Segmental Gracilis Flap & Donor Nerve Selection for Facial Reanimation – Anatomy and Preoperative Diagnostics

K. Can Bayezid, Libor Streit

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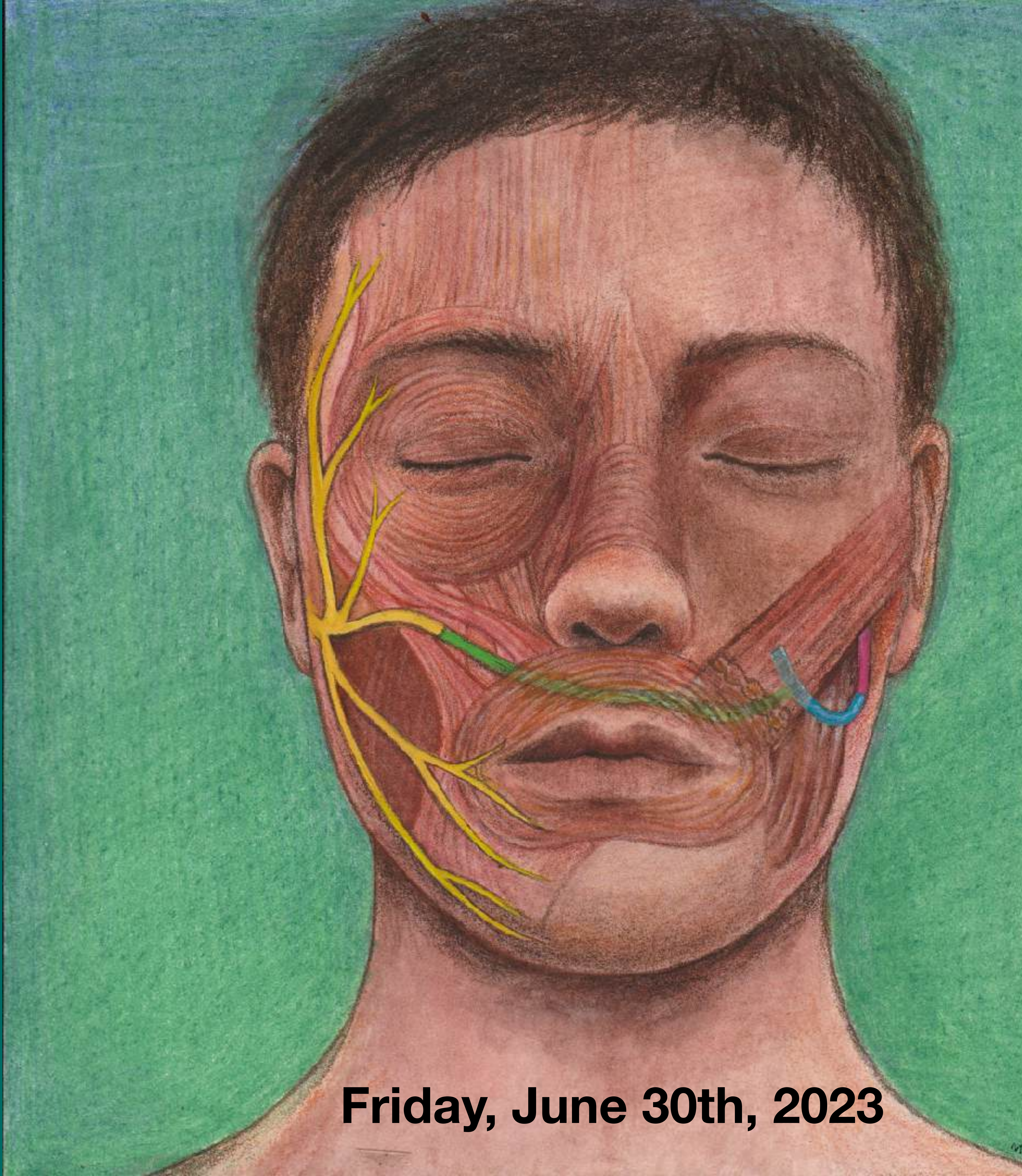
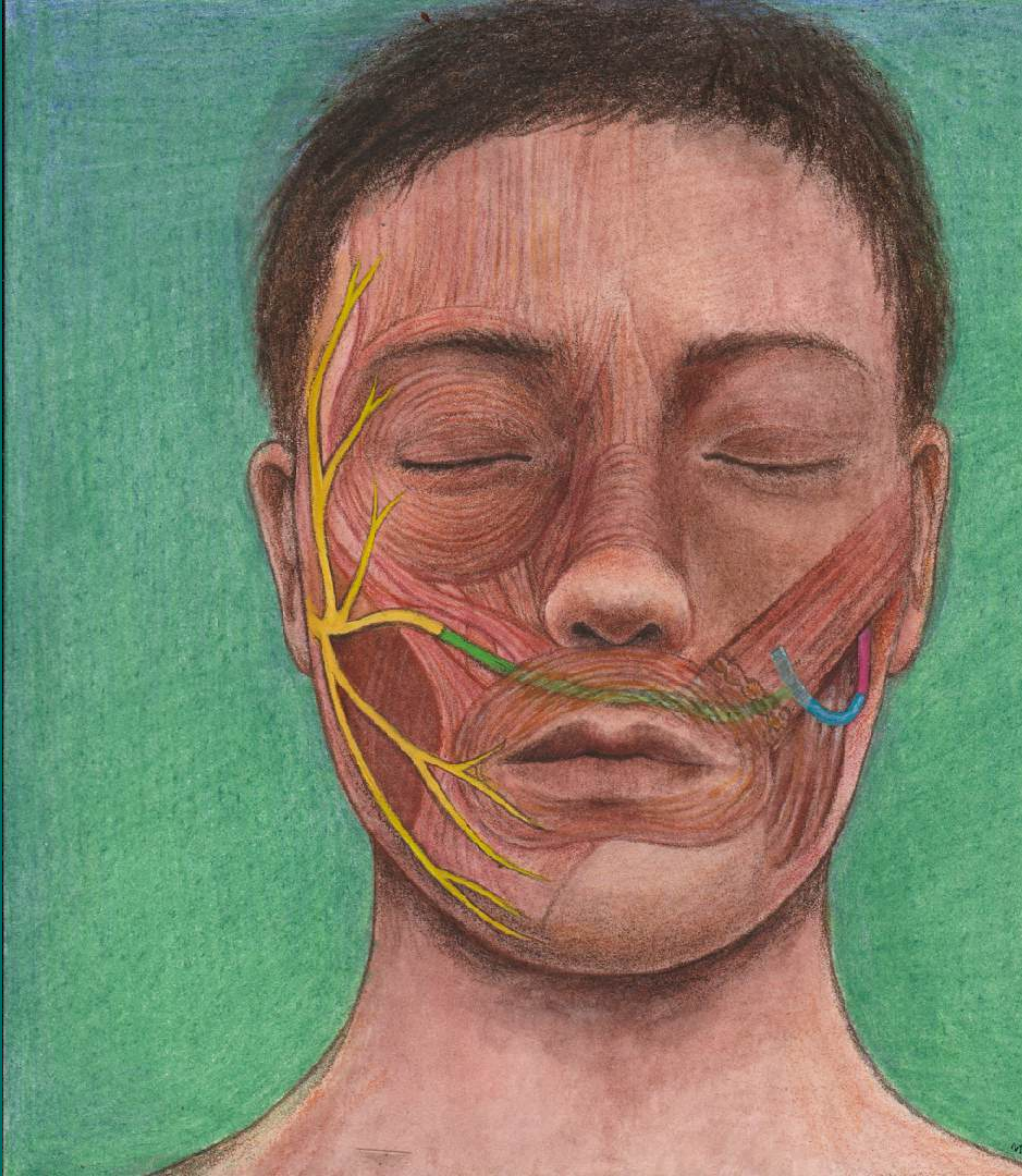


Friday, June 30th, 2023

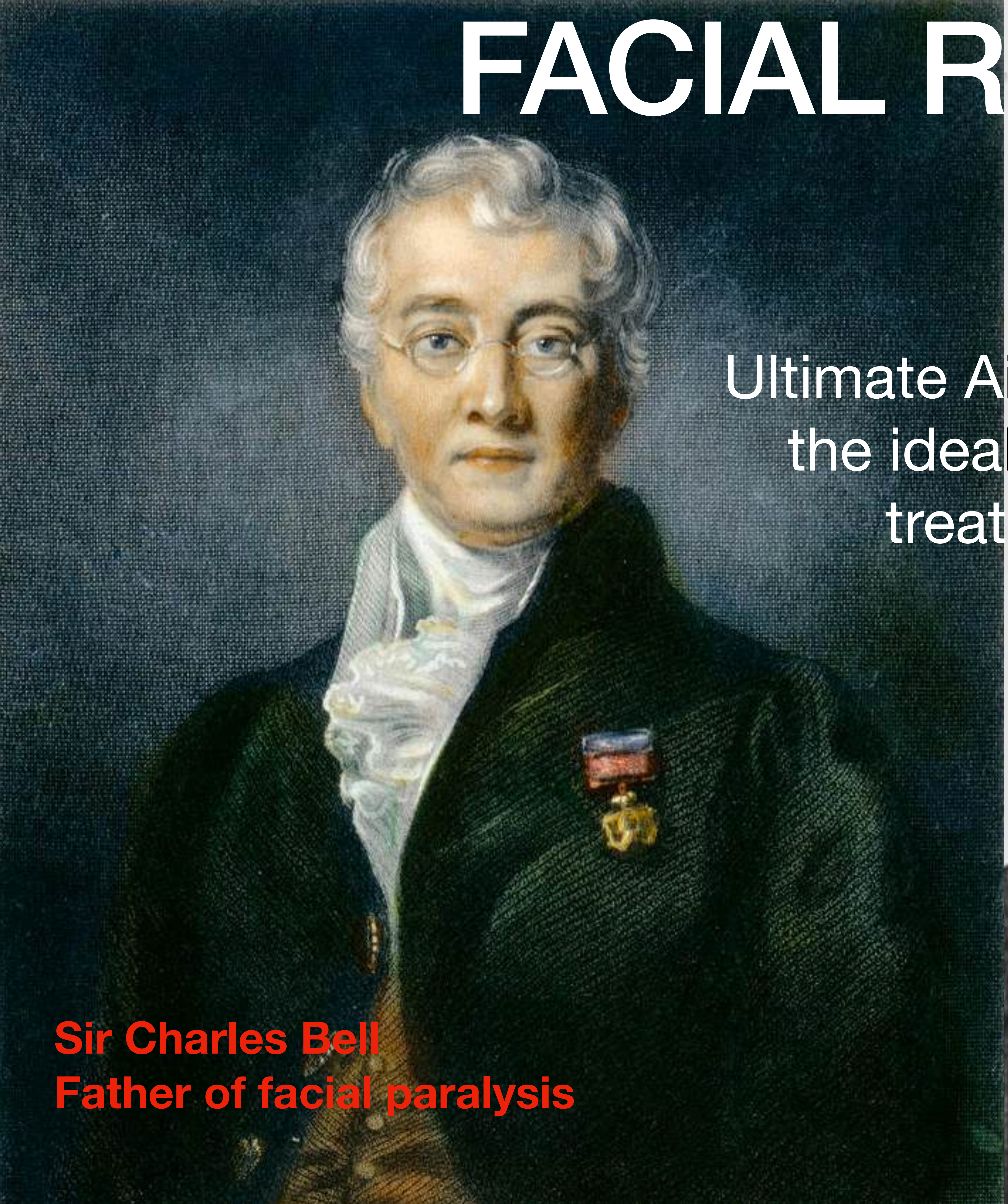
CONTENT

- Goals of Reanimation and Outline for Surgical Management
- Free Gracilis Muscle Transfer - Anatomy, Harvesting
- Basic Surgical Methodology
- Donor Nerve Comparison and Prevalence
- Dual-Innervation Concept
- Clinical Outcomes

