choice for reanimation. Although CFNG provides optimal spontaneity, many surgeons continue to use the masseteric nerve due to the potential for many more axons to reach the muscle. Several authors have been using more than one nerve to provide innervation to the gracilis and connecting these nerves in various ways.

Early use of a trigeminal nerve branch as the sole power to the gracilis provided some symmetry when the patient would activate the gracilis by biting down, but it did not allow for a predictable spontaneous smile.[2,3] In an effort to achieve spontaneous smile, several group have graft nerve from the unaffected facial nerve to the affected facial nerve or denervated muscles, referred to as a “cross face nerve graft” (CFNG).[4-6] In the late 1970s, O’Brien started using a two-staged technique: the first stage establishing the CFNG using a sural nerve sutured to the proximal buccal branches of the unaffected facial nerve, and the second stage performing a gracilis muscle transfer with coaptation to the already established CFNG.[5,7] He reported good to excellent restoration of spontaneous smile in 51% of patients.[7] One of the drawbacks is the long distance required for the nerve to regrow, resulting in less nerve signals.[12] Combined with the multiple coaptations required, this could increase the risk of failed reinnervation.[7,8]

Recent literature have reported using a combination of both a CFNG and the masseteric nerve for innervation of a free functional gracilis transfer.[9-15] Theoretically, the fact that the masseteric nerve has a large number of axons, results in faster recovery, stronger contraction, and a more symmetrical smile.[3,16,17] The CFNG contributes spontaneity that is hard to achieve consistently with masseteric nerve innervation alone. While conceptually appealing, it is not clear whether this method is comparable to the more simple single innervation method, and how best to achieve this combined input.

We reviewed published surgical series utilizing a combination of the masseteric nerve and the CFNG to re-innervate a transferred free functional gracilis muscle for facial reanimation. We were specifically interested in the descriptions of technique and associated clinical outcomes currently available in the literature.

Methods

Literature search strategy

A comprehensive search was conducted across several databases including the Ovid EMBASE, MEDLINE, Cochrane, and Scopus databases for studies published through May 2019. The search strategy was designed and conducted by a librarian with specialized training in literature retrieval. The search strategy was limited to human studies only. Keywords were used to search for cross facial nerve graft plus masseteric transfer. The actual terms used and how they are combined are shown in the search strategy (Appendix, Supplemental Digital Content 1). In addition, because the search did not include abstracts presented at meetings, we specifically searched for published abstracts from relevant meetings including American Society of Plastic Surgery, American Society of Peripheral Nerve, American Society of Reconstructive Microsurgery, and Facial Nerve Symposium.

Inclusion and exclusion criteria

Studies were included if they (1) reported data on patient demographics, outcomes, complications, and patient satisfaction and (2) were written in or translated into the English language. All age groups and sample sizes were included.

Studies were excluded if they were: (1) review papers, (2) pre-clinical studies, (3) technical notes, (4) animal studies, (5) used only single innervation techniques, (6) if there was no free muscle flap used, or (7) if they used a free muscle other than the gracilis muscle.

Selection of articles and data extraction

Two authors (T.B. and J.M.) independently screened the articles through review of article titles and abstracts. Duplicates were then eliminated and an independent full text review of the remaining potentially relevant studies was performed using the exclusion and inclusion criteria. The extracted data included: year of publication, study design, total number of patients and number of procedures, type of technique, surgical outcomes, complications, and patient satisfaction. Disagreement between the reviewers was resolved by discussion and consensus by a third independent reviewer (K.V.). This study complied with the guidelines outlined in the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA).[18]

Results

Literature search strategy

Figure 1 shows the PRISMA flow diagram of the performed search strategy. A total of 184 titles of potentially relevant publications were identified from the initial search strategy. After excluding 2 duplicates, 182 abstracts were screened, and 175 articles were excluded, with the most common reasons being the absence of free muscle transfer or only single innervation of the free muscle flap (see Figure 1, PRISMA flow diagram).

Full texts of 7 articles were reviewed and included in the final analysis (Figure 1 and Table 1). All the articles included were published between 2012 and 2019. All studies were case series. The indication for all patients was long standing facial paralysis (see Table 2, which demonstrates the characteristics of included studies individually). In addition, Table 3 contains the included abstracts. These have been separated due to very limited information available.