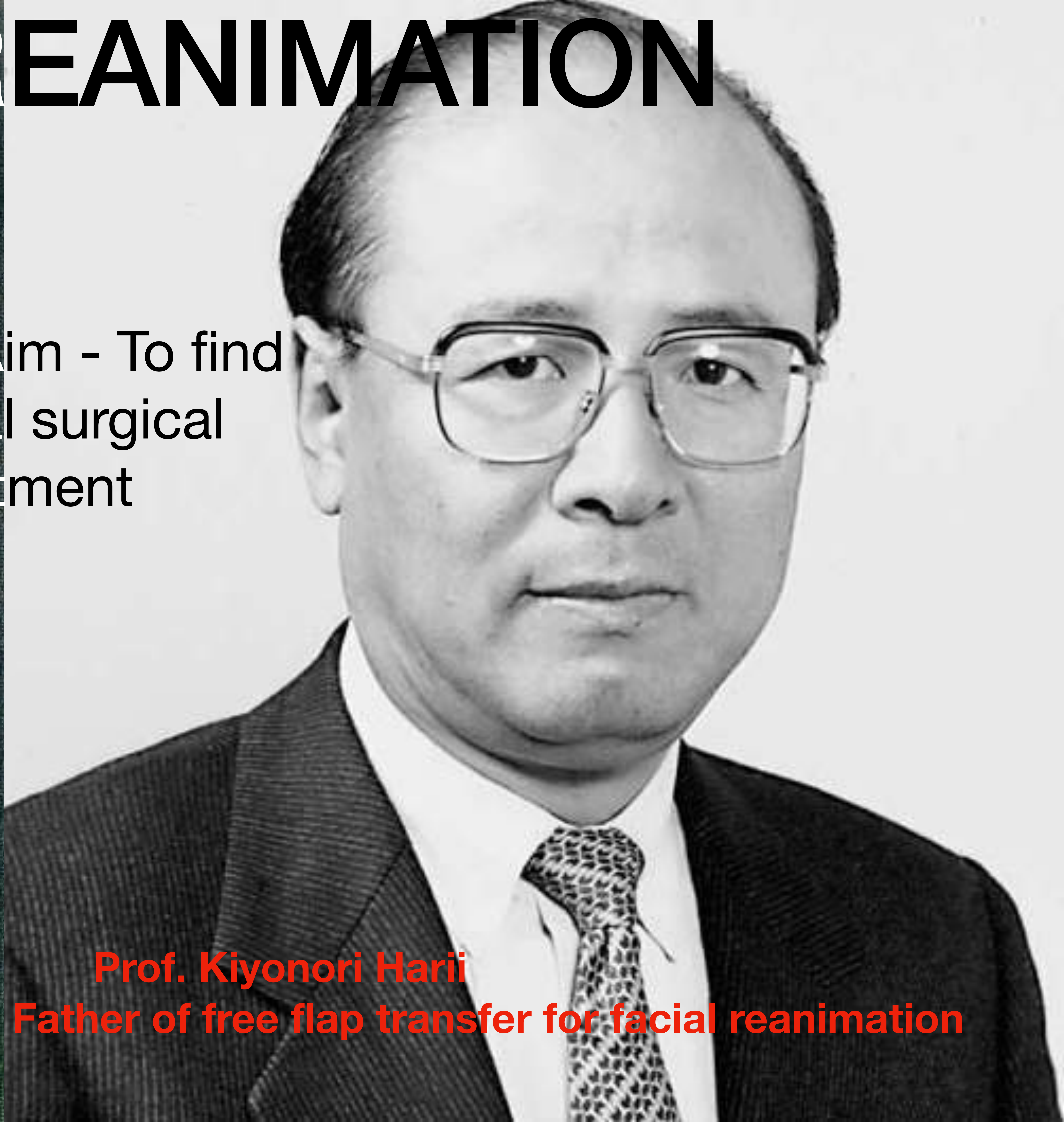


FACIAL REANIMATION

Ultimate Aim - To find the ideal surgical treatment

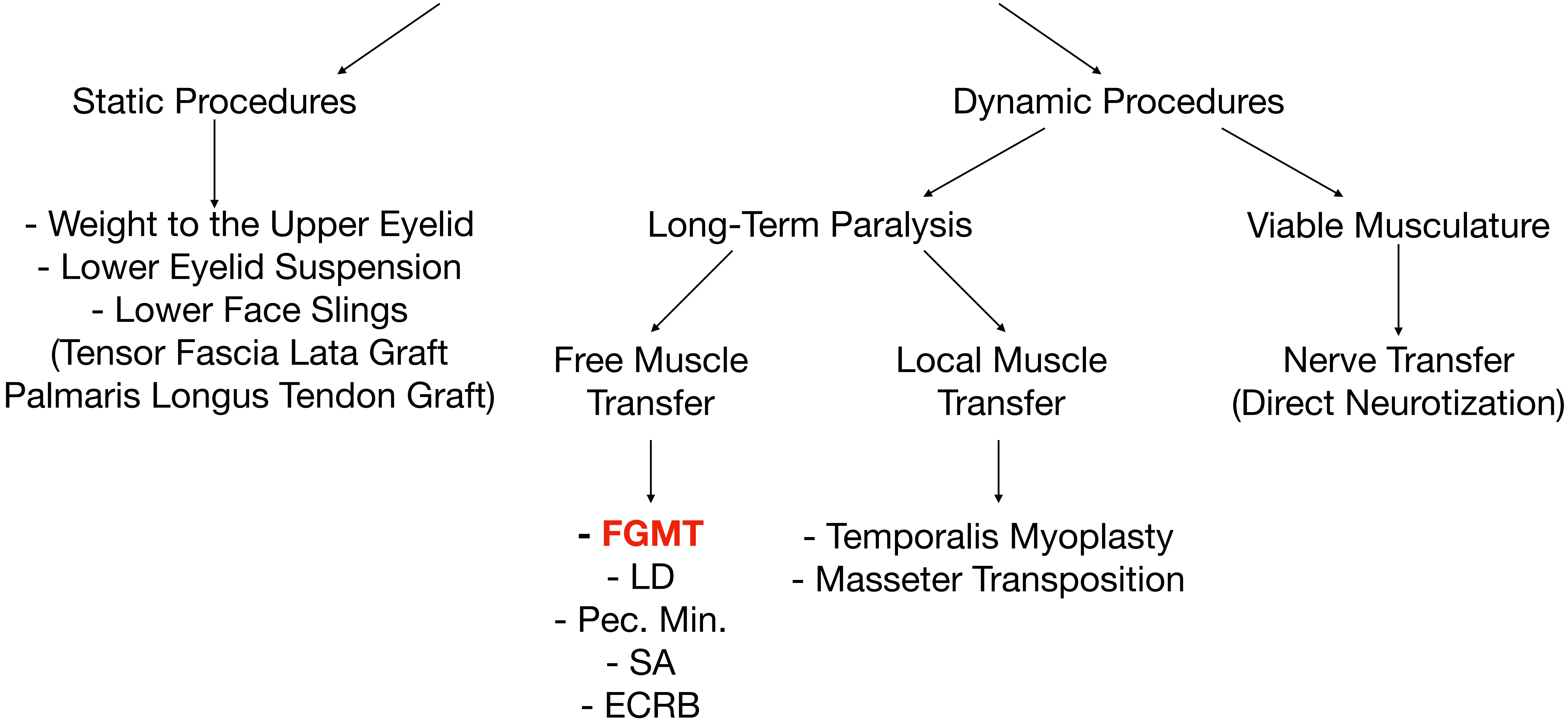


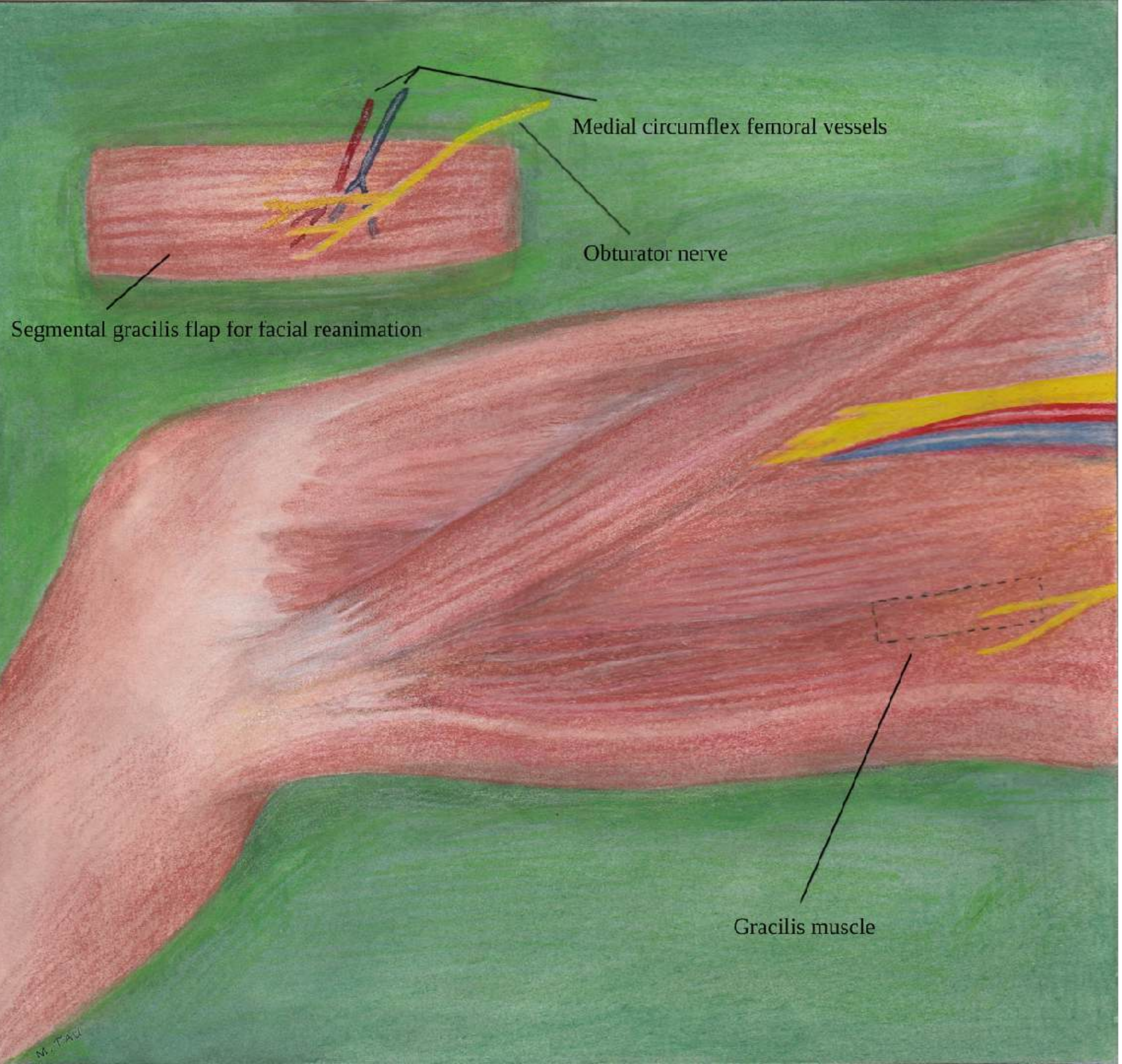
Sir Charles Bell
Father of facial paralysis

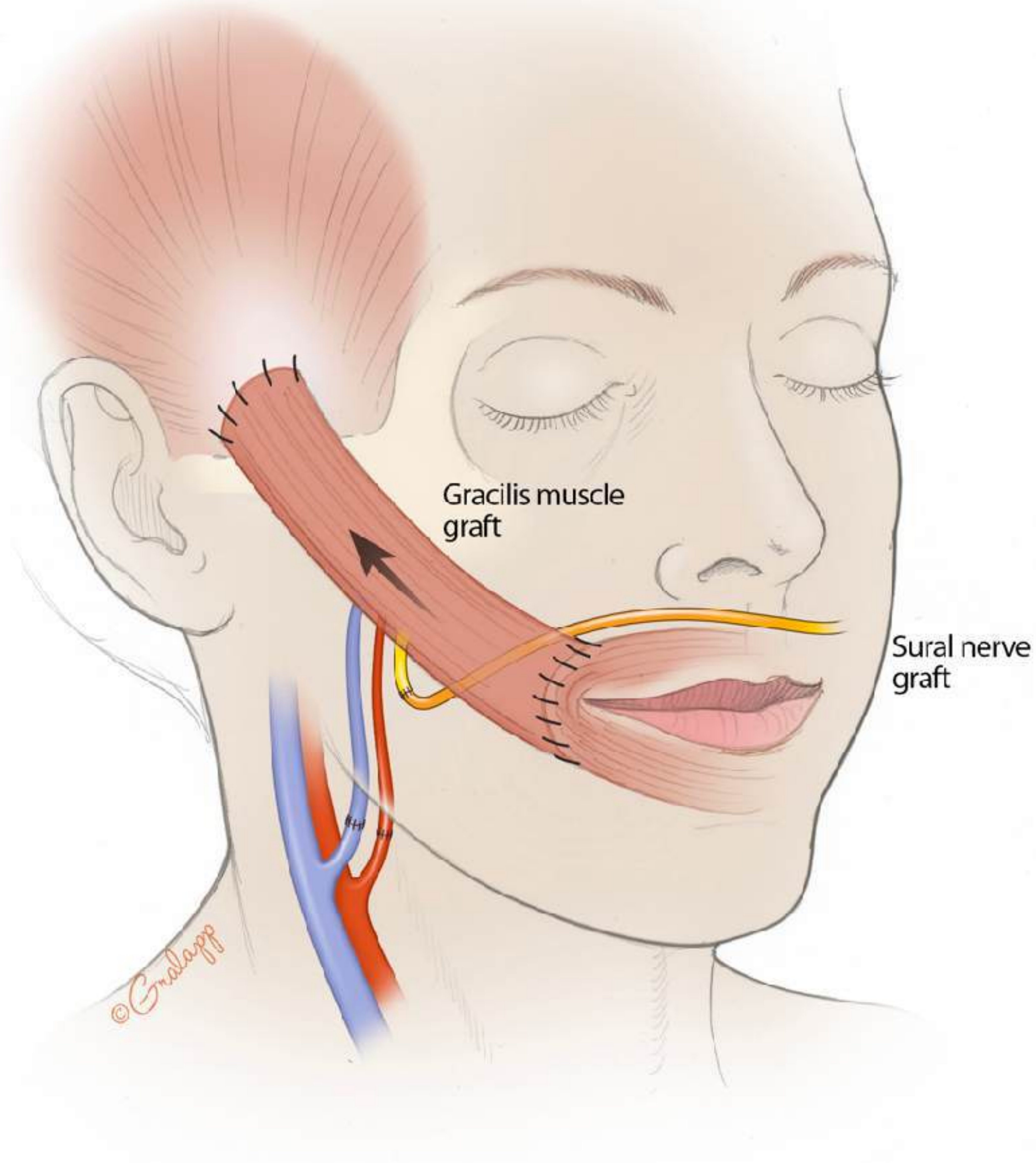


Prof. Kiyonori Harii
Father of free flap transfer for facial reanimation

Surgical Management of Facial Paralysis





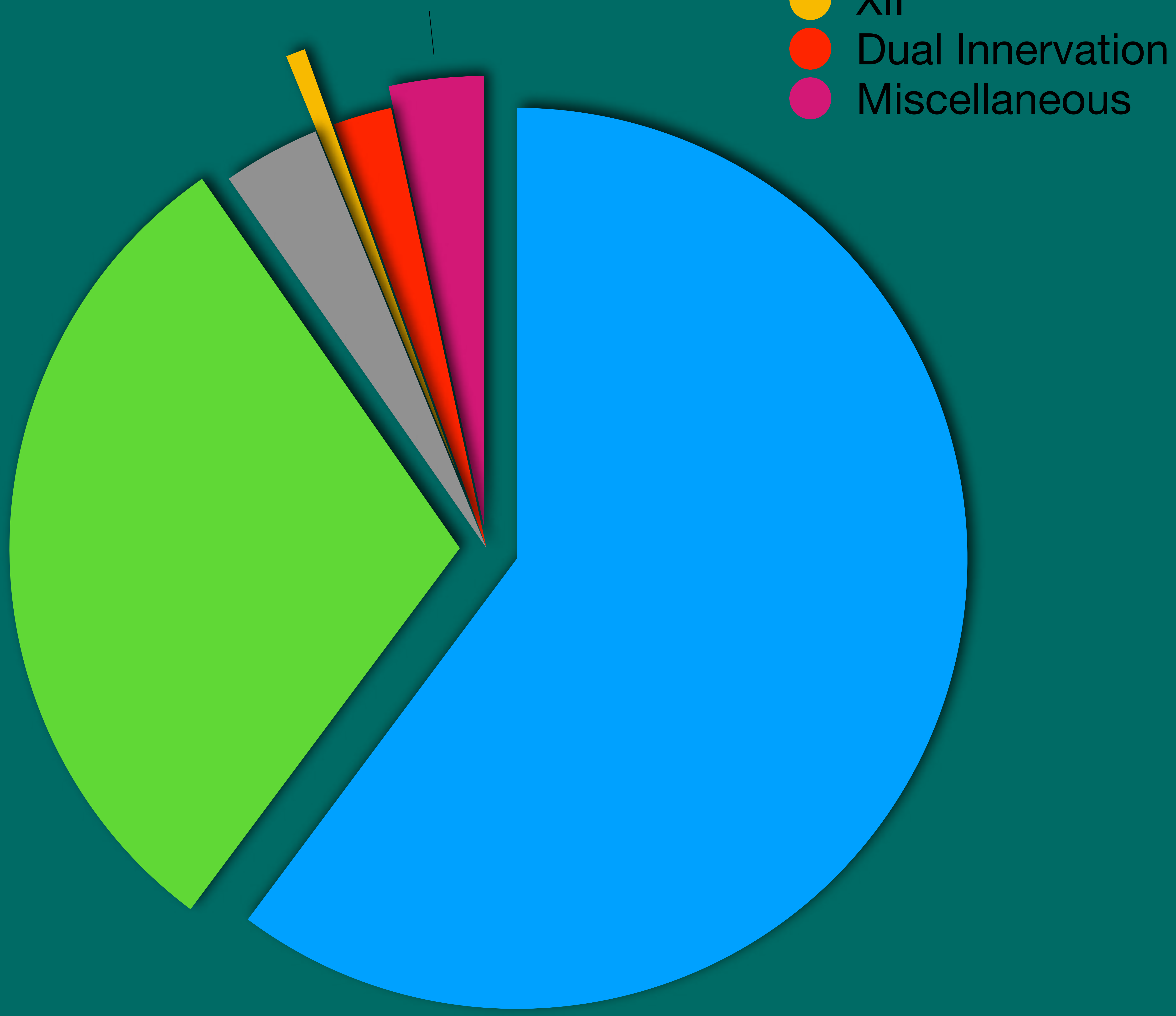


From Oto Surgery Atlas

Donor Nerve Selection in FGMT

(Data from Roy et al. 2019)

- CFNG - 60.2%
- Motor Nerve to Masseter - 30.1%
- Spinal Accessory Nerve - 3.5%
- Hypoglossal Nerve - 0.7%
- Dual Innervation - 2.1%



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Review

Donor nerve selection in free gracilis muscle transfer for facial reanimation. A systematic review and meta-analysis of clinical outcomes

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KEYWORDS
Facial palsy;
Facial reanimation;
Free gracilis muscle transfer;
Dual innervated free gracilis flap

Summary *Background:* One of the critical factors in facial reanimation is selecting the donor nerve. The most favored neurotizers are the contralateral facial nerve with a cross-face nerve graft (CFNG) and motor nerve to the masseter (MNM). A relatively new dual innervation (DI) method has shown successful results. This study aimed to compare the clinical outcomes of different neurotization strategies for free gracilis muscle transfer (FGMT).
Methods: The Scopus and WoS databases were queried with 21 keywords. Three-stage article selection was performed for the systematic review. Articles presenting quantitative data for commissure excursion and facial symmetry were included in meta-analysis, using random-effects model. ROBINS-I tool and Newcastle-Ottawa scale were used to assess bias and study quality.
Results: One hundred forty-seven articles containing FGMT were systematically reviewed. Most studies indicated CFNG as the first choice. MNM was primarily indicated in bilateral palsy and in elderly. Clinical outcomes of DI studies were promising. 13 studies including 435 observations (179 CFNG, 182 MNM, 74 DI) were eligible for meta-analysis. The mean change in commissure excursion was 7.15 mm (95% CI: 4.57-9.72) for CFNG, 8.46 mm (95% CI: 6.86-10.06) for MNM, and 5.18 mm (95% CI: 4.01-6.34) for DI. In pairwise comparisons, a significant difference was found between MNM and DI ($p = 0.0011$), despite the superior outcomes described in DI studies.


CFNG for spontaneity, coordination and natural appearance
Motor nerve to masseter for strength and fast recovery

3 Main Functional Goals of Midface Reanimation

1) Satisfactory recovery of the commissure excursion

2) Satisfactory recovery of the facial symmetry and muscle tone- at rest and during the smile

3) Recovery of the spontaneous smile

Neurotization Preferences in Smile Reanimation: A Discrete Choice Experiment

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Background: Common donor nerve options in smile reanimation include ipsilateral trigeminal motor or contralateral facial nerve branches. Neurotization preference may be influenced by multiple factors, whose relative importance remains poorly understood. In this article, decision-making in smile reanimation is assessed using a stated preference model.

Methods: Qualitative interviews with facial palsy patients identified five relevant attributes for study: smile type ("smile when biting" versus "smile spontaneously" as proxies for trigeminal versus cross-facial neurotization), number of operations, success rates, complication rates, and side effects. Community volunteers ($n = 250$) completed a discrete-choice experiment relevant to free muscle transfer for smile reanimation. Preoperative and postoperative states were demonstrated through video vignettes, together with explanation of surgical risks, consequences, and benefits. Attribute importance was modeled using hierarchical Bayes estimation.

Results: Two hundred forty-one responses met quality controls. Attribute importance ranked as follows: chance of success, 37.3 percent; smile type, 21.4 percent; side effects, 13.9 percent; complication rates, 13.8; and number of operations, 13.6 percent. All attributes significantly correlated with decision making ($p < 0.0001$). An aggregate response model revealed most participants (67.6 percent; standard error, 3.0 percent) preferred smile reanimation by cross-facial (assuming a success rate of 80 percent) as opposed to ipsilateral trigeminal motor branch neurotization. When the success rate for cross-facial neurotization was reduced below 67 percent, trigeminal neurotization was preferred.

Conclusions: Despite a higher risk of failure, most respondents preferred a cross-facial as opposed to trigeminal neurotization strategy for smile reanimation. These findings highlight the complexity of decision-making and need for individualized risk tolerance assessment in the field of facial reanimation. (*Plast. Reconstr. Surg.* 148: 407e, 2021.)

Preoperative Diagnostics

Ultrasound

EMG

- Help us understand the facial anatomy and viability of the muscles
- The strength of innervation of facial and masticatory vessels
- Presence of Masseteric Coactivation

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Pre-operative masseter muscle EMG activation during smile predicts synchronicity of smile development in facial palsy patients undergoing reanimation with the masseter nerve: A prospective cohort study☆

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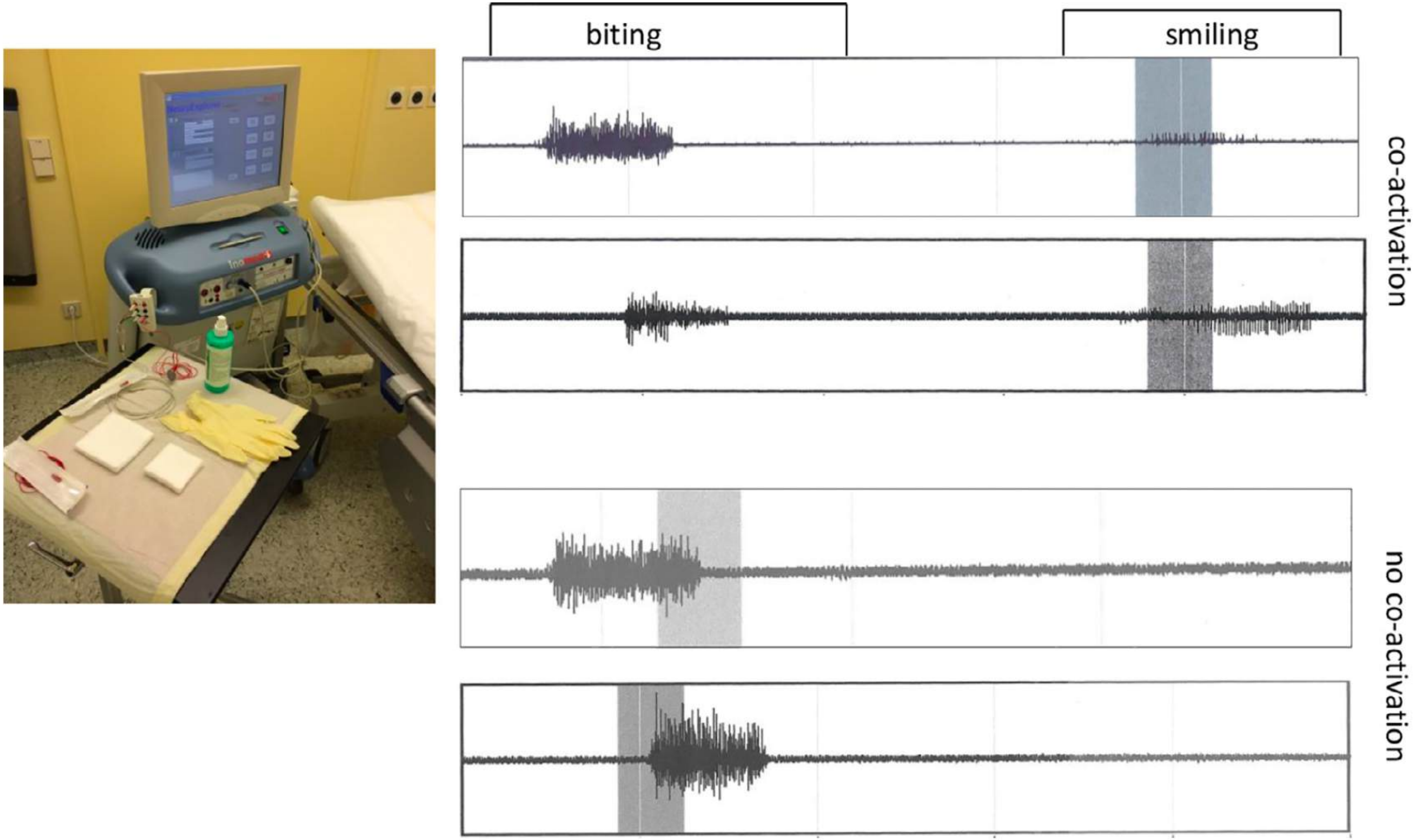
Received 9 May 2018; accepted 11 November 2018