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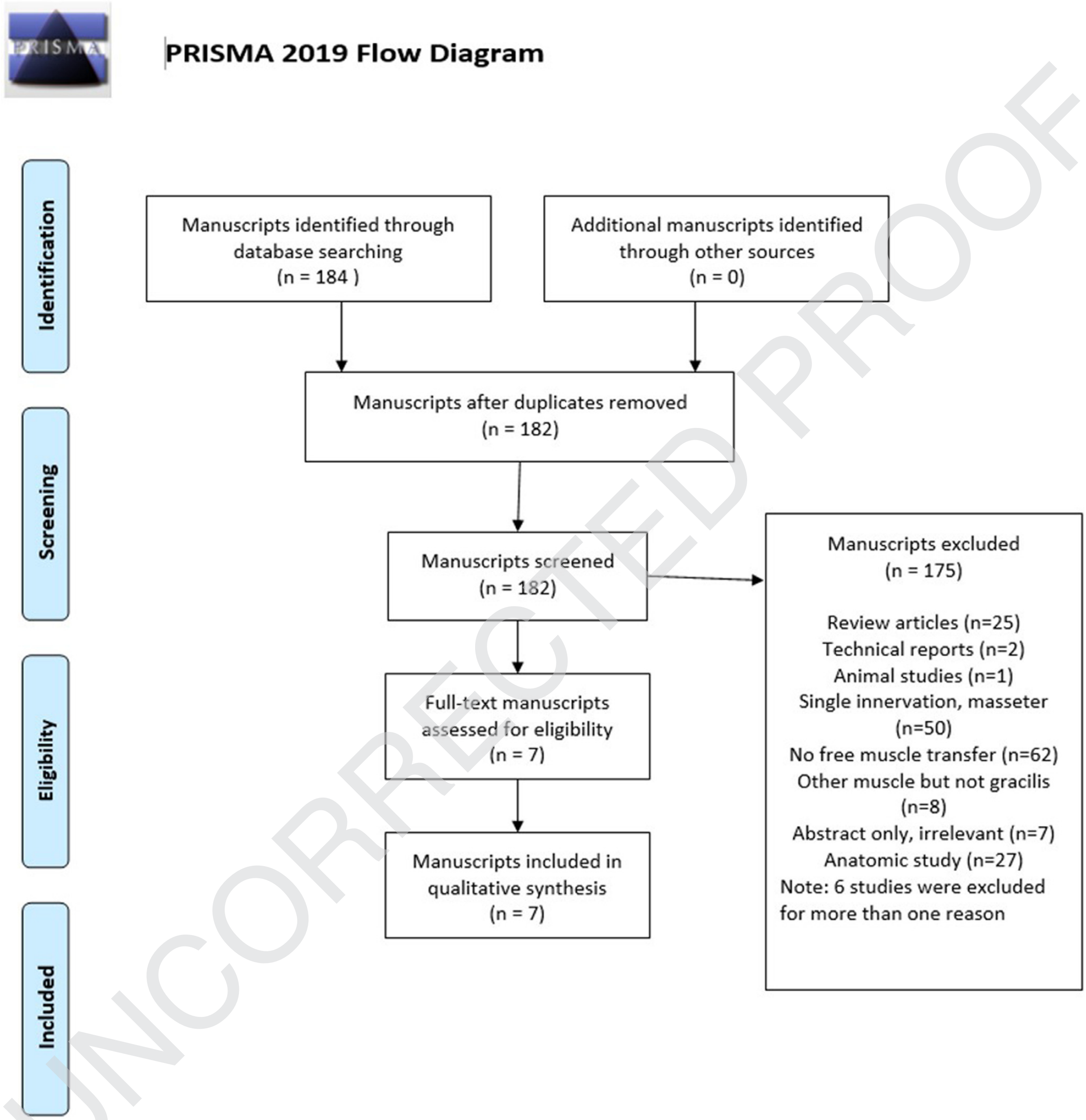

Figure 1 PRISMA flow diagram of the performed search strategy.

Methods of dual innervation

The majority of dual innervation procedures were performed using the ipsilateral masseteric nerve coapted end-to-end to the obturator nerve, with the CFNG sutured end-to-side to the obturator nerve. All CFNG were sutured end to end to the contralateral donor facial nerve (42 patients, 5 papers), see Figure 2. Cardenas-Mejia et al.[13] also discussed performing the reverse innervation, with the CFNG as an end-to-end coaptation to the obturator and the masseteric nerve as an end-to-side coaptation to the obturator ($n = 9$), see Figure 3. Cardenas-Mejia et al.[13] were the only authors to perform a two-stage procedure; all other authors performed a single stage operation.[10-12,14,15,19] Cardenas-Mejia et al. performed the masseteric nerve end to side coaptation 1 cm from the gracilis muscle hilum. Sforza indicated opening an epineural window for the end to side anastomosis.[14] The other authors reviewed did not specify the exact location or method of end to side anastomosis. Uehara and Shimizu[15] discussed performing a procedure where they su-

Table 1 Characteristics of studies describing free gracilis muscle transfer with dual innervation from CFNG and masseteric nerve for facial reanimation.