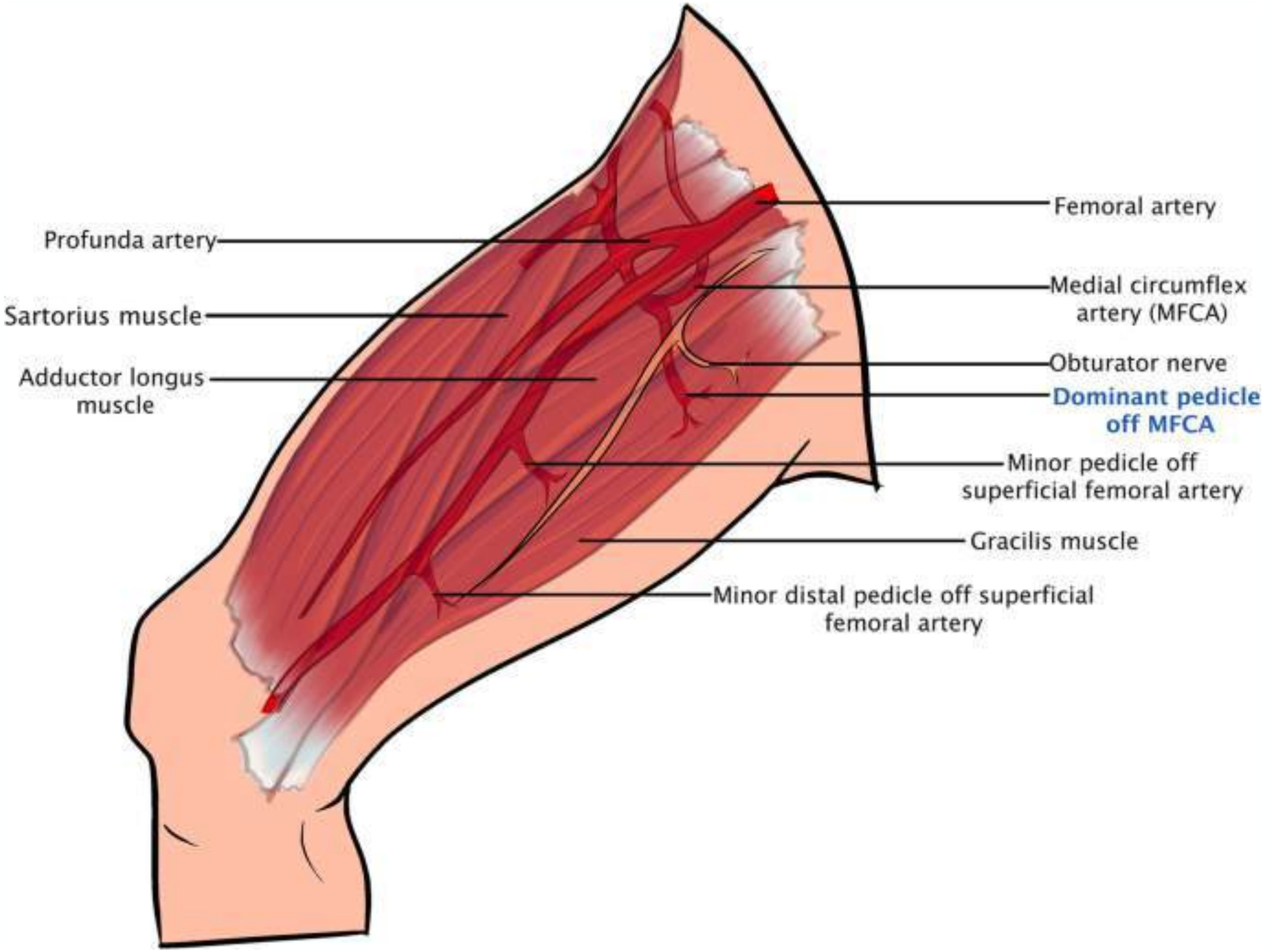
KEYWORDS
Facial paralysis;
Facial reanimation surgery;
Free functional muscle transfer;
Head and neck reconstruction;
Masseteric nerve;
Microsurgery

Summary *Background:* Synchronicity of the oral commissure movement of a bilateral smile is a significant goal for reconstruction in facial reanimation and may only be guaranteed with use of the facial nerve as a donor nerve. Yet over the years several studies report some degree of spontaneity in certain patients when using a non-facial donor nerve, which indicates that synchronous initiation of the smile might be achievable with other donor nerves. We designed a prospective cohort study to evaluate whether pre-operative involuntary activation of the masseteric nerve during smile predicts development of a synchronous smile development when using the masseteric nerve for reanimation.

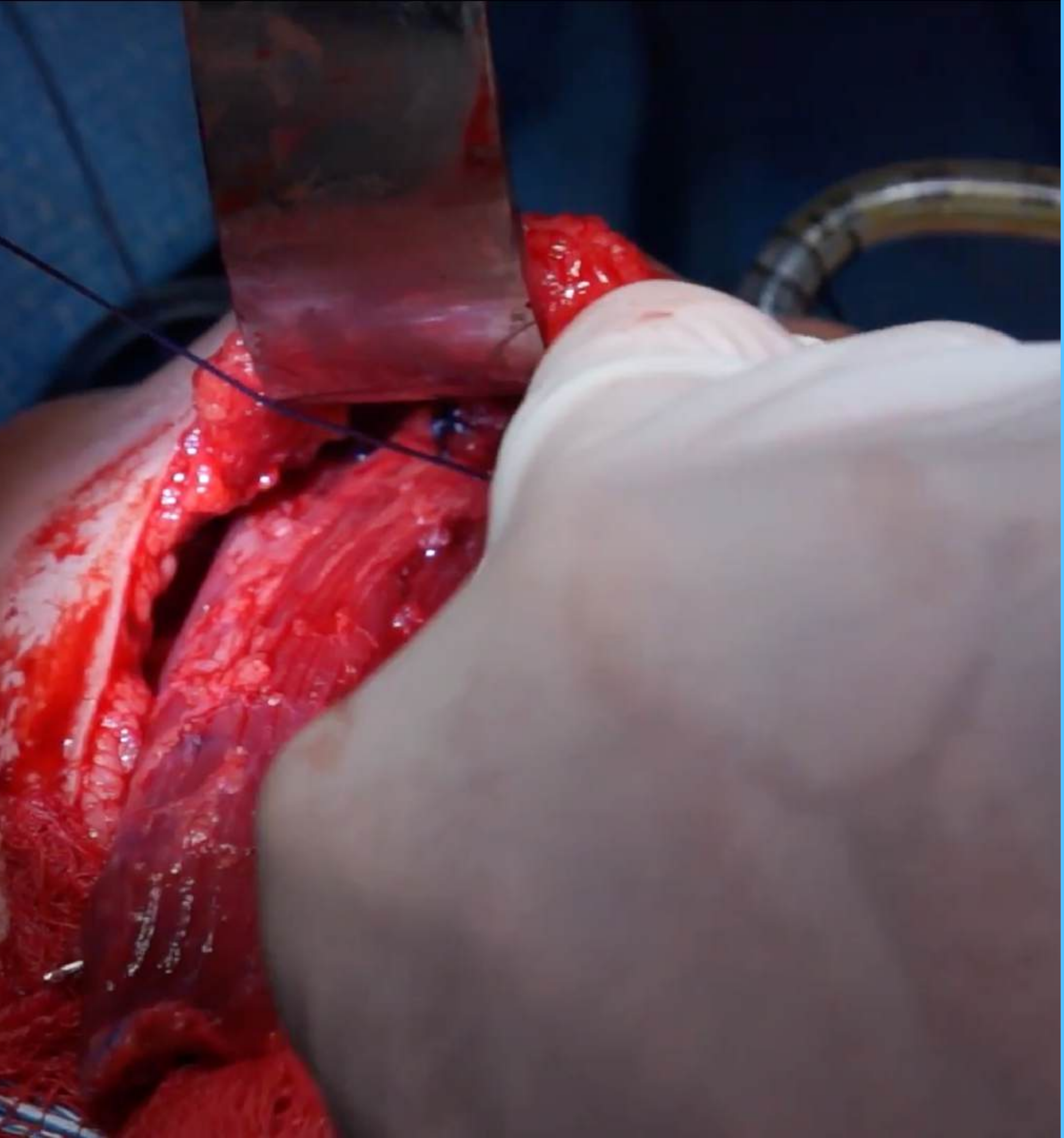
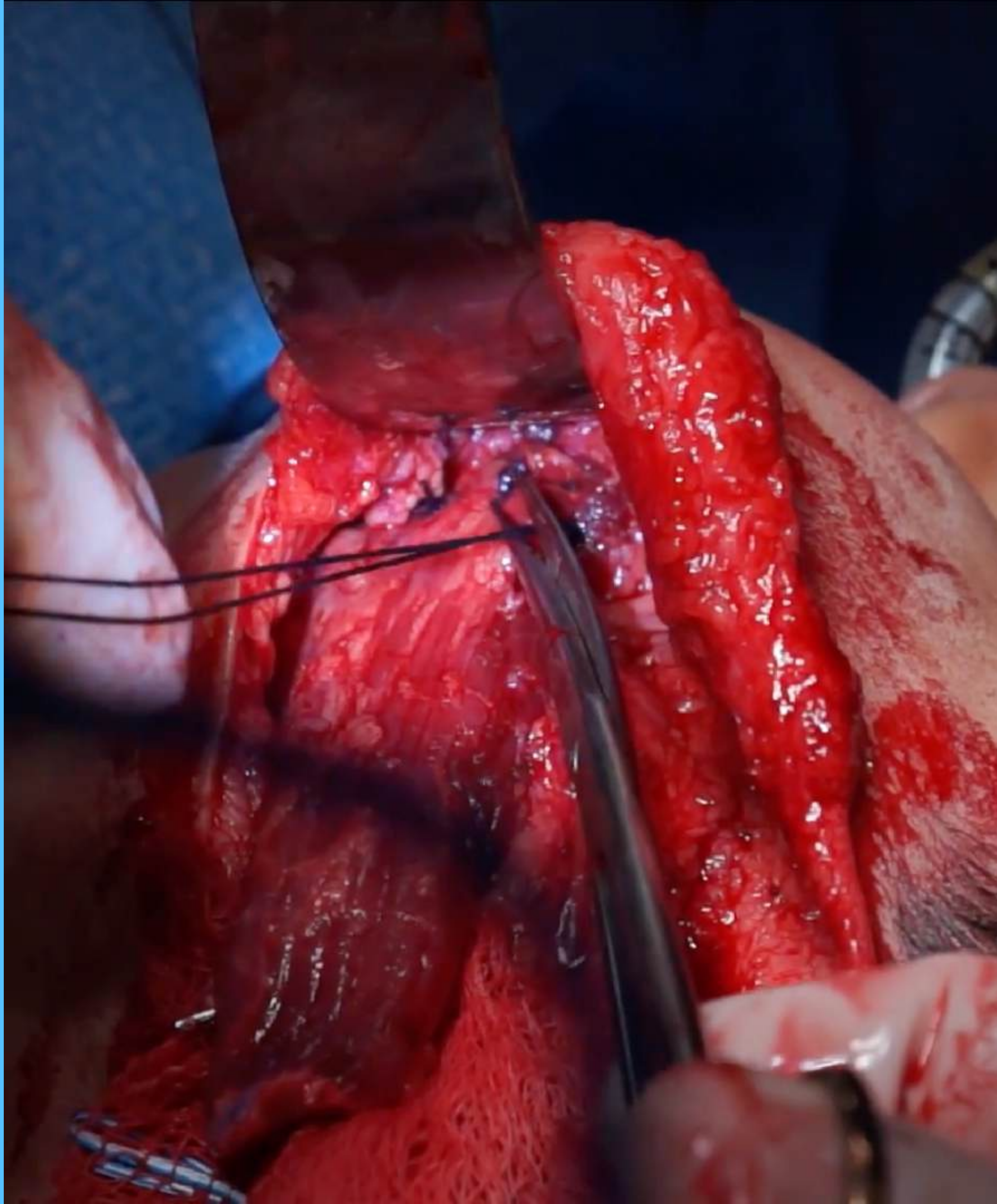
Methods: In a prospective cohort study unilateral long-standing facial palsy patients scheduled for dynamic smile reanimation with a free functional muscle transplant using the masseteric nerve as a donor nerve were preoperatively evaluated via EMG for involuntary activation of the masseter muscle upon smiling, which we called coactivation. Postoperatively, six months after noting the first muscle contraction smile synchronicity was evaluated. We analyzed the


biting
smiling
co-activation
no co-activation

SURGICAL METHODOLOGY



Comprehensive Atlas of Upper and Lower Extremity Reconstruction pp 247–257

Donor Nerve Selection in FGMT

(Data from Roy et al. 2019)

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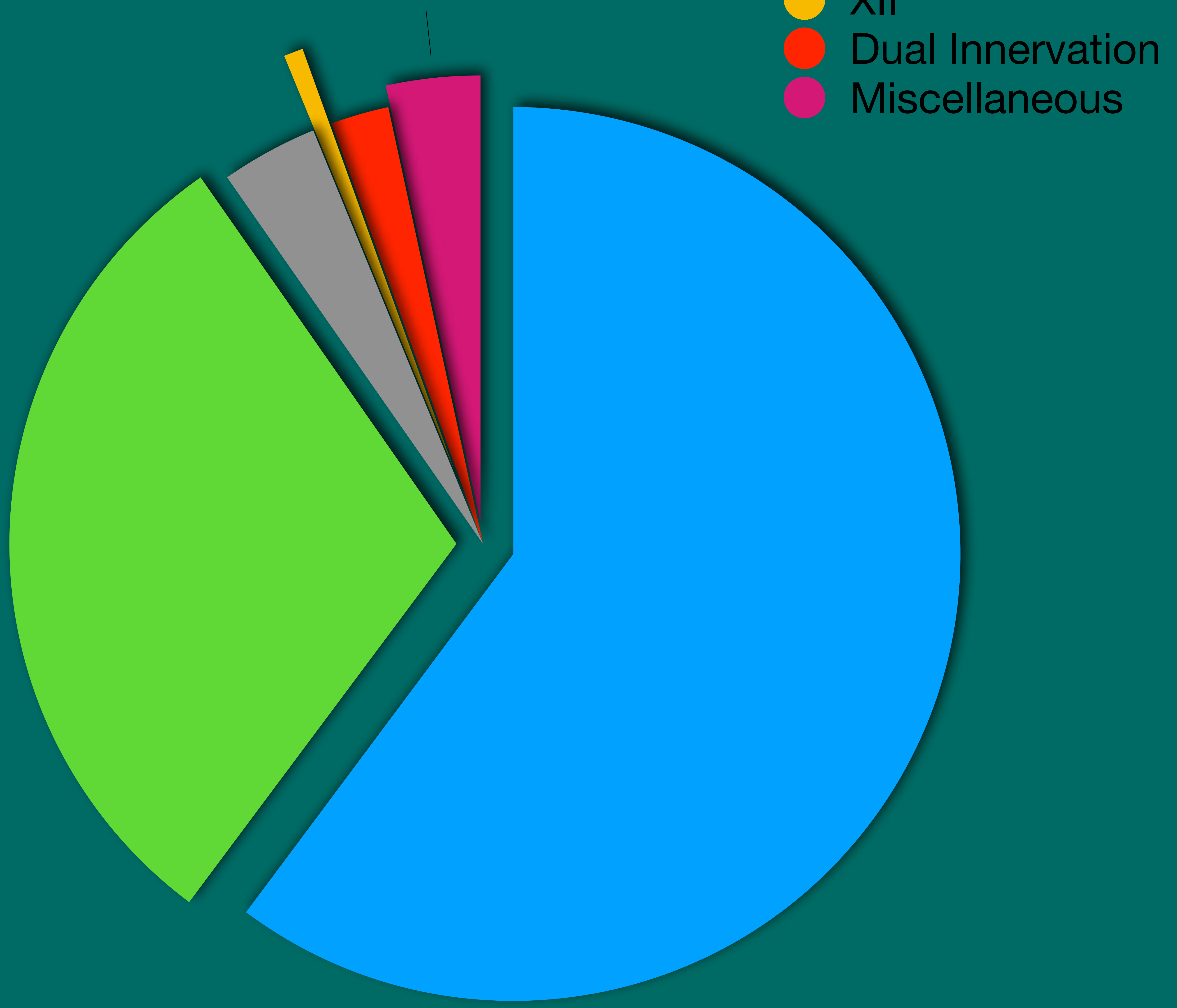
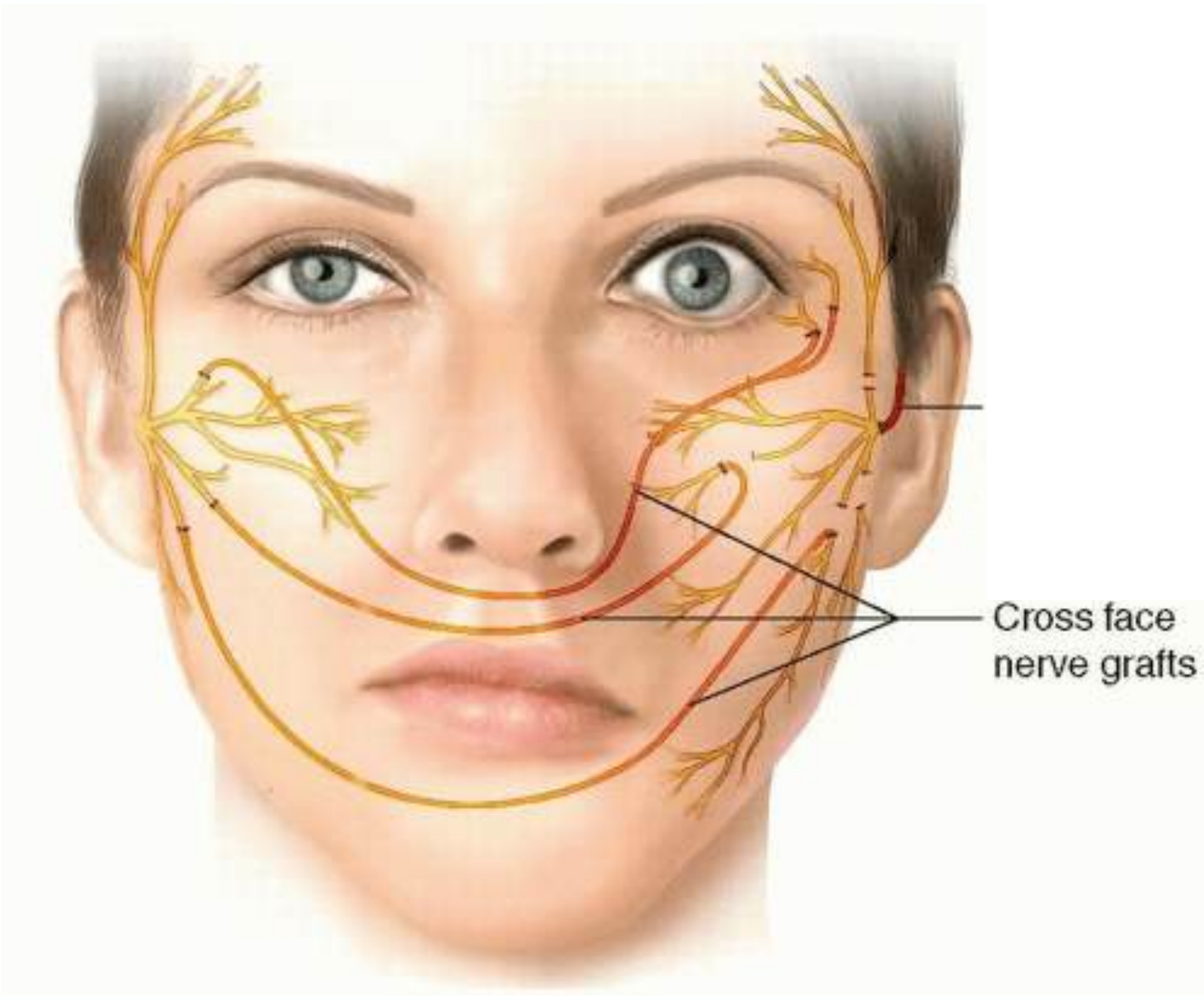
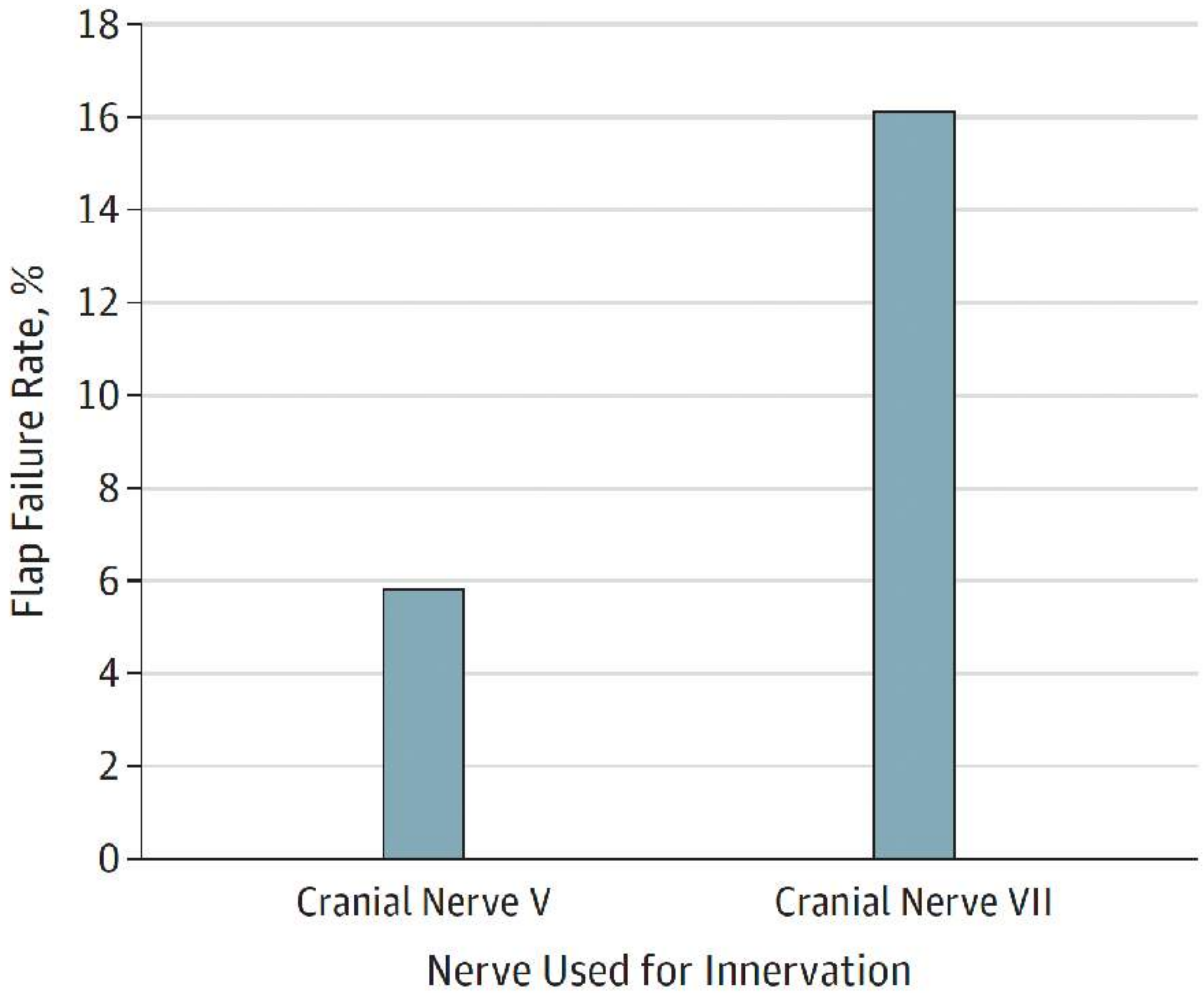