Method	CFNG as end-to-side coaptation and masseteric nerve as end-to-end	CFNG (1st stage) as end-to-end coaptation and masseteric nerve as end-to-side	End-to-end coaptations for both nerves using proximal and distal obturator
Number of papers	5 (Biglioli, Bianchi, Boahene, Sforza, Oh[d])	1 (Cardenas-Mejia)	1 (Uehara)
Number of patients	42	9	6
Age (mean, range)(years)	39.6 (6-75)	37.6 (13-60)	56.7 (37-79)
Number of stages	1	2	1
Follow up (mean)(months)	Unclear in 1 paper; 18; 4 and 17	26.7	>12
Number of patients achieving gracilis movement by the masseter	40 of 42 (95%)	9 of 9 (100%)	6 of 6 (100%)
Time to movement of transferred gracilis by masseter (average in months)	3.9[a]	3.2	5.1
Was spontaneous smile achieved?	26 of 30 (86.6%)[b]	Not discussed	6 of 6 (100%)
Time to spontaneous smile (months)	Only discussed in one paper with mean 7.2 (6-8.8)	Not discussed	9.5
Terzis grading scale	Moderate (1/17, 5.8%), Good (9/17, 53%), Excellent (7/17, 41%)[c]	Moderate (1/9, 11%), Good (4/9, 44%), and Excellent (4/9, 44%)	Not used
Other grading scale used	Facial asymmetry index, and optoelectronic motion analysis 3D motion analyzer	N/A	Ratio of distance from angle of mouth when smiling compared to contralateral normal side

[a] With one paper where no evaluation was performed prior to 10 months, not included in the average.
[b] One paper with 5 patients did not discuss spontaneous smile.
[c] Two papers with 18 patients did not use Terzis score.
[d] For Suk et al., no average numbers are included in the table as they have 7 patients with the dual innervation and 3 patients with masseter only innervation. There was no breakdown of the data between these patients, and therefore we excluded their data in the average calculations such as follow-up period and time to movement of transferred gracilis.

tured an intramuscular motor branch of the gracilis to the ipsilateral masseteric nerve end-to-end, while the obturator nerve was also sutured end-to-end to the CFNG ($n = 6$), see Figure 4. The reviewed abstracts (Table 3) did not have details regarding the dual innervation method.

Outcome of clinical studies

Table 1 summarizes the general characteristics of the included studies including procedures, number of patients, follow-up, complications and outcomes. 57 patients (mean age of 42.1 years, range 6-79 years) underwent procedures with no serious adverse events reported. Table 3 summarizes the outcome of the abstracts. 43 patients from three abstracts were included, with one in the pediatric population and two in the adult population. There were no adverse events reported.[20-23] The Terzis Facial Grading System was used to evaluate outcomes in 26 patients.[10,11,13] The vast majority of these achieved good-to-excellent results, with no differences between the different methods of dual innervation coaptation. Pediatric patients were included in three series,[9,13,14] but there was not a detailed breakdown of individual outcomes, preventing the assessment of the influence of age on surgical outcome. In the abstract, McNeely et al.[22] presented 9 pediatric patients with age ranging from 5 to 15 years old. They reported voluntary movement after 4 months, with 3 reporting spontaneous movement by 3 months. Continued improvement in all patients was noted until 12 months. The exact method of innervation was not specified. Note that Oh et al.[19] report a 10 patient case series with 7 patients who underwent dual innervation. Unfortunately, as they did not separate their results, we had to exclude their data from select calculations such as age and time-to-spontaneous smile.

Follow-up time ranged widely from 4 months[12] to 18 months.[11] In the abstracts, only mean follow time was given, with McNeely et al. reporting the longest follow up at mean 27.33 months, with Win et al. and Dusseldorp et al. reporting a 12 month follow-up.[21-23] All studies reported what they felt was the time to gracilis innervation from the masseteric nerve, by assessing how long it took before the gracilis would contract when the jaw was clenched. 55 of 57 (96%) patients were able to smile while clenching/biting down, all within 2-5 months. The two abstracts that reported time-to-movement and spontaneous smile were by Win and Kallirroi,[23] with results consistent with the full studies, and by McNeely et al.,[23] with results discussed above. Some studies

Table 2 Detailed breakdown of included manuscripts.

	No. of patients	Age (median, range)	No. of stages	Nerve anastomosis method	How was spontaneous smile assessed?	Time to movement of transferred gracilis by masseter (average in months)	Months to spontaneous smile	Rehab protocol?	Other grading scale used	Terzis Outcome classification	Follow up period
Bianchi et al., 2014	13	28 (6-73)	Single	CFNG as end-to-side coaptation and masseteric nerve as end-to-end	smile independent of biting contraction (no further details); "emotional activation"	3 (2-4 months); 3.9 months in the 4 unilateral gracilis transplantation with double innervation	not discussed; note all achieved spontaneity (4/4 and 9/9); dual gracilis - more rapid & powerful contraction than gracilis w/ CFNG alone	physiotherapy, smile independent from biting contraction	-	Dual: 2 good, 2 excellent, CFNG + masseter: 1 moderate, 5 good, 3 excellent	Unclear
Biglioli et al., 2012	4	49 (46-53)	Single	CFNG as end-to-side coaptation and masseteric nerve as end-to-end	observation by family member first detection, then by talking to patients and watch comedic movie for 10 mins	3.8 (2-4.8 months)	7.2 (6-8.8 months), all achieved spontaneous smile	physiotherapist guided exercises in front of them without mirror	EMG, and electroneurography. EMG: demonstrated reinnervation by CFNG when smiling w/o clenching; also demonstrated reinnervation by masseteric nerve during teeth clenching Electroneurography: able to directly stimulate gracilis via CFNG; unable to directly stimulate via masseteric nerve due to artefact from direct muscle stimulation.	2 excellent, 2 good	18 months

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Table 2 (*continued*)

	No. of patients	Age (median, range)	No. of stages	Nerve anastomosis method	How was spontaneous smile assessed?	Time to movement of transferred gracilis by masseter (average in months)	Months to spontaneous smile	Rehab protocol?	Other grading scale used	Terzis Outcome classification	Follow up period
Boahene et al., 2018	5	41(23-64)	3 Single, two patients 2 stages	CFNG as end-to-side coaptation and masseteric nerve as end-to-end	not specifically discussed, 'standard video analysis'	By 4 months, not specifically discussed	Not discussed.	Not discussed	dynamic smile zone analysis; Gingival and dentition analysis, Facial asymmetry index (FAI), using Canfield Mirror imaging software	Not discussed	4 months
Sforza et al., 2015	13	41 (9-75)	Single	CFNG as end-to-side coaptation and masseteric nerve as end-to-end	Funny video	10 months evaluation (sd, 5-16 months); all patients able to smile by clenching (2 patients did not regain any movement)	Not discussed; 9/12 patients able to perform spontaneous smile at a detectable level.	Not discussed	Optoelectronic motion analysis 3D motion analyzer; 'activation ratio' compared to healthy side.	Not discussed	17 months (SD 3)
Cardenas-Mejia et al., 2015	9	38 (13-60)	Two stages	CFNG (1st stage) as end-to-end coaptation and masseteric nerve as end-to-side	Not discussed	Time to reinnervation = 8.78 weeks (8-12 weeks); visible movement = 12.89 weeks (12-15)	Not discussed	Not discussed.	EMG used to assess reinnervation & motor unit recruitment	Moderate in 1, good in 4, and excellent in 4.	26.7 months (12-42)

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Table 2 (*continued*)

	No. of patients	Age (median, range)	No. of stages	Nerve anastomosis method	How was spontaneous smile assessed?	Time to movement of transferred gracilis by masseter (average in months)	Months to spontaneous smile	Rehab protocol?	Other grading scale used	Terzis Outcome classification	Follow up period
Uehara et al., 2017	6	57(37–79)	Single	Intramuscular branch of gracilis end to end to masseteric nerve, obturator transferred to CFNG.	Monthly evaluation, ask to smile with clenching and without clenching	4.7 months	9.5 months (9-12 months) (unclear clenching was involved or not, as only discussed 'synchronous' movement of the angle of the mouth bilaterally.	Biofeedback using mirror, >3 times daily.	Ratio of distance from angle of mouth when smiling compared to contralateral normal side, EMG, CMAP of CFNG.	Not used.	>18 months

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Table 3 List of available abstracts from search of relevant meetings including American Society of Plastic Surgery, American Society of Peripheral Nerve, American Society of Reconstructive Microsurgery, and Facial Nerve Symposium.