	Contralateral Facial Nerve with CFNG
Advantages:	- Native nerve for facial animation
	- Higher ability to achieve a natural, spontaneous smile
	- Better synchronized to the healthy side in unilateral cases, giving more commissural coordination, and excursion symmetry
	- Better resting symmetry. Decent excursion in young patients
	- Progressive improvement in the quality of smile, with superior long term results
	- No significant donor morbidity
Disadvantages:	- Two-staged procedure
	- Longer recovery period with later flap contraction
	- CFNG harvest leads to additional donor site exposure (typically the leg for sural nerve harvest)
	- Less axons reach their target due to long distance and additional anastomotic sites
	- Higher risk of flap failure

Figure 3. Gracilis Flap Failures by Nerve



The y-axis shows the percentage of total flaps innervated by the nerve denoted on the x-axis that failed over the study period. *P* = .09 by Fisher exact test.

Placheta et al.

Catapano et al.

EXPERIMENTAL

Enhancement of Facial Nerve Motoneuron Regeneration through Cross-Face Nerve Grafts by Adding End-to-Side Sensory Axons

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Christine Lafontaine, M.Sc.
Edward H. Liu, M.D.
J. Michael Hendry, M.D.
Doychin N. Angelov, M.D.
Manfred Frey, M.D.
Tessa Gordon, Ph.D.
Gregory H. Borschel, M.D.

Vienna, Austria; Toronto, Ontario, Canada; and Cologne, Germany

Background: In unilateral facial palsy, cross-face nerve grafts are used for emotional facial reanimation. Facial nerve regeneration through the grafts takes several months, and the functional results are sometimes inadequate. Chronic denervation of the cross-face nerve graft results in incomplete nerve regeneration. The authors hypothesize that donor axons from regional sensory nerves will enhance facial motoneuron regeneration, improve axon regeneration, and improve the amplitude of facial muscle movement.
Methods: In the rat model, a 30-mm nerve graft (right common peroneal nerve) was used as a cross-face nerve graft. The graft was coapted to the proximal stump of the transected right buccal branch of the facial nerve and the distal stumps of the transected left buccal and marginal mandibular branches. In one group, sensory occipital nerves were coapted end-to-side to the cross-face nerve graft. Regeneration of green fluorescent protein–positive axons was imaged in vivo in transgenic *Thy1*–green fluorescent protein rats, in which all neurons express green fluorescence. After 16 weeks, retrograde labeling of regenerated neurons and histomorphometric analysis of myelinated axons was performed. Functional outcomes were assessed with video analysis of whisker motion.
Results: "Pathway protection" with sensory axons significantly enhanced motoneuron regeneration, as assessed by retrograde labeling, in vivo fluorescence imaging, and histomorphometry, and significantly improved whisker motion during video analysis.
Conclusion: Sensory pathway protection of cross-face nerve grafts counteracts chronic denervation in nerve grafts and improves regeneration and functional outcomes. (*Plast. Reconstr. Surg.* 135: 460, 2015.)

Cross-Face Nerve Grafting with Infraorbital Nerve Pathway Protection: Anatomic and Histomorphometric Feasibility Study

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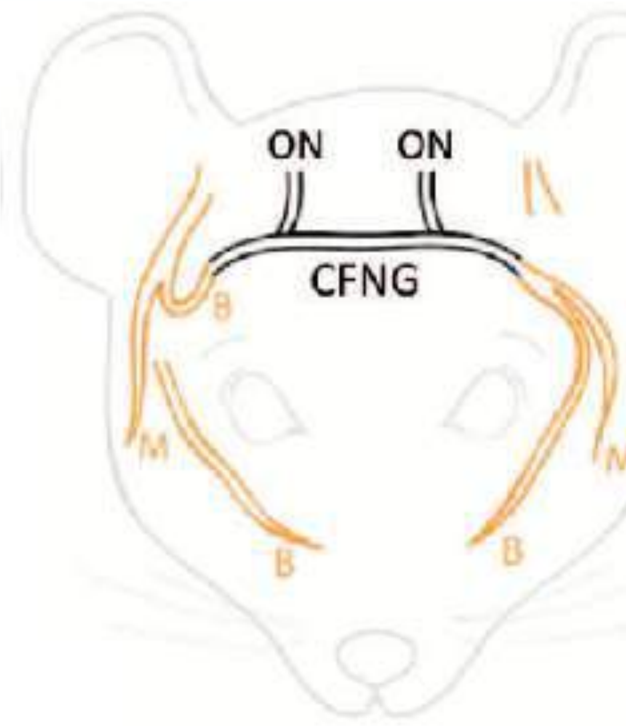
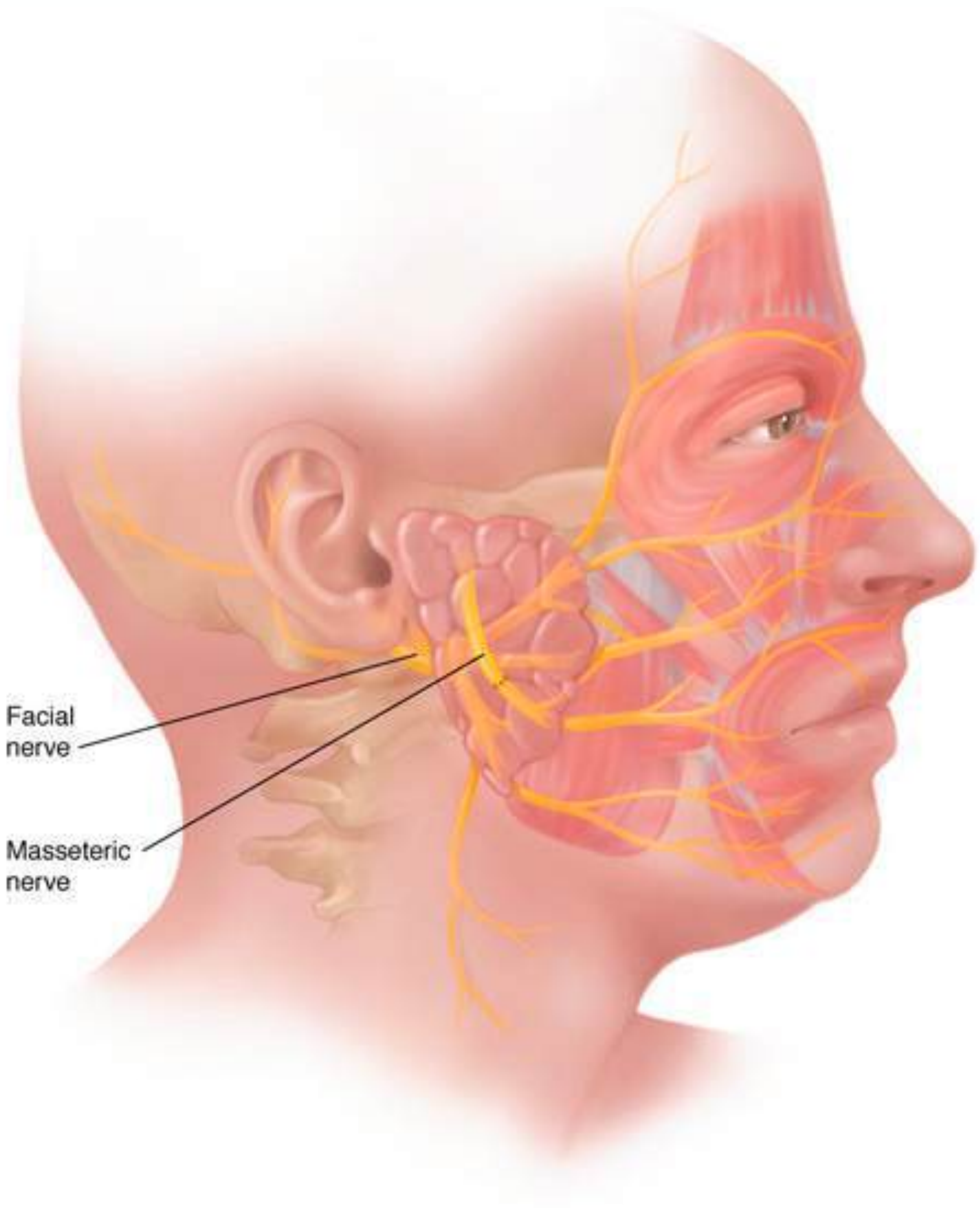
Daniel R.B. Demsey, MD,*†‡
Emily S. Ho, BSc, OT Reg. (Ont.), MEd,*†
Ronald M. Zuker, MD,*†‡
Gregory H. Borschel, MD*†‡

Smiling is an important aspect of emotional expression and social interaction, leaving facial palsy patients with impaired social functioning and decreased overall quality of life. Although there are several techniques available for facial reanimation, staged facial reanimation using donor nerve branches from the contralateral, functioning facial nerve connected to a cross-face nerve graft (CFNG) is the only technique that can reliably reproduce an emotionally spontaneous smile. Although CFNGs provide spontaneity, they typically produce less smile excursion than when the subsequent free functioning muscle flap is innervated with the motor nerve to the masseter muscle. This may be explained in part by the larger number of donor motor axons when using the masseter nerve, as studies have shown that only 20% to 50% of facial nerve donor axons successfully cross the nerve graft to innervate their targets. As demonstrated in our animal studies, increasing the number of donor axons that grow into and traverse the CFNG to innervate the free muscle transfer increases muscle movement, and this phenomenon may provide patients with the benefit of improved smile excursion. We have previously shown in animal studies that sensory nerves, when coapted to a nerve graft, improve axonal growth through the nerve graft and improve muscle excursion. Here, we describe the feasibility of and our experience in translating these results clinically by coapting the distal portion of the CFNG to branches of the infraorbital nerve. *(Plast Reconstr Surg Glob Open 2016;4:e1037; doi: 10.1097/GOX.0000000000001037; Published online 23 September 2016.)*



	Ipsilateral Motor Nerve to Masseter
Advantages:	- Enriched in axonal fibers (high donor nerve axonal density)
	- Consistent anatomy and in proximity with flap insertion site
	- Greater commissural excursion
	- One-stage procedure
	- Fast and reliable results in early postoperative period
	- No significant donor morbidity
Disadvantages:	- Volitional rather than emotional smile, especially in the beginning
	- Appearance of the smile is not as natural
	- Involuntary excursion while mastication occur in most of the patients
	- Requires persistent training in from of the mirror to achieve spontaneous smile via cerebral cortical reorganization.
	- 59% of the patients who underwent mirror therapy achieve spontaneous smile routinely.



PEDIATRIC/CRANIOFACIAL

The Degree of Facial Movement following Microvascular Muscle Transfer in Pediatric Facial Reanimation Depends on Donor Motor Nerve Axonal Density

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Adel Y. Fattah, Ph.D., F.R.C.S.(Plast.)
Leanne Zive
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St. Louis, Mo.; Liverpool, United Kingdom; and Toronto, Ontario, Canada

e

THERAPEUTIC

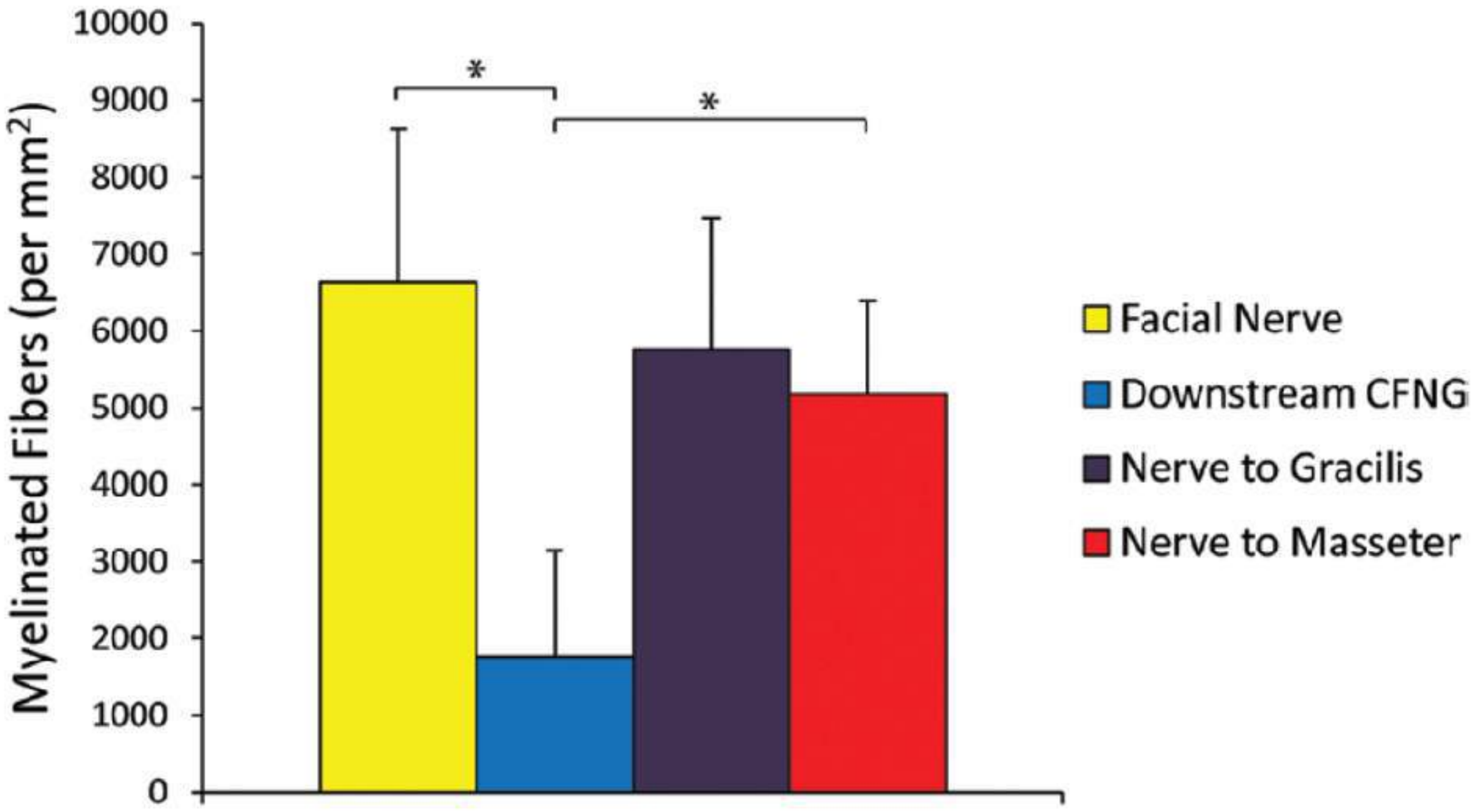
Background: Free functional muscle transfer to the face is a standard of facial animation. The contralateral facial nerve, via a cross-face nerve graft, provides spontaneous innervation for the transferred muscle, but is not universally available and has additional shortcomings. The motor nerve to the masseter provides an alternative innervation source. In this study, the authors compared donor nerve histomorphometry and clinical outcomes in a single patient population undergoing free muscle transfer to the face.

Methods: Pediatric patients undergoing dynamic facial (re-)animation with intraoperative nerve biopsies and gracilis transfer to the face powered by either the contralateral facial nerve via a cross-face nerve graft or the motor nerve to the masseter were reviewed over a 7-year period. Myelinated nerve counts were assessed histomorphometrically, and functional outcomes were evaluated with the Scaled Measurement of Improvement in Lip Excursion software.

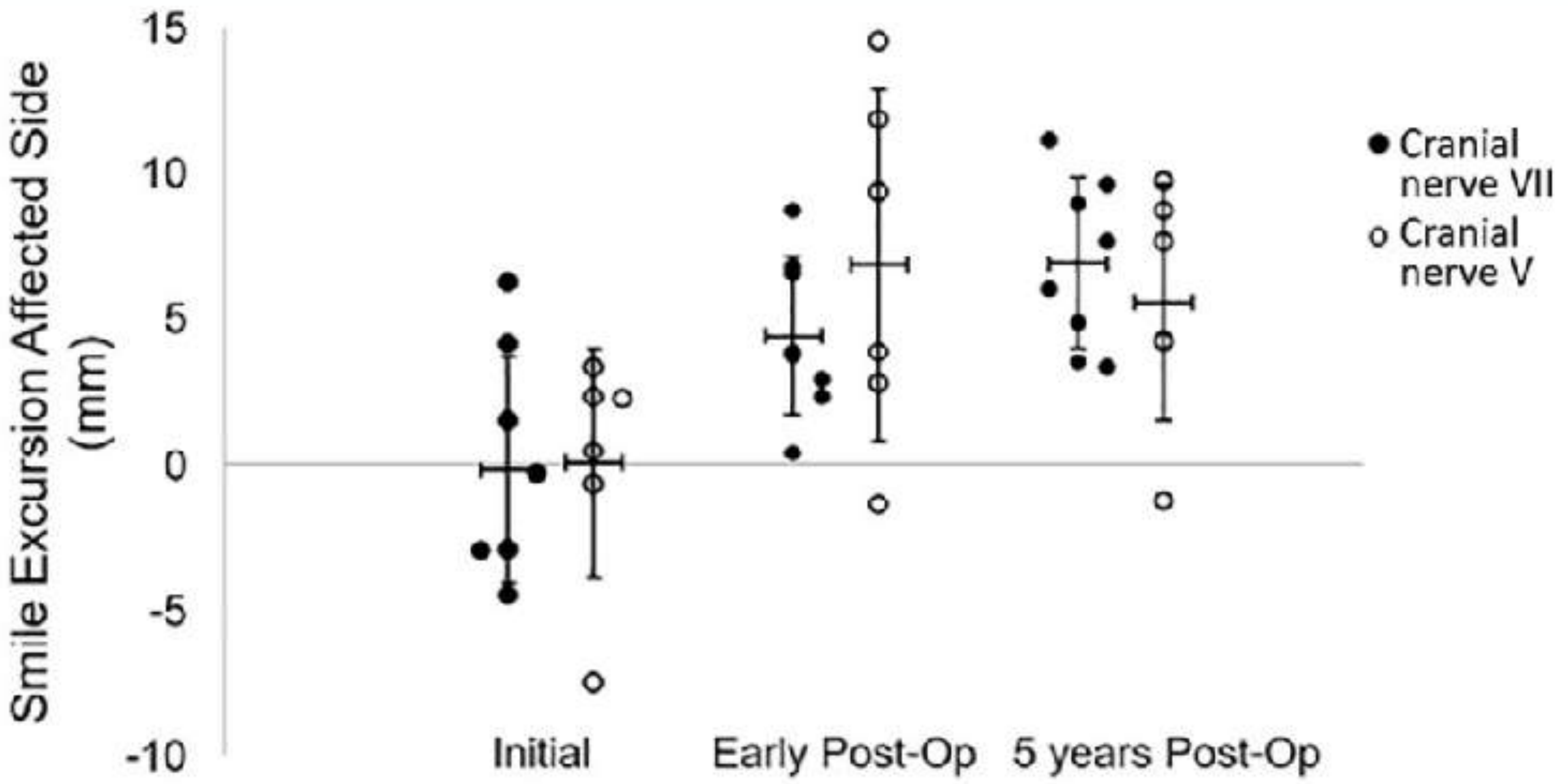
Results: From 2004 to 2011, 91 facial (re-)animation procedures satisfied study inclusion criteria. Average myelinated fiber counts were 6757 per mm2 in the donor facial nerve branch, 1647 per mm^2 in the downstream cross-face nerve graft at the second stage, and 5289 per mm^2 in the masseteric nerve. Reconstructions with either innervation source resulted in improvements in oral commissure excursion and smile symmetry, with the greatest amounts of oral commissure excursion noted in the masseteric nerve group.

Conclusions: Facial (re-)animation procedures with use of the cross-face nerve graft or masseteric nerve are effective and result in symmetric smiles. The masseteric nerve provides a more robust innervation source and results in greater commissure excursion. (*Plast. Reconstr. Surg.* 135: 370e, 2015.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.



Greene et al.



Long-Term Outcomes of Free Gracilis Muscle Transfer for Smile Reanimation in Children

Jacqueline J. Greene, MD, Joana Tavares, MD, Suresh Mohan, MD, Nate Jowett, MD, and Tessa Hadlock, MD

Objective To evaluate long-term outcomes of free gracilis muscle transfer (FGMT) for smile reanimation on smile excursion, facial symmetry, and quality of life in a cohort of children with facial palsy.
Study design A retrospective analysis of 40 pediatric patients who underwent FGMT for facial palsy at the Massachusetts Eye and Ear Infirmary Facial Nerve Center was performed. Preoperative and postoperative photography and videography were used to quantify smile excursion and facial symmetry. Preoperative and postoperative quality of life was assessed with the Facial Clinimetric Evaluation (FaCE) survey, a validated, patient-based instrument for evaluating facial impairment and disability.
Results Of the 40 patients who underwent FGMT for facial palsy, 38 patients had complete data including preoperative and postoperative photography and videography from 3 months to 10 years following surgery; 13 cases had >5 years of follow-up. FGMT resulted in significant improvements in smile excursion within several months, with continued improvements in smile excursion and symmetry demonstrated more than 5 years later. Fifteen patients completed preoperative and postoperative FaCE surveys, which demonstrated significant improvement in quality of life scores following FGMT.
Conclusions FGMT significantly improves smile, facial asymmetry, and quality of life for years after this surgery for facial palsy. *(J Pediatr 2018;[redacted]:[redacted]-[redacted]).*

Chuang et al.

RECONSTRUCTIVE

Using the "Sugarcane Chewing" Concept as the Directionality of Motor Neurotizer Selection for Facial Paralysis Reconstruction: Chang Gung Experiences

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Johnny Chuieng-Yi Lu, M.D.
Tommy Nai-Jen Chang, M.D.
Ahmet Hamdi Sakarya, M.D.

Taipei-Linkou, Taiwan

Background: Facial paralysis and postparalysis facial synkinesis both cause severe functional and aesthetic deficits. Functioning free muscle transplantation is the authors' preferred method for reconstructing both deformities.
Methods: From 1985 to 2017, a total of 392 patients underwent 403 gracilis functioning free muscle transplantations for facial reanimation. Different motor neurotizers were used: cross-face nerve graft (74 percent), spinal accessory nerve (17 percent), and masseter nerve (8 percent). Smile excursion score, cortical adaptation stage, patient questionnaire, Hadlock lip excursion, and the Terzis evaluation systems were used to assess outcomes.
Results: For smile excursion score, the spinal accessory and masseter nerve groups showed higher scores than the cross-face nerve graft group in the first 2 years, but no difference by 3-year follow-up. For cortical adaptation stage, nearly all cross-face nerve graft patients achieved stage IV or V spontaneity, the spinal accessory nerve group achieved at least stage III (independent) movement, but individuals in the masseter nerve group achieved only stage III or less. The cross-face nerve graft group also achieved higher scores according to the Hadlock system and the Terzis evaluation system compared with the other two groups.
Conclusions: The concept of "sugarcane chewing" where the sweetness is the least at the tail but the most at the head can be simply applied for surgeons and patients in weighing the benefits and drawbacks during the motor neurotizer selection. Cross-face nerve graft–innervated gracilis is analogous to chewing sugarcane from tail to head; despite lower outcome measures earlier, it yields the highest scores at 3 years postoperatively. Masseter-innervated gracilis is akin to chewing sugarcane from head to tail, with greater outcome scores initially but little improvement at longer follow-up. Spinal accessory–innervated gracilis results fall in between these two groups. *(Plast. Reconstr. Surg. 144: 252e, 2019.)*
CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, IV.

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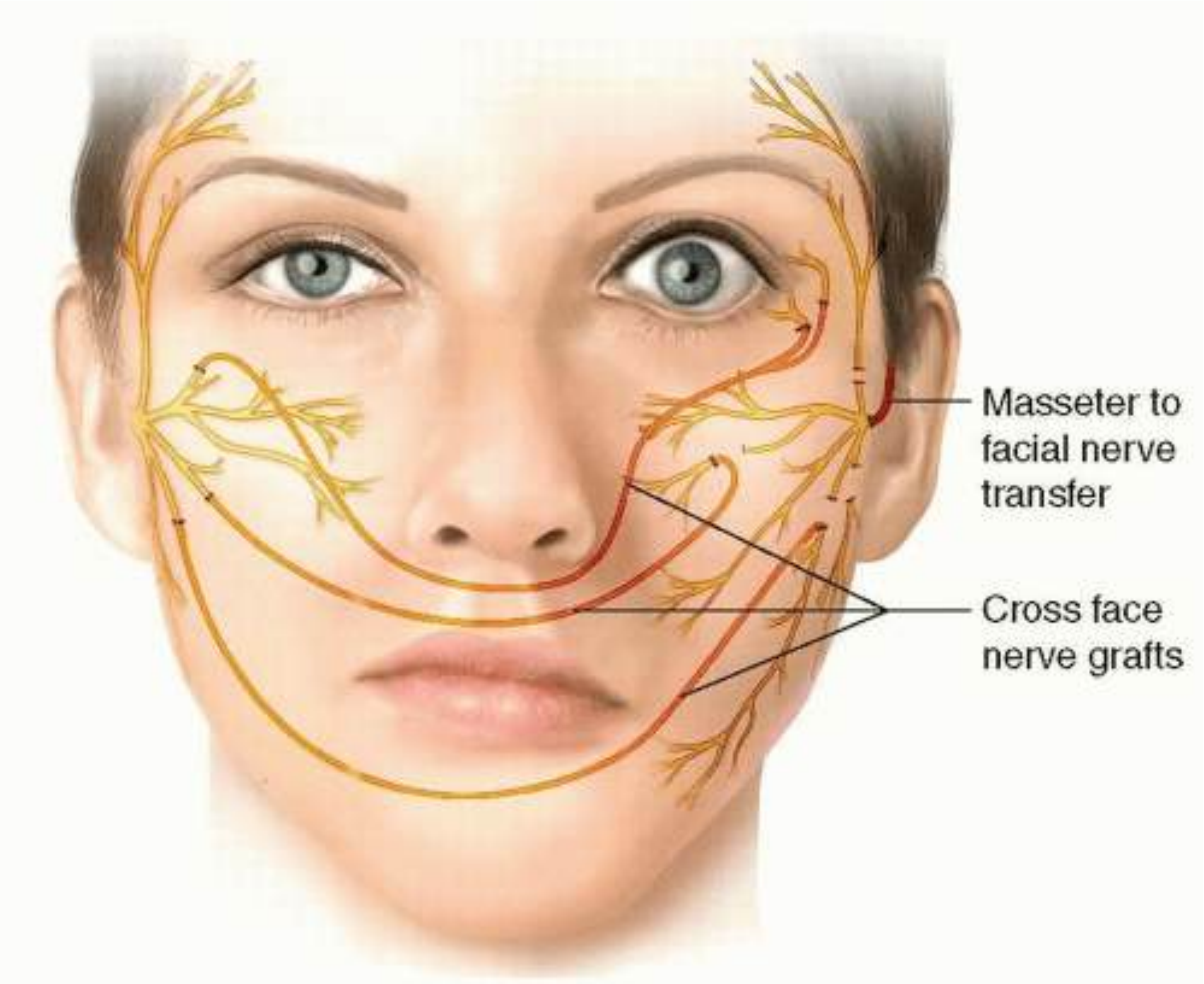
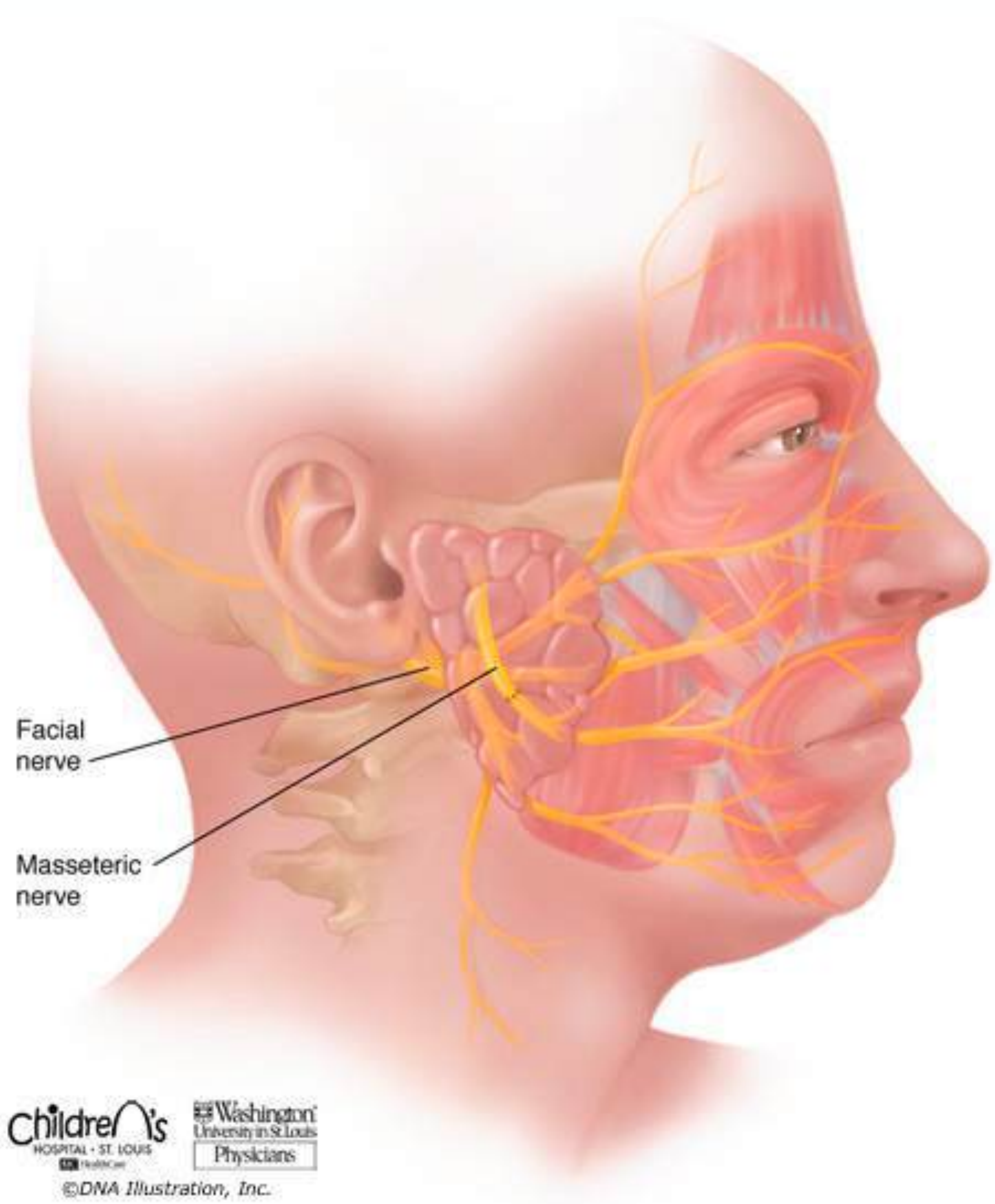
THERAPEUTIC


Masseter to facial nerve transfer
Cross face nerve grafts


Facial nerve
Masseteric nerve
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Washington University in St. Louis Physicians
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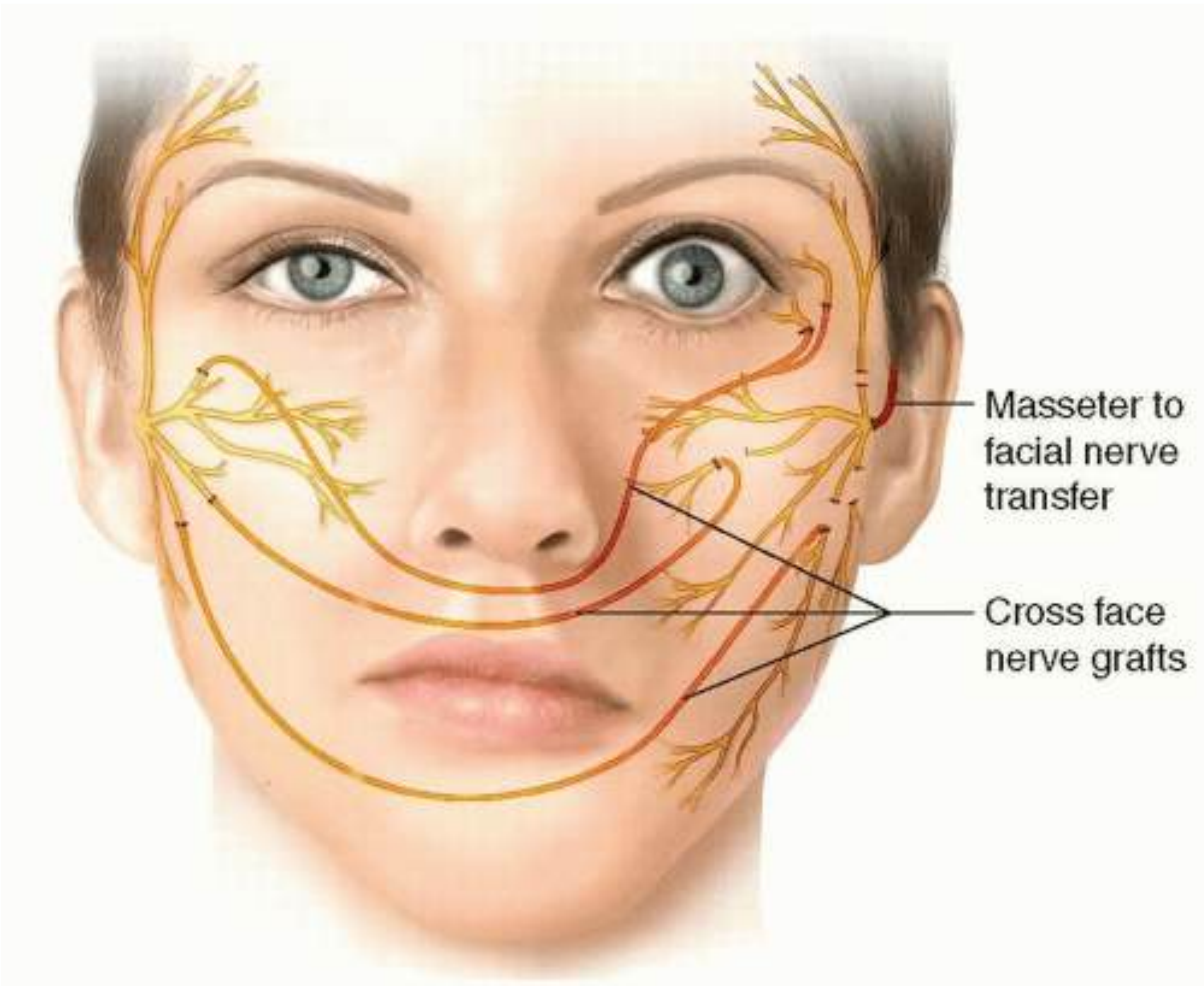
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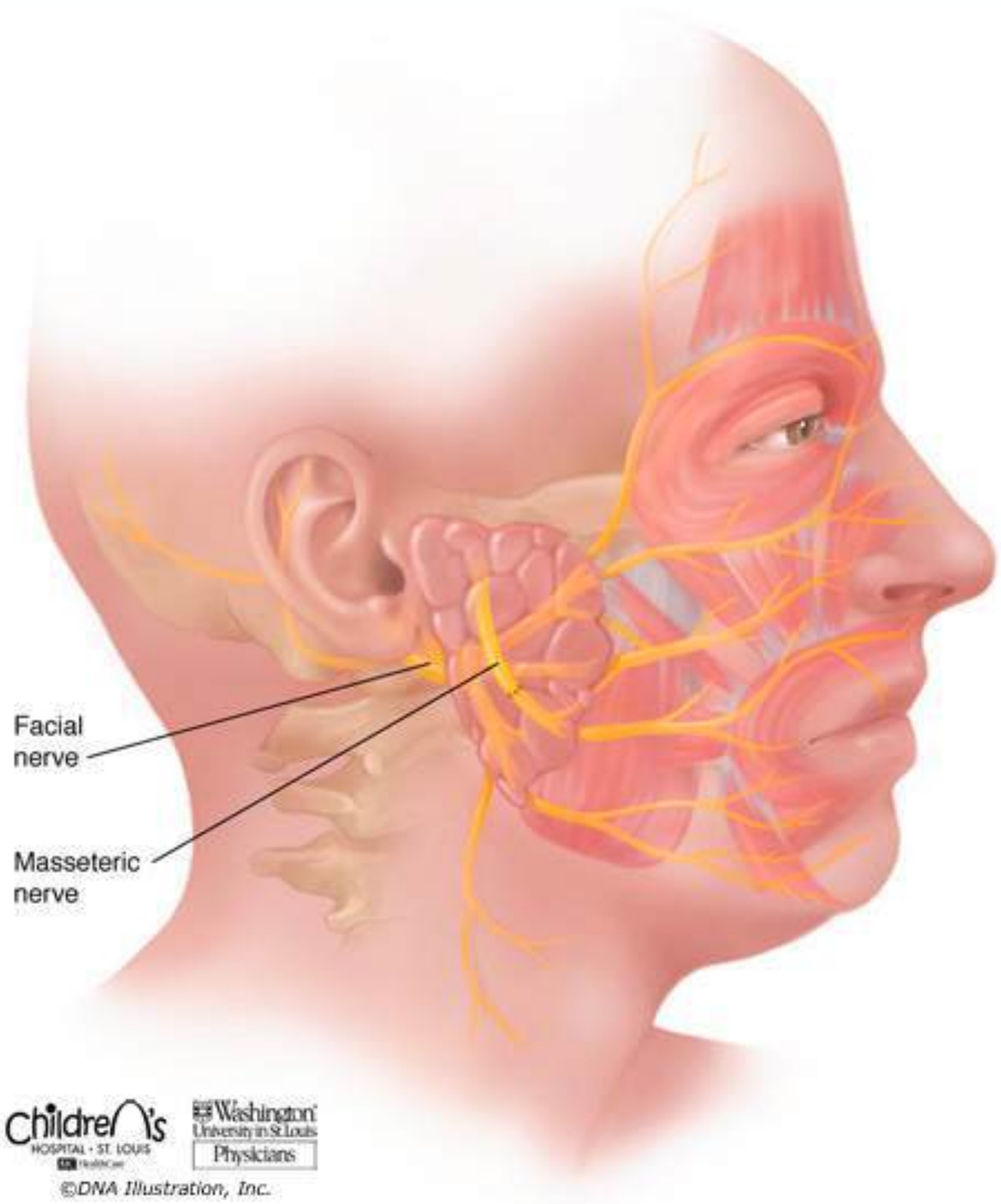
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2012 - Dual Innervation