	No. of patients	Age (median, range)	No. of stages	Nerve anastomosis method	How was spontaneous smile assessed?	Time to movement of transferred gracilis by masseter (average in months)	Months to sponta-neous smile	Rehabs protocol?	Other grading scale used	Terzis Outcome classifica-tion	Follow up period
Win et al., 2014	8	35 (range 30–46)	2	Both CFNG and ipsilateral masseteric nerve	NA	3	10	Yes	EMG used	Used, but no results	12 months
McNeely et al., 2019	9	8.6 years (range: 5 to 15 years)	2	Both CFNG and ipsilateral masseteric nerve	NA	All patients demonstrated initiation of voluntary movement on the paralyzed side by 4 months, with three demonstrating spontaneous movement by 3 months. Improvements in excursion were noted to continue at 6 months, before stabilizing around 12 months.	Info in box to left	NA	House-Brackmann (HB) scores Eight patients had initial HB scores of VI and one patient had an initial HB score of V. Final HB ratings included five patients with a score of IV, three patients with a score of III and one patient with a score of II.	NA	Mean follow up was 27.33 months (SD 27.31)

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Table 3 (*continued*)

	No. of patients	Age (median, range)	No. of stages	Nerve anastomosis method	How was spontaneous smile assessed?	Time to movement of transferred gracilis by masseter (average in months)	Months to spontaneous smile	Rehabs protocol?	Other grading scale used	Terzis Outcome classification	Follow up period
Dusseldorp et al., 2018	26	NA	NA	Both CFNG and ipsilateral masseteric nerve	Validated humorous videos.	NA	NA	NA	eFACE and FaCE instrument A novel computer vision algorithm was employed to detect expression of joy during both voluntary and spontaneous smiling. eFACE and FaCE scale improvements were statistically significant. Results of both voluntary and spontaneous expression of joy in CFNG, NTM and dually innervated gracilis flaps will be presented.	NA	12

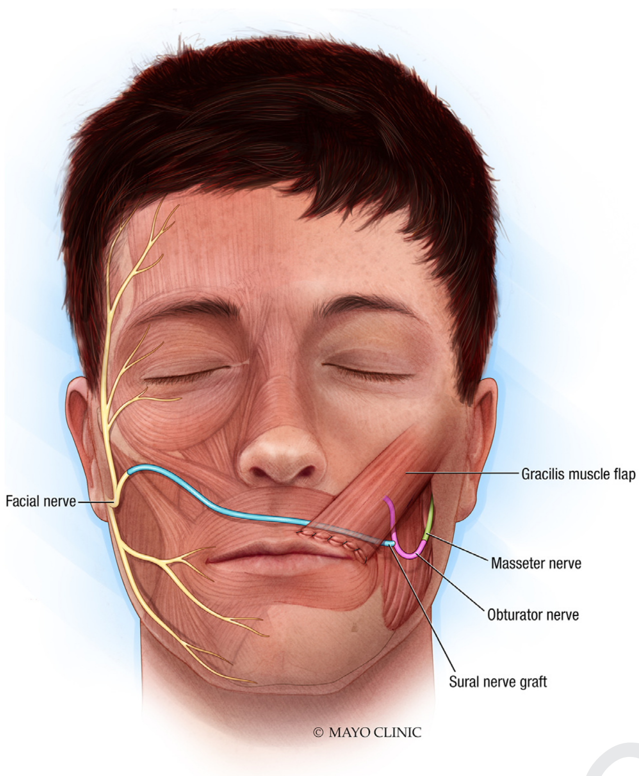

Figure 2 Dual innervation using two end-to-end coaptations: CFNG with the obturator nerve, and the masseteric nerve with an intramuscular motor branch.