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Double innervation in free-flap surgery for long-standing facial paralysis

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[d] C. Mondino National Institute of Neurology Foundation, IRCCS, Pavia, Italy
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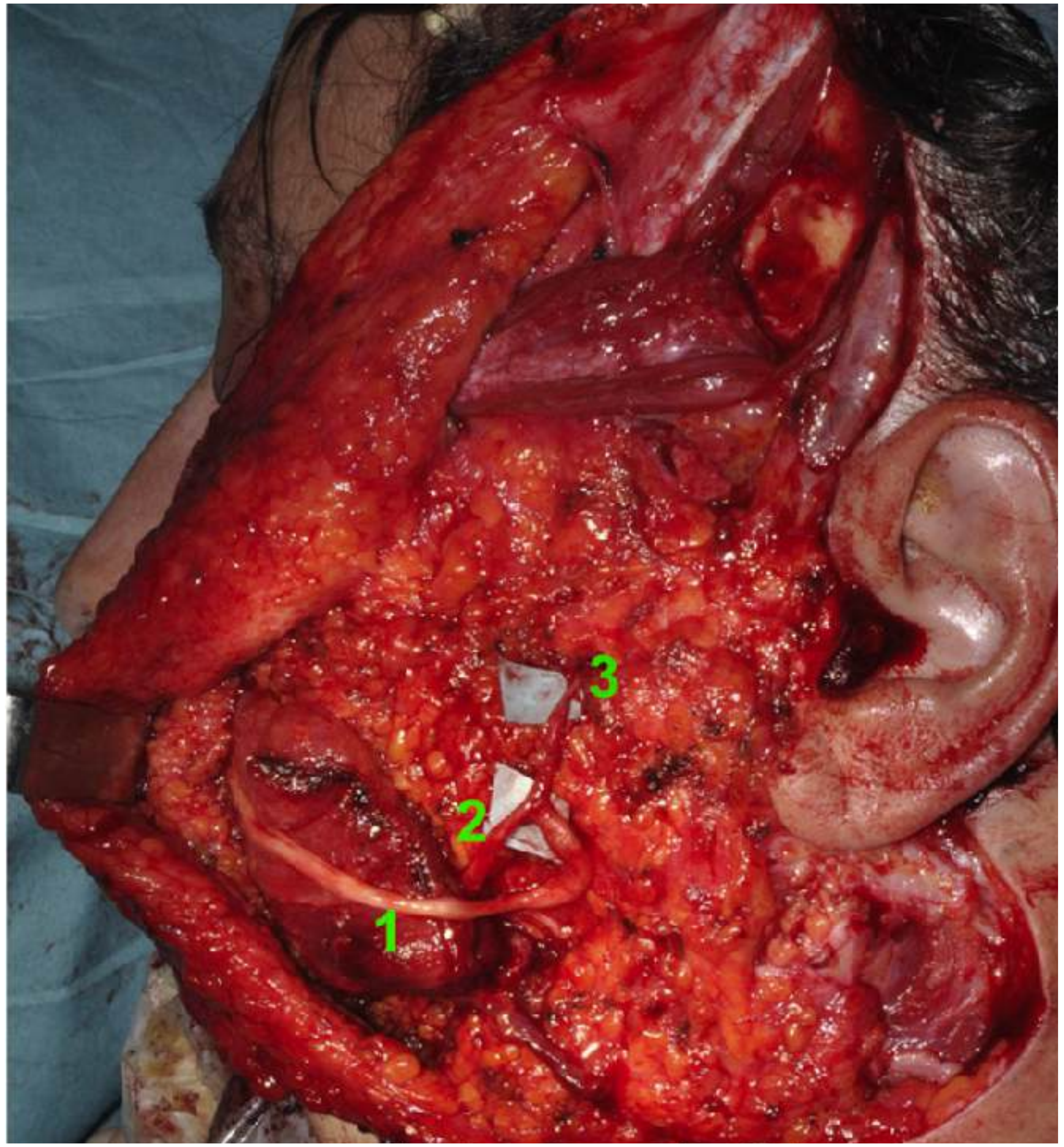
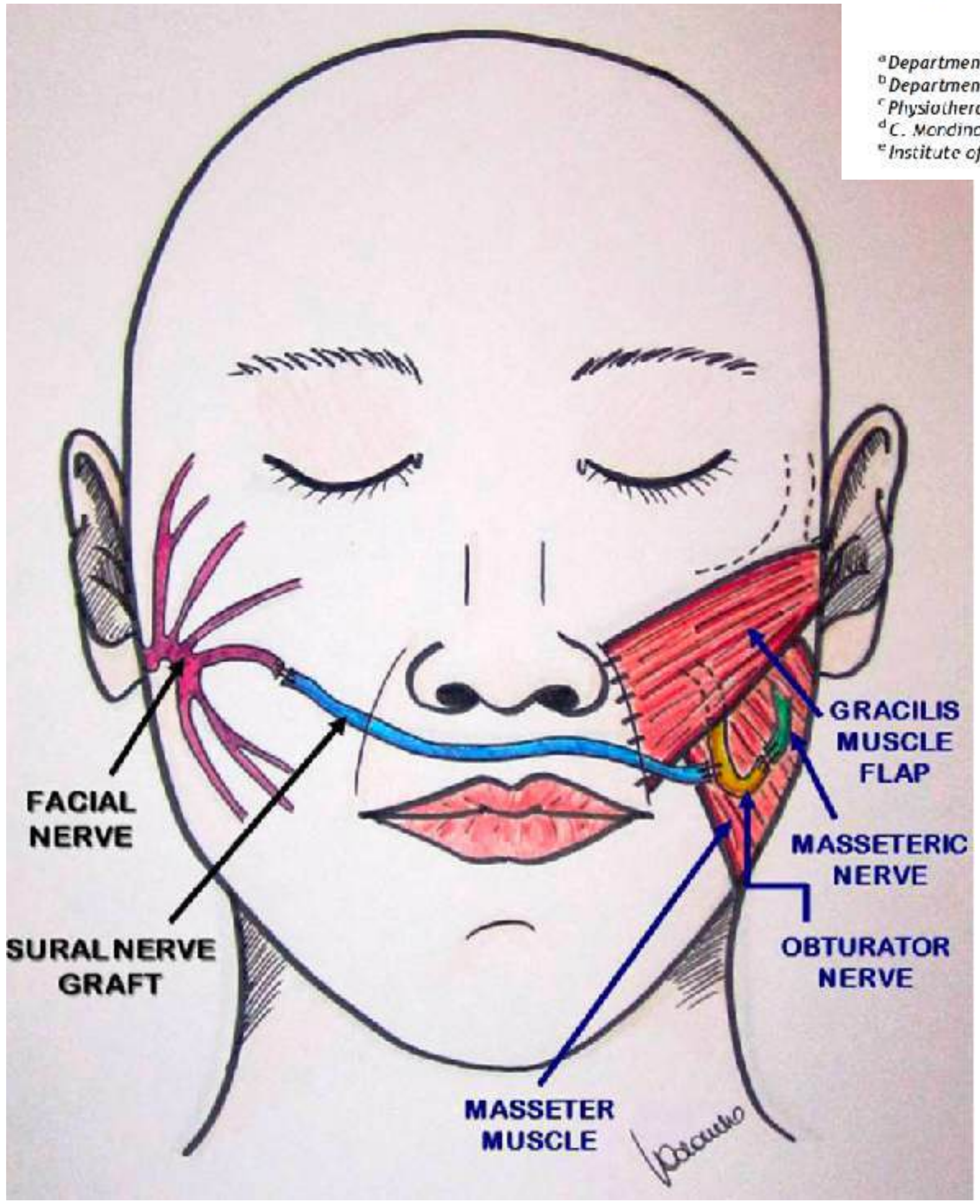
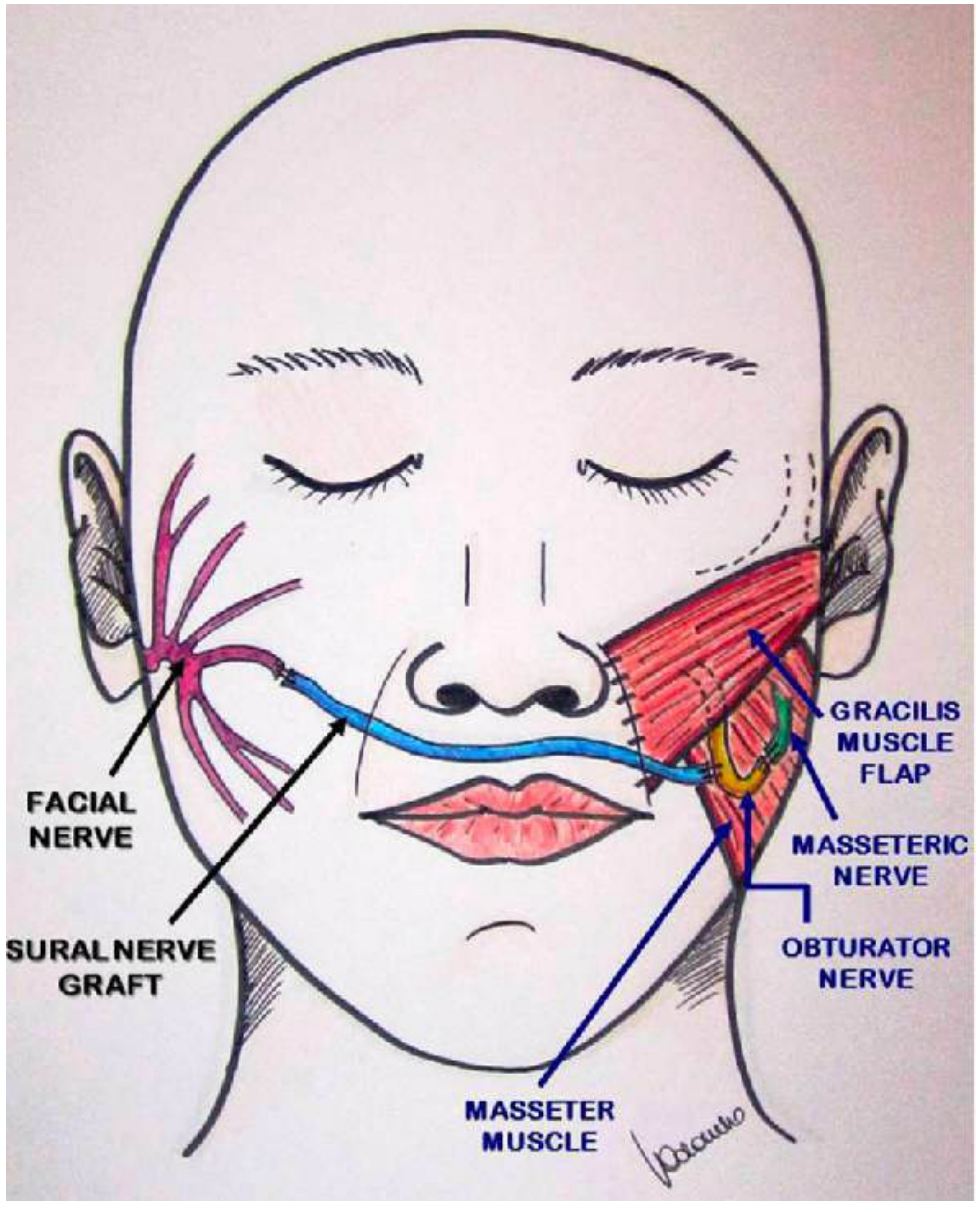
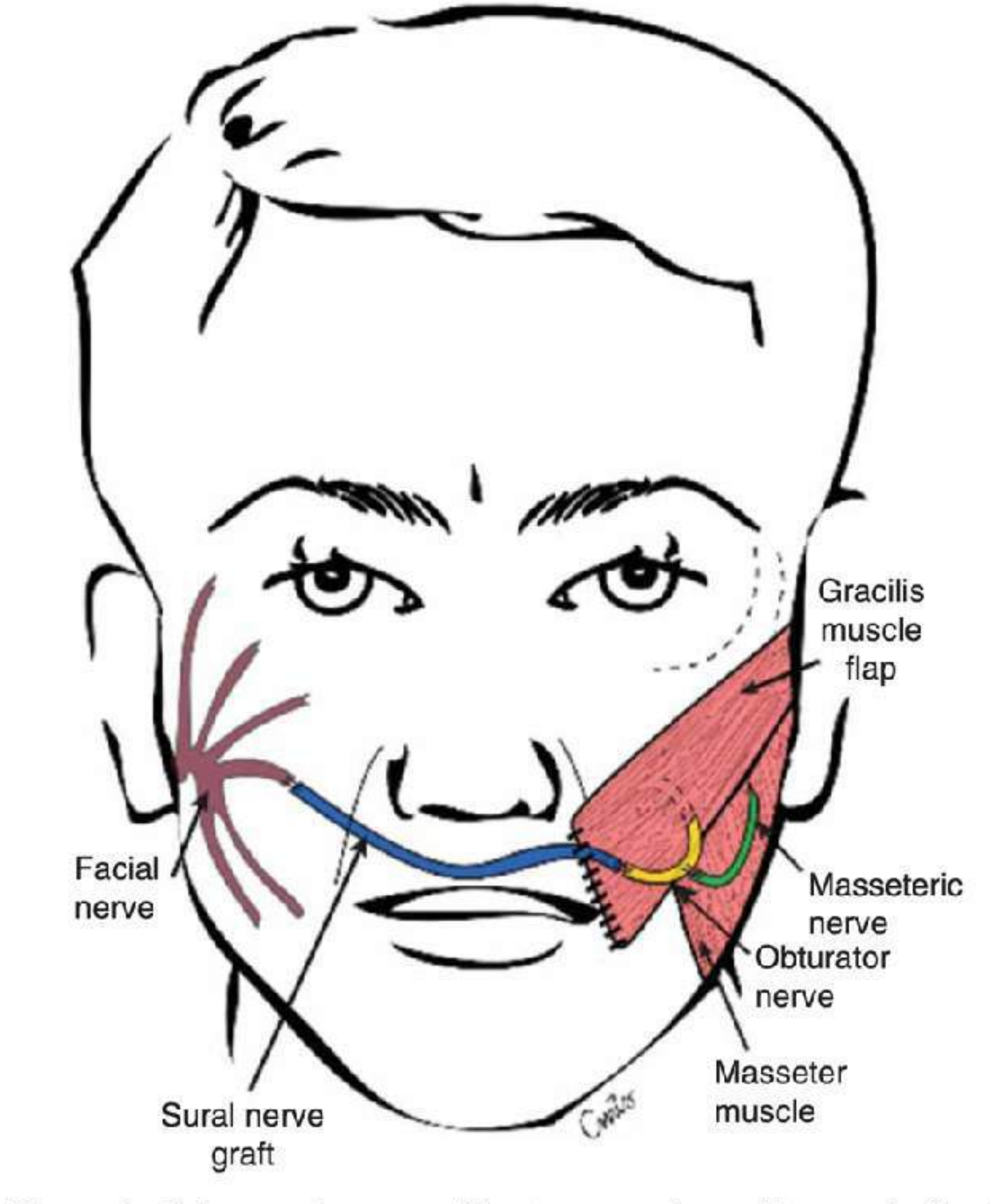




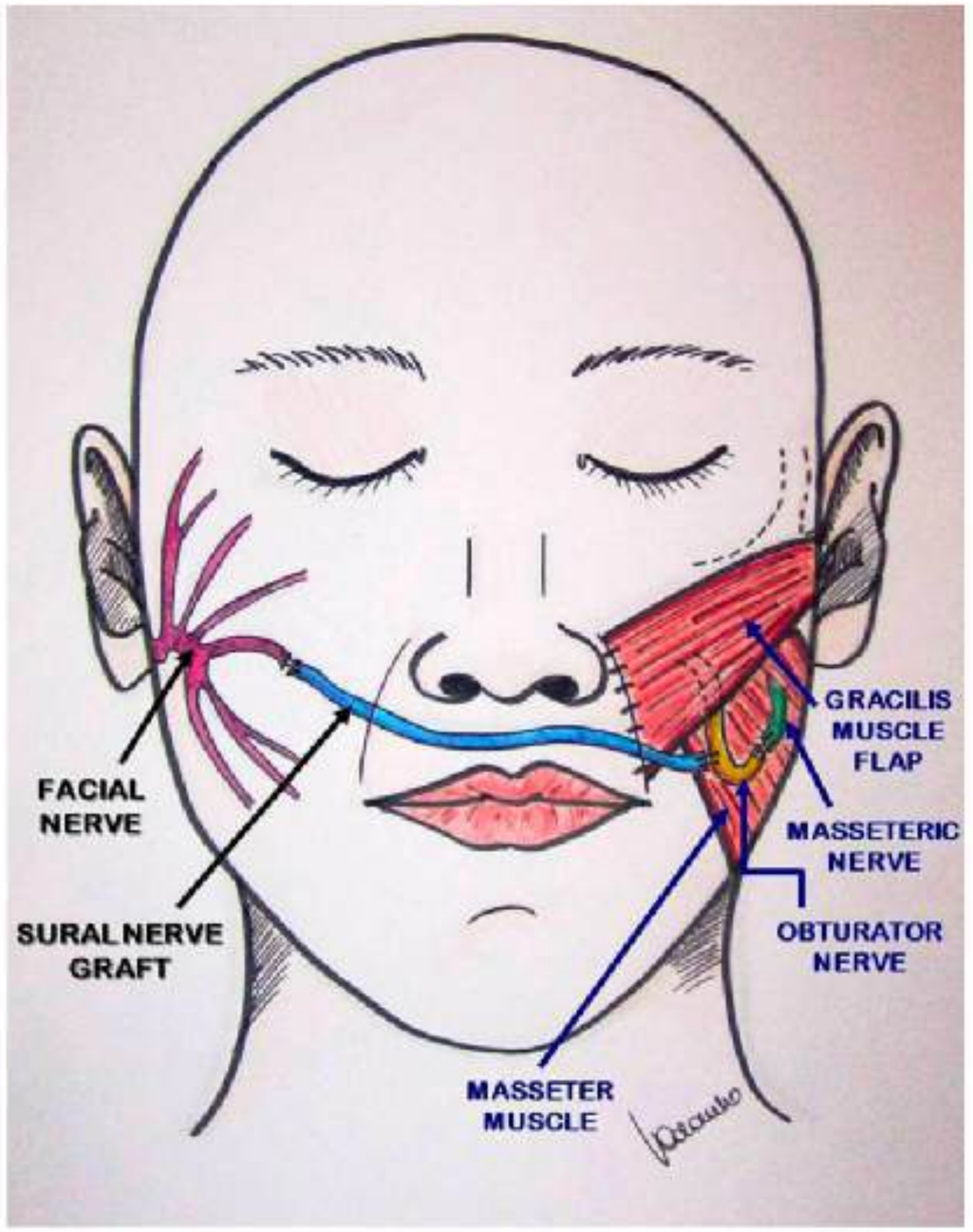
Biglioli 2012:



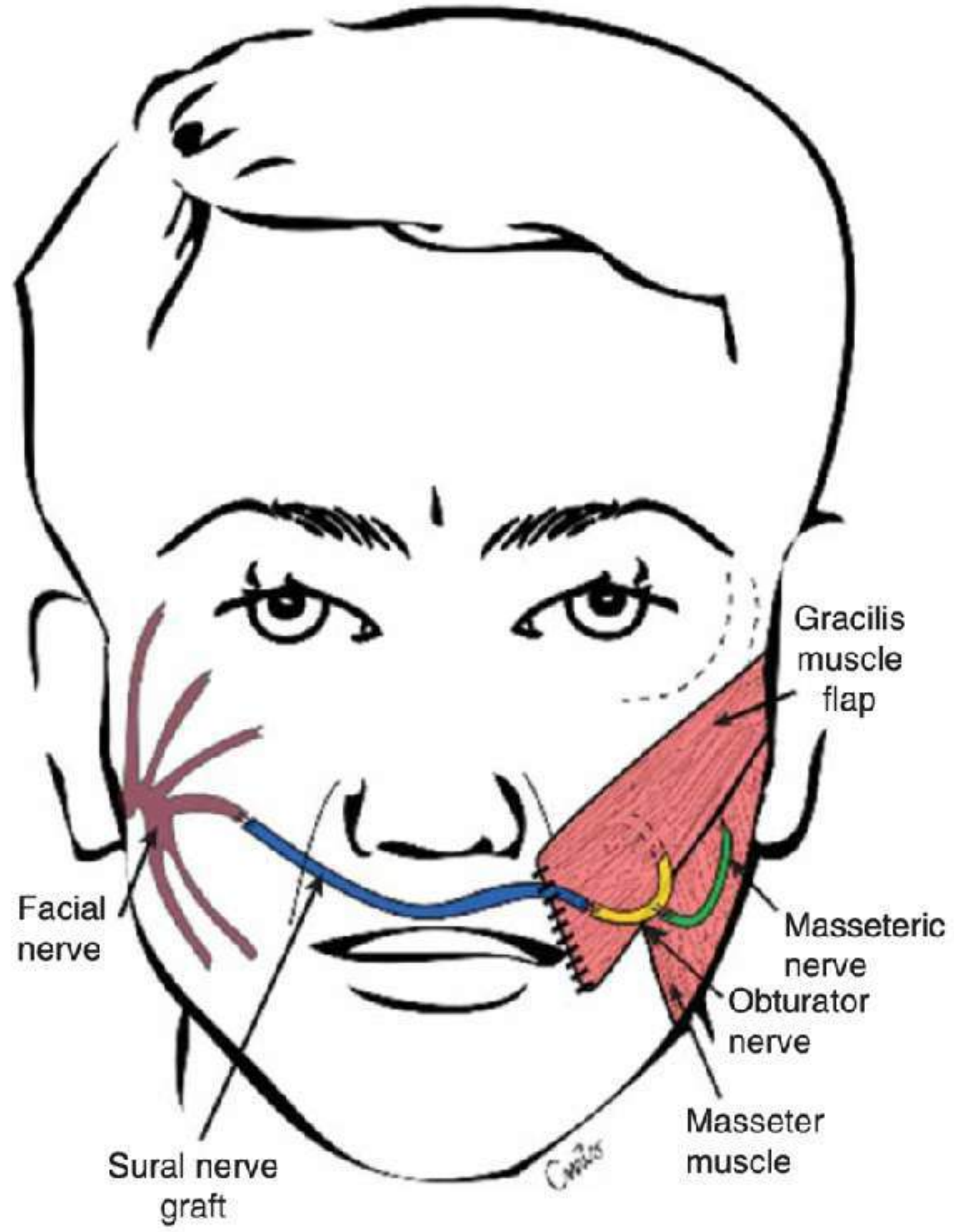
Cardenas-Meija et al. 2014:



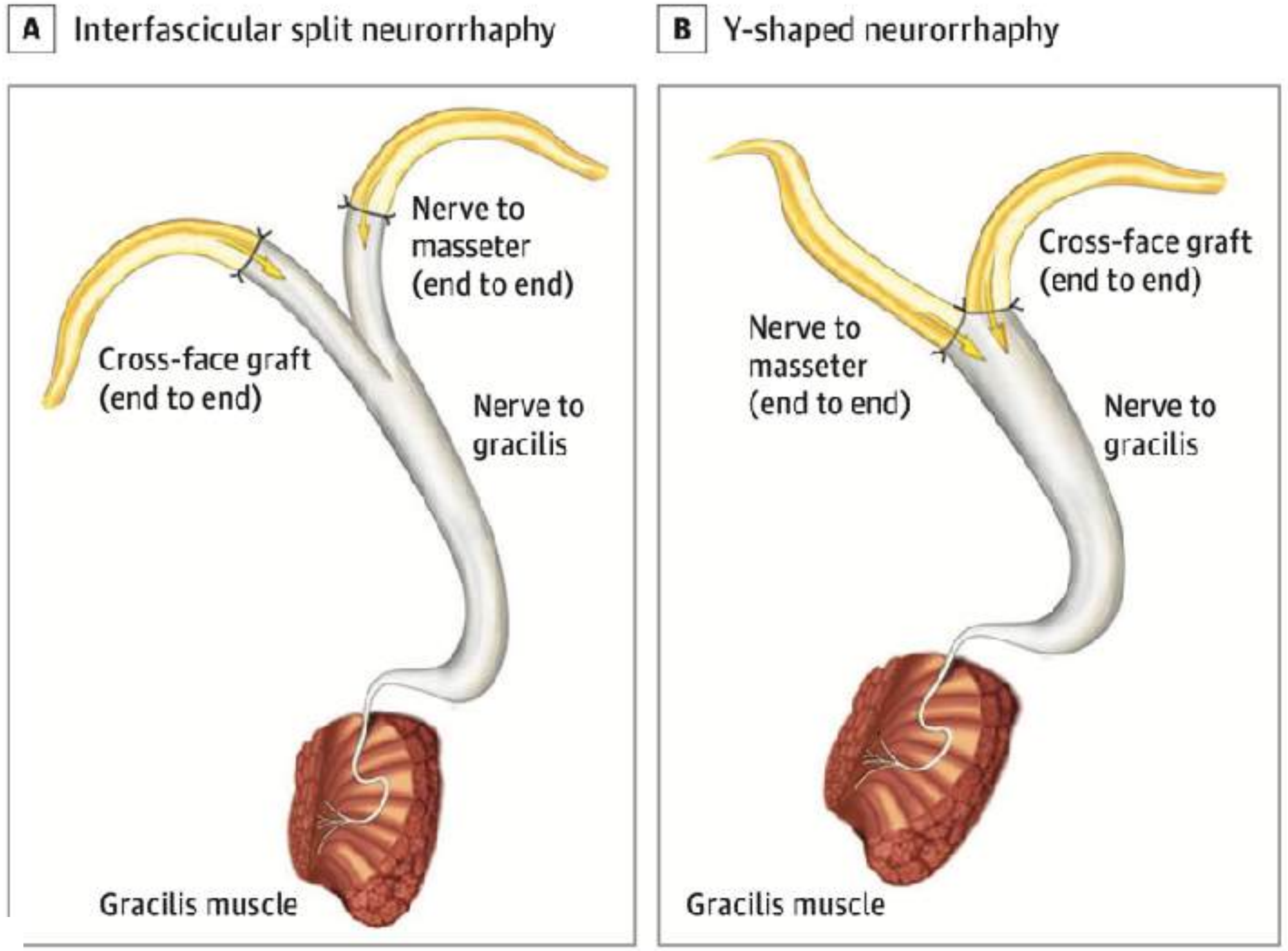
ANASTOMOTIC APPROACHES



Biglioli

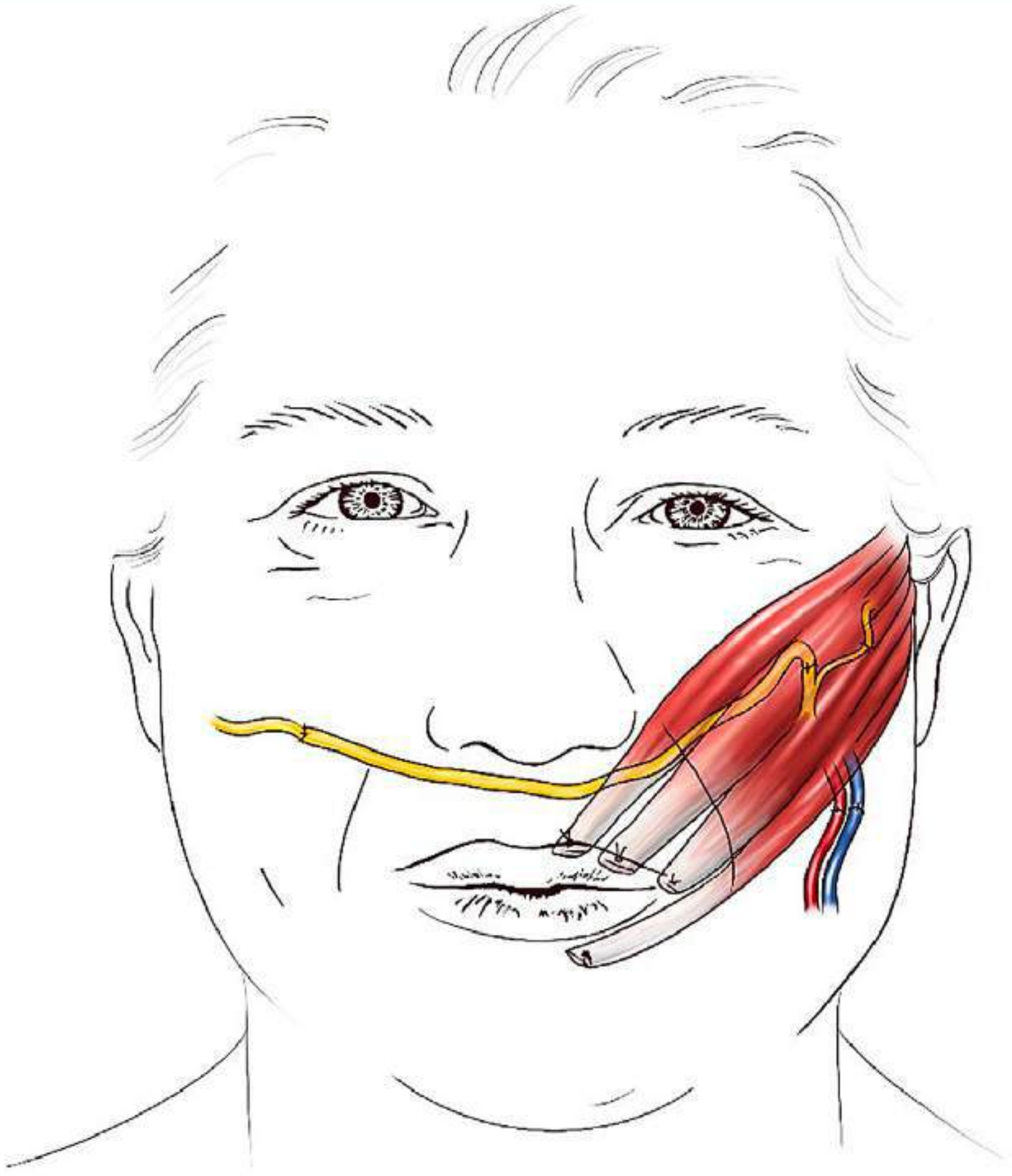


Cardenas-Mejia



Dusseldorp

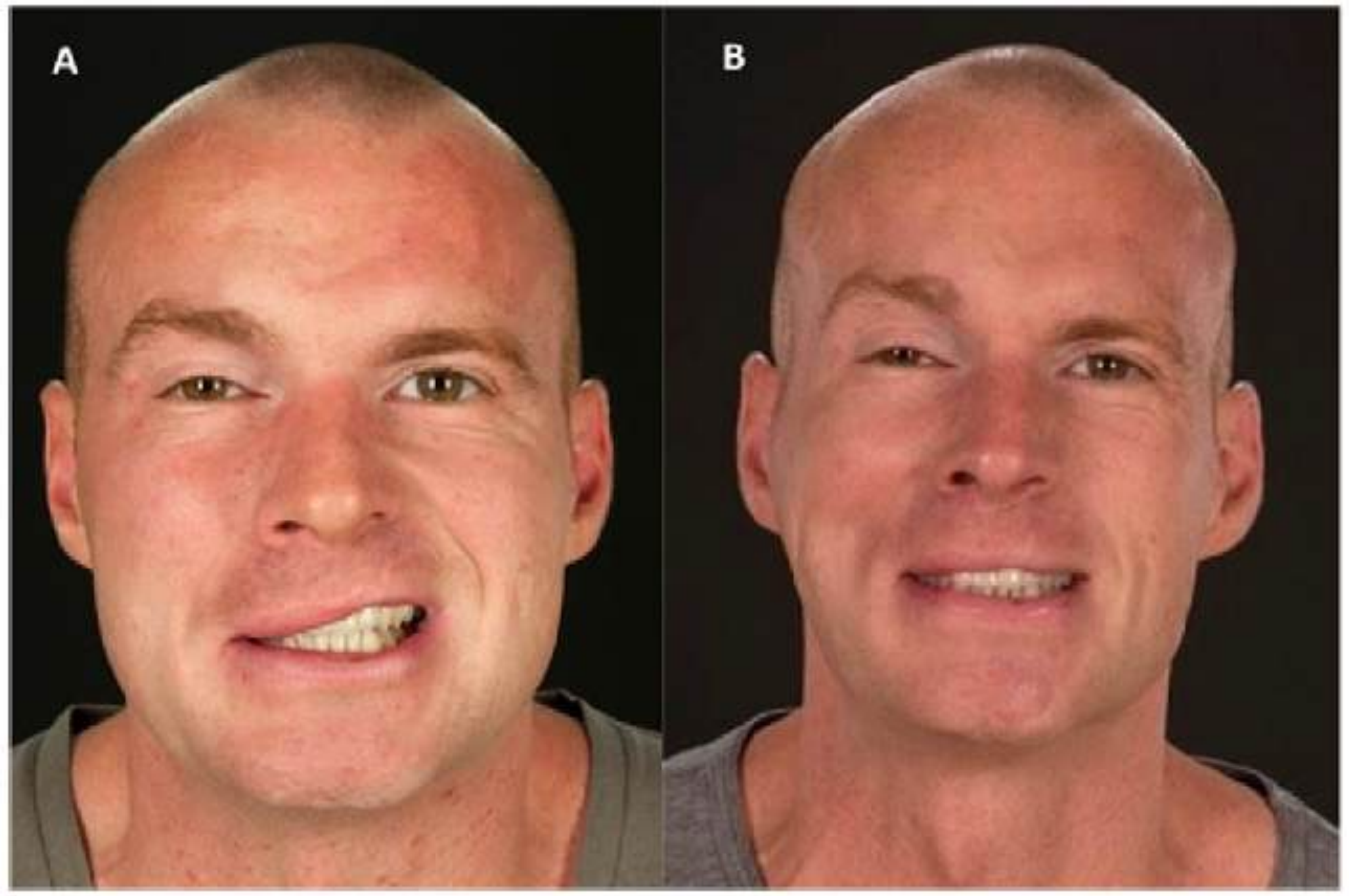
Tzafetta et al. 2021



Dr. Kallirroi Tzafetta

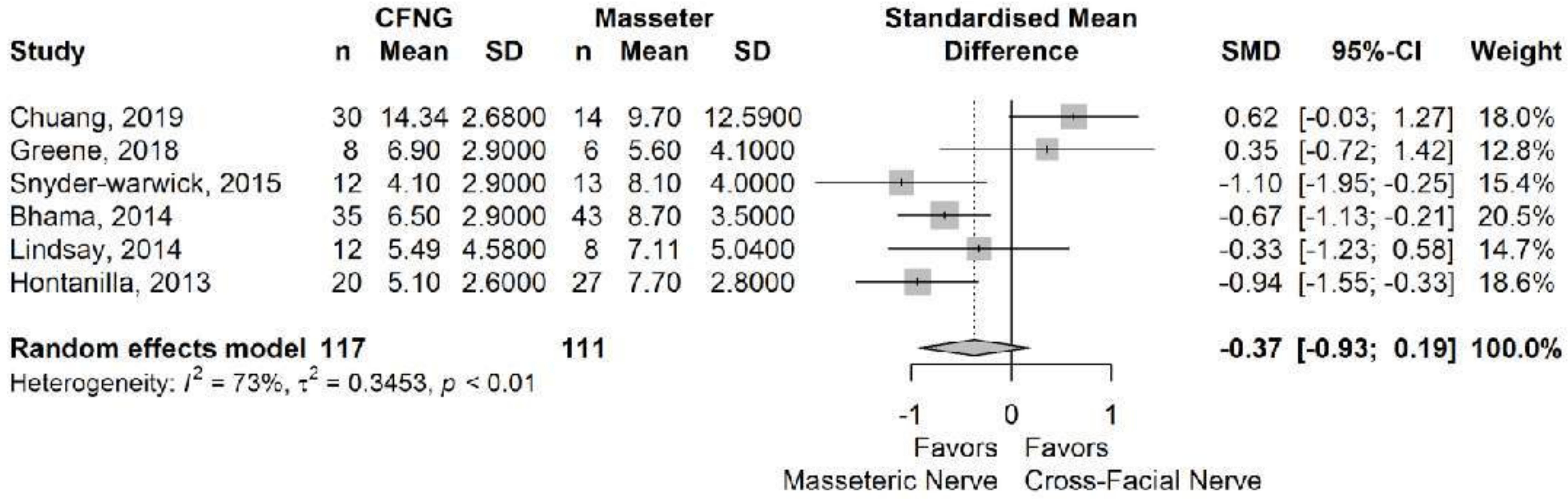
Obturator Nerve Split. One half shortening.
End-to-end anastomosis