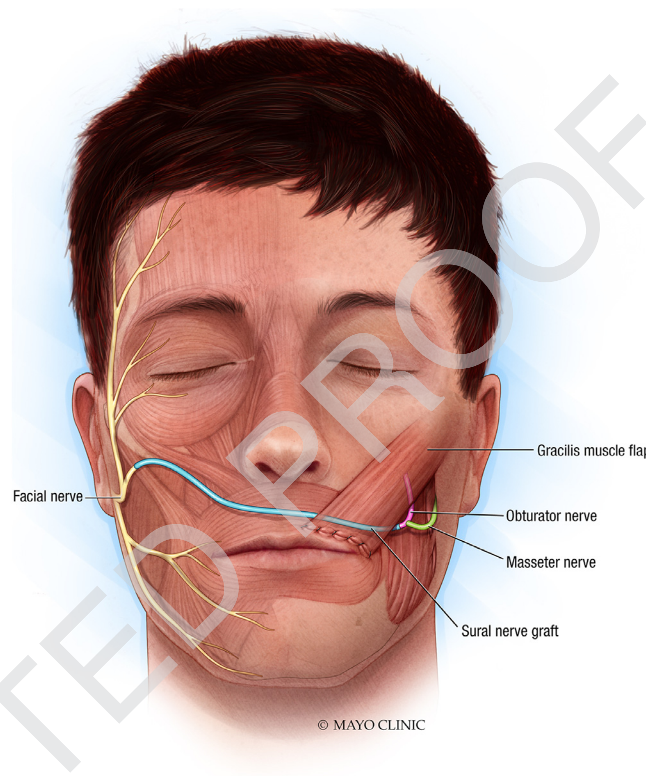

Figure 3 Dual innervation using CFNG as an end-to-side coaptation to the obturator and the masseteric nerve as an end-to-end to the obturator nerve.

looked only at overall outcome, while others tried to differentiate the strength of gracilis activation with biting down versus a more emotional/spontaneous activation. Of the 36 patients where the presence of spontaneity was measured, 88% ($n = 32$) were able to achieve a spontaneous smile. As expected, the time to a spontaneous smile was delayed compared to the time to gracilis activation with biting. Two series (Biglioli et al. and Uehara et al.) assessed the time to a spontaneous smile, reporting a mean of 7.2 months (6-8.8) and 10 months (9–12), respectively.[11,15] McNeely et al. reported spontaneous smile in 3 of 8 pediatric patients by 3 months.[22]

There were varied approaches to assessing whether a smile was truly spontaneous or emotional in nature. Biglioli et al., Bianchi et al., Sforza et al., and Dusseldorp et al. displayed funny videos to assess spontaneity.[10,11,14,21] Bianchi et al. and Uehara et al. indicated that they specifically instructed the patient to not bite down during the assessment for spontaneous smile.[9,15]

Neurophysiology and rehabilitation

Three papers included electromyography (EMG) data. Cardenas-Mejia et al. described a mean latency of 4.14 milliseconds and a motor unit recruitment of 68.3% by one year post-surgically, which they counted as a great outcome. They did not specifically discuss how they stimulated the muscle, however.[13] Biglioli et al. used EMG to verify the CFNG function, by inserting an EMG coaxial needle electrode into the gracilis muscle to assess motor units while electrically stimulating the contralateral facial nerve.[11] Uehara and Shimizu provided electrical stimulation of the contralateral facial nerve at the tragus and upper lip and measured the motor potential amplitudes over the transferred muscle on the affected side.[15] They reported compounded motor action potentials ranging from 23 to 287 microvolts in the 6 patients described. Interestingly, in the two cases from their series with detailed descriptions of electrophysiologic testing, the gracilis flap was noted to be innervated by the contralateral facial nerve and ipsilateral masseteric nerve in one patient, and by only the masseteric nerve in the other.

In addition to the surgical procedure, three series described post-operative physical therapy, including rehabilitation protocols consisting of mirror biofeedback and physiotherapist-guided exercises transitioning to smiling independent from biting.[10,11,15] In the abstracts, only Win et al. reported use of EMG, but no further details were available.[23]

Discussion

Dual innervation of a free gracilis flap with a combination of a CFNG and the ipsilateral masseteric nerve is a safe procedure with >95% of patients achieving some activation of the gracilis by 2-5 months.