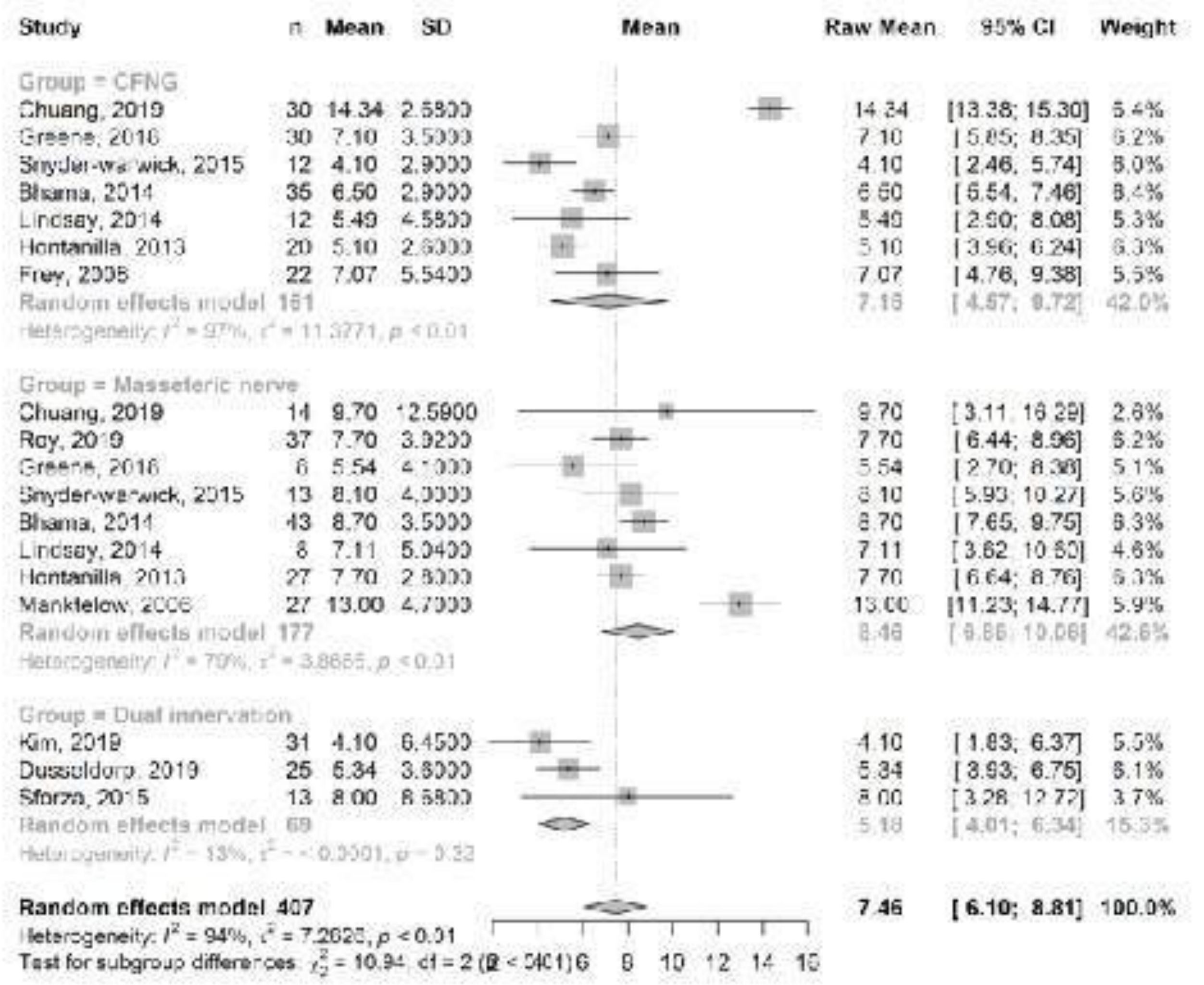
Tzafetta:



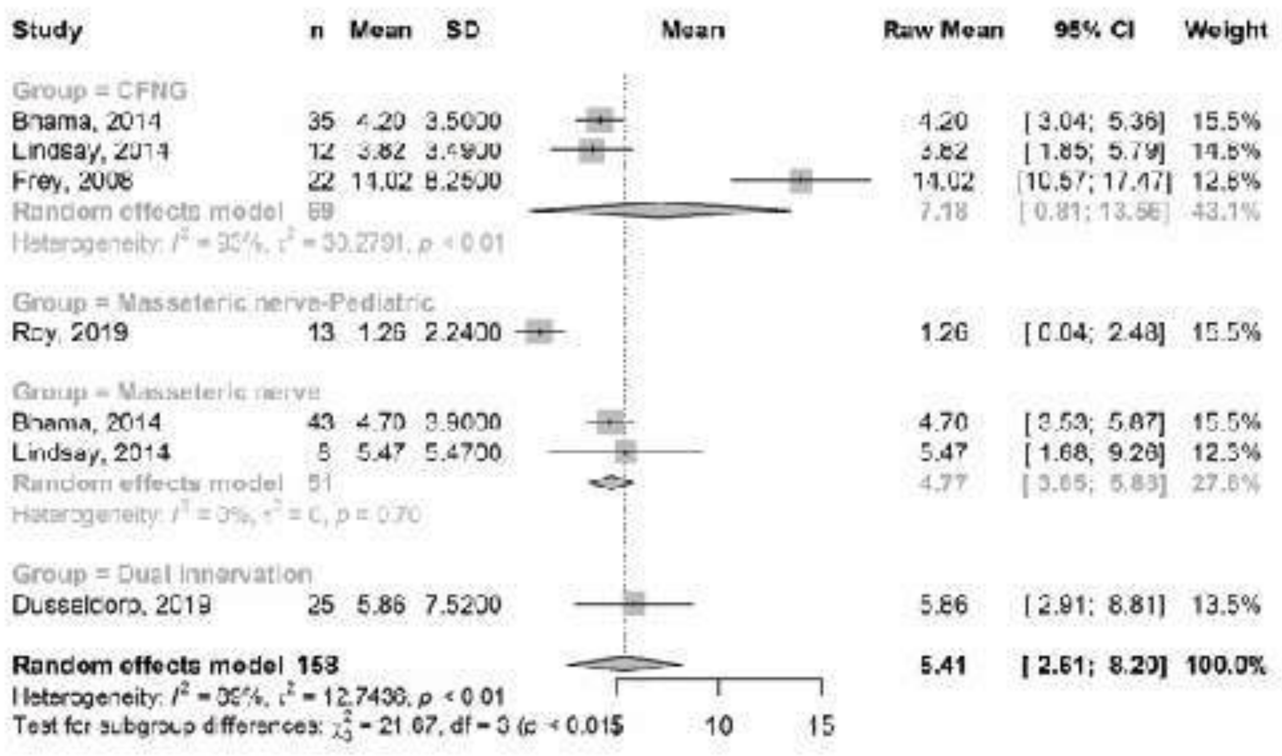
Results from Meta-Analysis

- 13 studies with 435 observations (179 CFNG, 182 masseteric nerve, 74 dual-innervation)

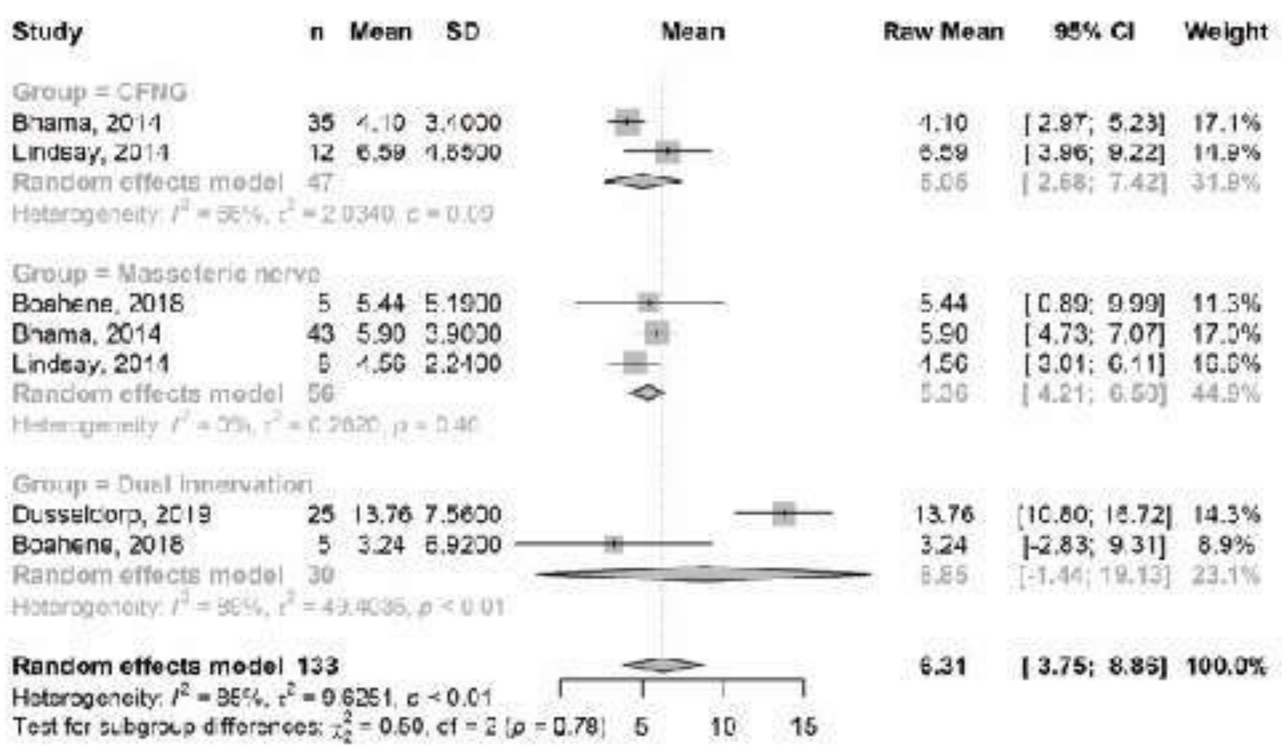




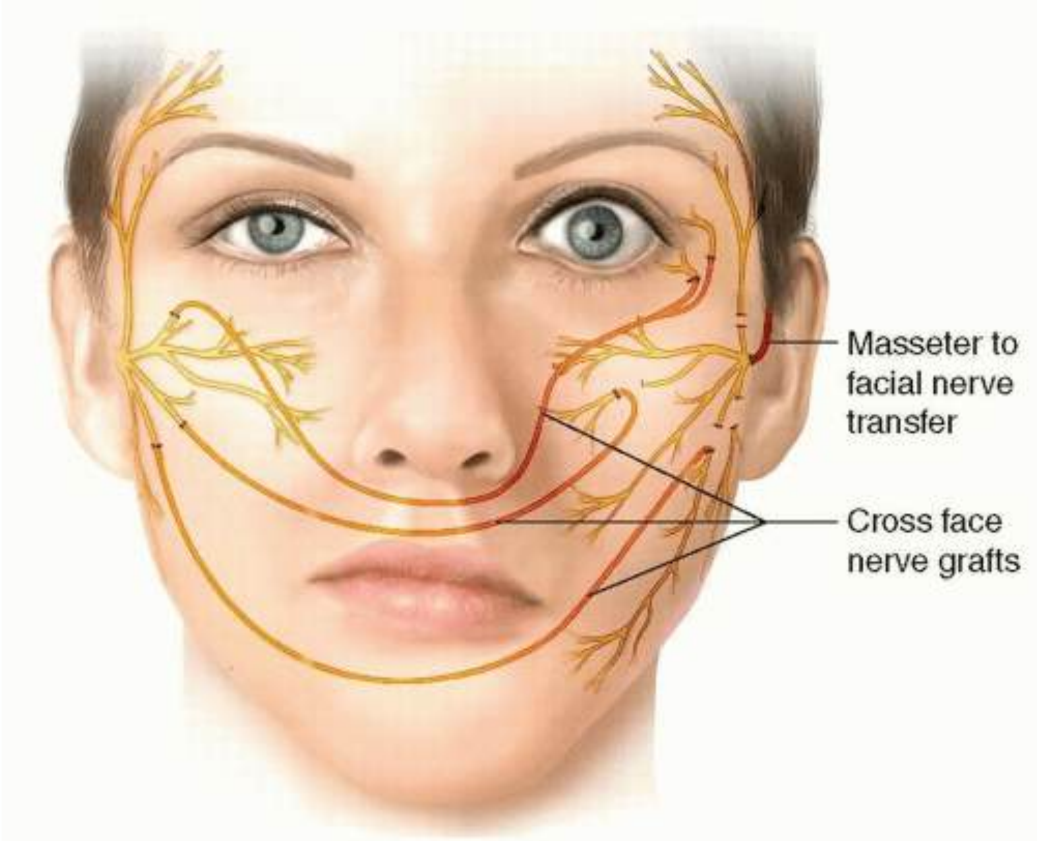
A



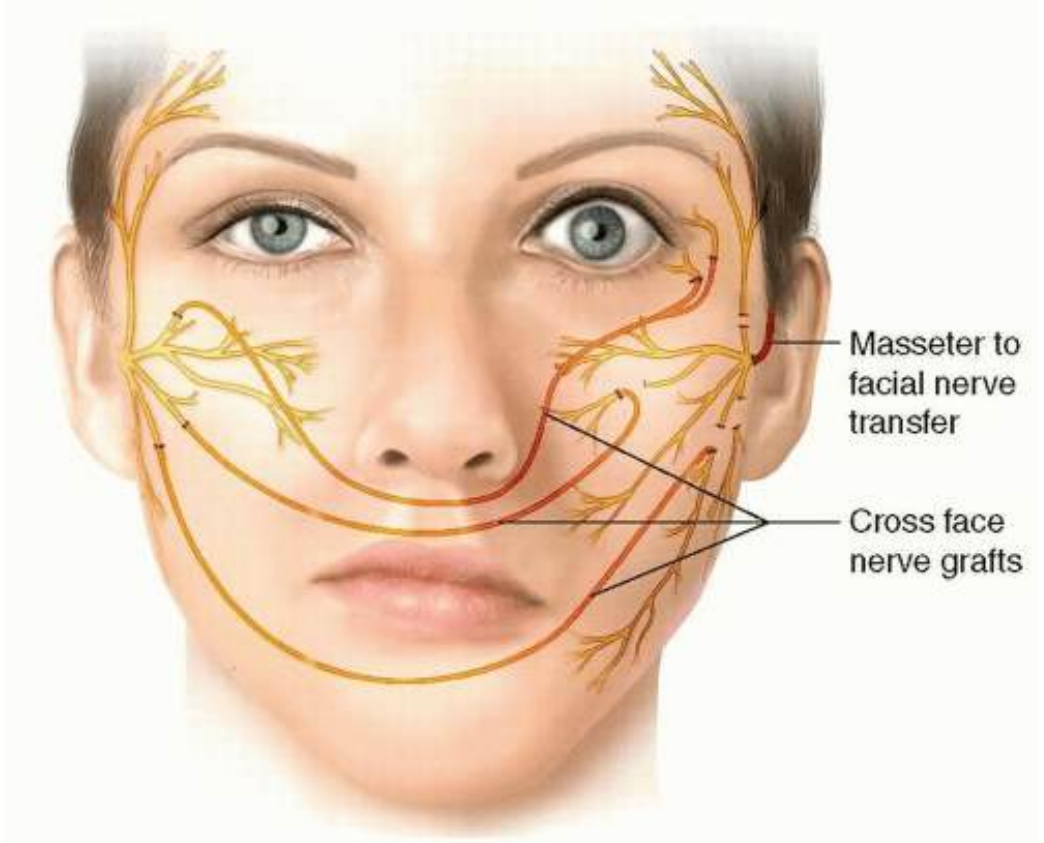
B



- **CFNG -** pediatric patients, young adults (reliable peripheral nerve regeneration)



- **Dual innervation -** older adults. Better if they are positive for co-activation (fibers from motor nerve to the masseter to warrant adequate excursion)



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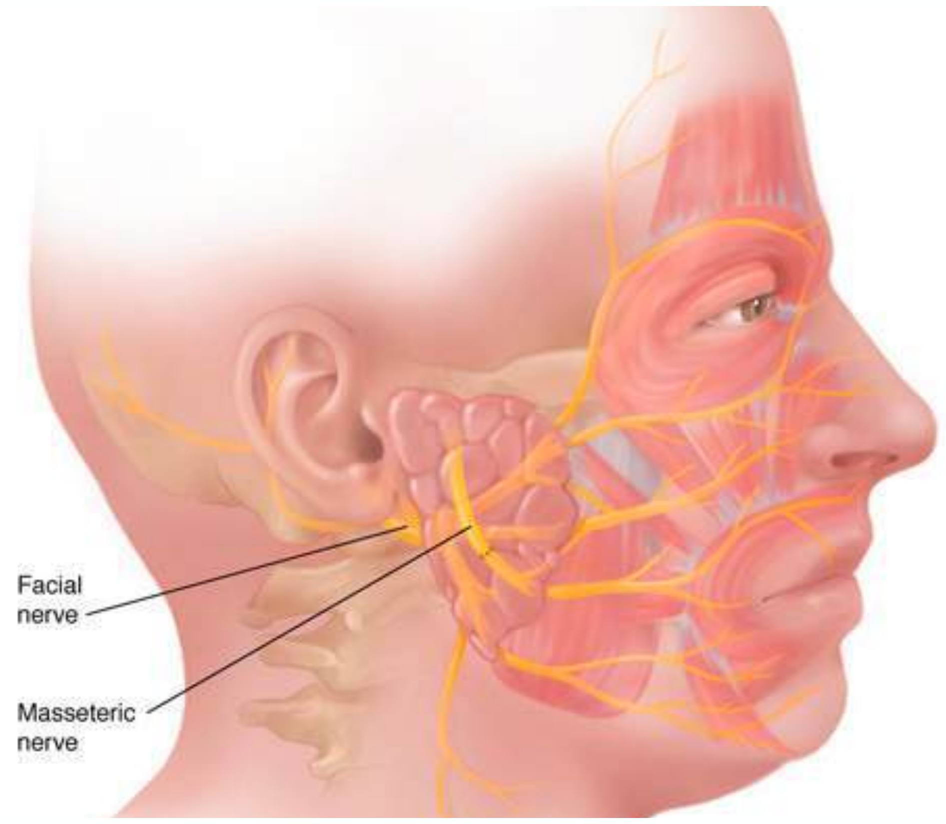
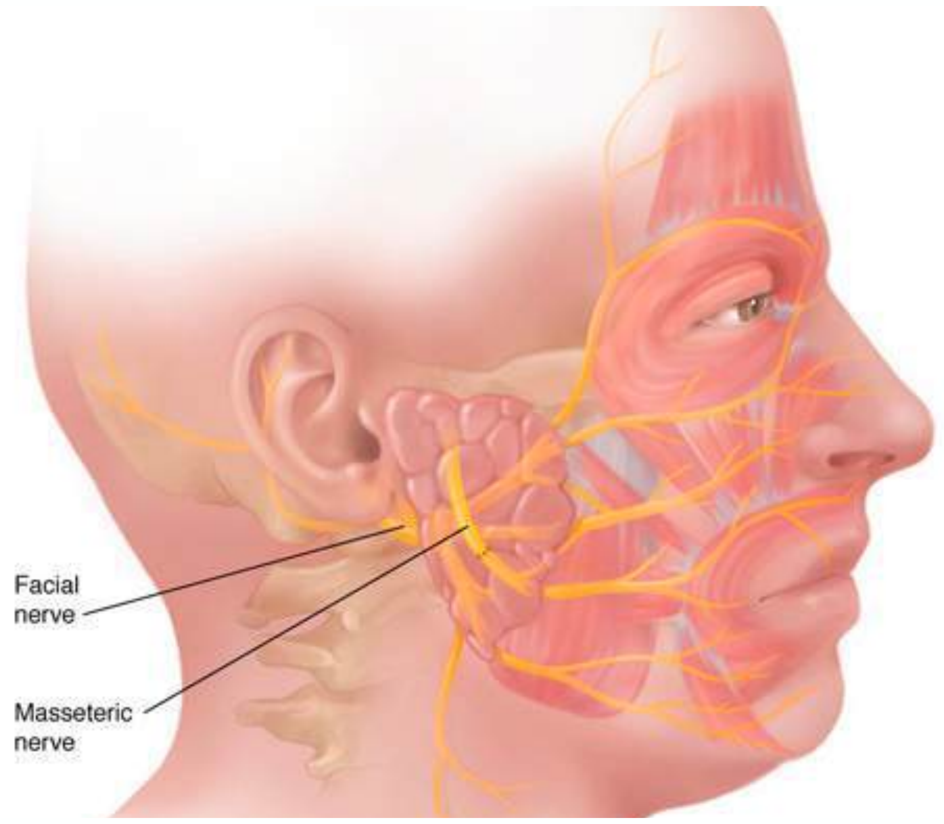


Motor nerve to the masseter - bilateral palsy, Moebius syndrome



Thank You