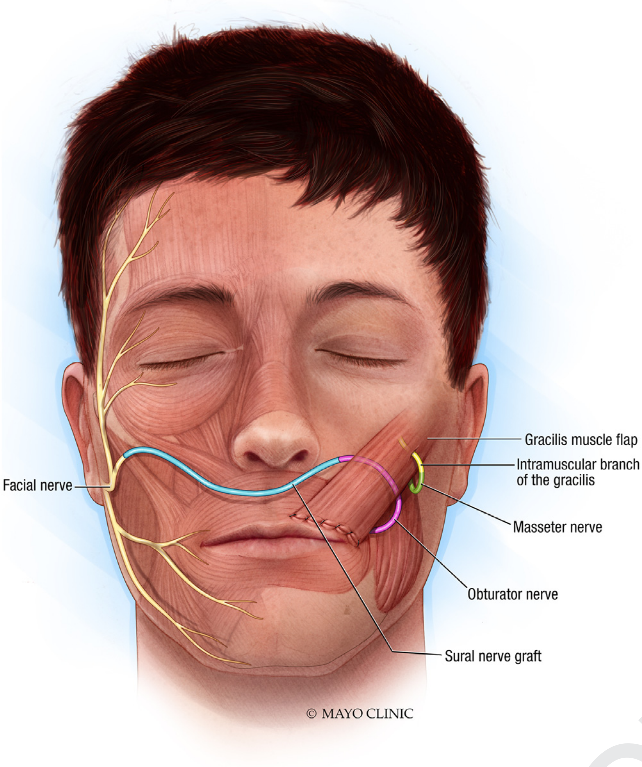

Figure 4 Dual innervation using CFNG as an end-to-end coaptation to the obturator and the masseteric nerve as an end-to-side to the obturator nerve.

Comparison to single innervation methods

In single innervation studies, masseteric-innervated gracilis muscles typically achieve a better excursion than CFNG-innervated muscles, but lack a consistent spontaneity.[2,3,17] Different methods of assessment were used, making excursion comparison difficult. Based on the timing to onset of gracilis movement and the moderate to excellent results reported when the Terzis grading scale was applied, dual innervation method achieved comparable results to series of gracilis muscle transfers using the masseteric nerve alone.[7,16,17,24] O those in whom the outcome of spontaneity was recorded, 88% (32-36) of patients were able to achieve a spontaneous smile, similar to the spontaneity rate reported in gracilis muscle transfers innervated by CFNG alone.[2,7,25,26]

Time to gracilis reinnervation was reported by all authors, ranging from 3.2 to 5.1 months. This is similar to the 2-4 month time-to-activation of the gracilis muscle reported with single innervation with the masseteric nerve. The time to spontaneous smile as measured by Biglioli et al. and Uehara et al. of 7.2 and 9.5 months is also consistent with previously reported function after CFNG innervation of about 1-2 year.[2,3,7,27] In the abstracts, Win et al.[23] reported a time to gracilis reinnervation of 3 months, and time to spontaneous smile of 10 months, but no further details were given.

Comparison between methods of dual innervation

It is too early in the description of dual innervated gracilis transfers to be able to compare adequately the different methods of innervation. Our review did not see any major differences in outcome between the methods employed. We have categorized the approaches into three groups as summarized in Table 1 and Figures 2-4. The most common approach has been the use of the coaptation of the masseteric nerve end-to-end with the obturator with the CFNG as an end-to-side coaptation to the obturator nerve.[9-12] Our review also found an abstract-only article with an additional 8 patients using this approach, with good results.[23] This would seem to put the masseteric nerve at a great advantage, with any innervation from the CFNG acting as a supplementary signal rather than providing the primary nerve input. Cardenas-Mejia et al. described the reverse, coapting the masseteric nerve end-to-side to the obturator nerve, and the CFNG end-to-end to the obturator nerve, using two stages.[13] They reported a similar time to masseteric re-innervation to other approaches. Uehara et al. found a distal stump of the intramuscular motor branch of the obturator nerve and used this as an end-to-end coaptation to the masseteric nerve (Figure 4), therefore also permitting end-to-end coaptation of the CFNG to the obturator nerve.[15] With only one series describing this unique double end-to-end innervation method, it is not clear yet whether this provides a better, similar, or worse outcome when compared to other dual innervation techniques.

Snyder-Warwick et al.[29] studies the myelinated fiber counts in their pediatric facial reanimation patients. The downstream count in the CFNG at the second stage was only 24% of the count at the facial nerve donor branch, while the count from the masseteric nerve was 78%.[29] This study confirmed the fact that the masseteric nerve provides much stronger signal compared to the CFNG, which translated into a significant difference in the degree of movement of the gracilis.[29] Several animal studies in rats also looked into the differences between end-to-side vs. end-to-end coaptations.[30-32] Both Liao et al. and Jaeger et al. concluded that end-to-end coaptations of motor nerves resulted in faster innervation and better muscle recovery following denervation compared to end-to-side innervation, although the end-to-side method also provided reasonable reinnervation potential.[30,31] In contrast, Viterbo et al.[32] did not see any differences between the two methods. The work by Isaac et al.[33,34] looking at the mechanism of end-to-side coaptation, in addition to the clinical experience by Barbour et al.[35] and Terzis et al.[36], also supports end-to-side coaptation as a viable method. Taking into account the findings by Snyder-Warwick et al.[29] and Liao et al.,[30] Jaeger et al.[31] and Viterbo et al.[32], it is reasonable to conclude that the masseter end-to-end method by Biglioli et al., Bianchi et al., Sforza et al., and Oh et al.,[9,11,14,19] allows the masseter nerve to provide the majority of the input to the gracilis, while still allowing some signal from the CFNG through end-to-side coaptation. The masseteric nerve as end-to-side coaptation into the obturator as described by Cardenas-Mejia et al.,[13] should allow more advantage to the CFNG as this is coapted end-to-end, while still allowing strong signal from the masseteric nerve. The abstract did not

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detail the connection type, and was therefore not included here.

Single versus two-staged procedure

Both Biglioli et al. and Uehara et al. report using a single stage procedure, where the CFNG is placed at the same setting as the distal coaptation and the masseteric nerve transfer to the free gracilis flap.[11,15] Given that they performed the procedure in one stage, it seems unlikely that the longer CFNG would reach the contralateral side before the masseteric nerve. The animal experiment by Liao et al. further shows that end-to-side coaptation is slower and results in less nerve input compared to end-to-end.[30] Because the masseteric nerve seems to innervate the gracilis first whether the procedure is performed in one or two stages, this may explain why the time-to-onset of gracilis activation was similar in all studies in our series.

Spontaneity of smile with dual innervation models

A common question is, how much of the patient's subsequent smile is due to the innervation originating from the masseteric nerve, and how much is from the CFNG? The most popular method of addressing spontaneity was by counseling the patients to smile without clenching their teeth, with the assumption that this would be considered a "spontaneous smile" and be attributed to the CFNG innervation.[10,11,14,15] However, many patients with only masseteric nerve innervated gracilis transfers are eventually able to achieve a smile without biting down.[37] Manktelow et al.,[37] indicated in a patient questionnaire study that 69% of their patients with masseteric nerve innervated gracilis transfers learned to smile without biting down, after repeated practice and training (average follow up of 4.7 years). In contrast, Chuang et al., described a series of 22 patients with masseteric nerve innervated gracilis, and none of the patients achieved a spontaneous smile using a "tickle test" (average follow up >2 years).[2] It is therefore difficult to know whether the patients in our review of the literature who were reported to have a spontaneous smile by "smiling without clenching" achieved this spontaneity based on the additional CFNG, or cortical plasticity.[38,39] Perhaps a better method of evaluating true spontaneity and even an emotive smile was done by Biglioli et al., Bianchi et al., Sforza et al. *and Dusseldorp* et al., when they measured gracilis activation after a funny video.[9,11,14,21] However, even this level of spontaneity has been reported with masseteric innervation alone.[38] In the pediatric patients reported by McNeely et al.[22] patients appear to achieve spontaneous smile earlier, with 3 of 9 with spontaneous smile by 3 months. Whether the entire group of 9 patients achieved spontaneous smile was not clear from the abstract. Future studies using dual innervation gracilis transfer models may benefit from EMG evaluations similar to those used by Uehara et al. and Biglioli et al., where the CFNG input is assessed more objectively through measurement of the CFNG compound muscle action potential (CMAP) and by stimulating the proximal CFNG while measuring the motor unit response in the gracilis muscle.[11,15]

The case series that were available in the literature did not use consistent methods for post-surgical evaluation, making direct comparisons difficult. Also, there are surgical centers that may be performing dual innervation of the gracilis muscle who have not yet published, and for this reason we tried to review the available abstracts in the literature as well. While these abstracts did provide some additional details on outcome, detailed evaluations were not available. Finally, it is possible that there has been publication bias preventing publication of negative results from these or additional novel dual innervation models. This highlights the need for further publications with standardized electrophysiological and clinical outcome measures.

Conclusions

Surgical centers have only started to incorporate dual innervated gracilis transfers for facial reanimation in the past 6 years. It is still too early to know if one specific method of coaptation yields a better surgical outcome than others. Based on the available literature to date, we do know that the dual innervated free gracilis muscle utilizing the masseteric nerve and CFNG seems to be a safe procedure, with gracilis activation similar in timing to single innervation procedures using just the masseteric nerve, and a substantial number of patients also achieving spontaneity.[10,11,14,15,37]

In order to better evaluate these procedures and determine the optimal approach, future studies should be designed with standardized measures of spontaneity, including the incorporation of emotive stimuli (such as funny videos or "the tickle test") and electrophysiologic techniques.

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Supplementary materials

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