37. Facial Reanimation

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FACIAL NERVE ANATOMY

Components

- **Branchial motor:** Voluntary motor control of facial musculature
- **Visceral motor:** Parasympathetic control of lacrimal, submandibular, and sublingual glands
- **General sensory:** Innervation of the external auditory canal
- **Special sensory:** Taste in anterior two thirds of the tongue

Three Segments

1. Intracranial

- Facial nucleus cell bodies that give rise to the **frontal branch** receive bilateral cortical input.
- All other facial nucleus cell bodies receive contralateral cortical input.

TIP: Ipsilateral supranuclear lesions give contralateral facial paralysis but maintain frontalis function.

2. Intratemporal

- Facial nerve enters the internal auditory canal and travels with the acoustic and vestibular nerves for approximately 8-10 mm.
- Facial nerve then enters the **fallopian canal** by itself, where it travels for 30 mm.
- Fallopian canal has **three segments** (Fig. 37-1).
  1. **Labyrinthine segment**
     - 3-5 mm long, from entrance of the fallopian canal to the geniculate ganglion
     - Narrowest segment: 1.42 mm diameter on average, nerve occupies 83% of available space
     - Greater petrosal nerve: First branch of facial nerve, from geniculate ganglion, supplies parasympathetic nerves for lacrimal gland
     - Junction of labyrinthine and tympanic segments formed by an acute angle: Shearing occurs commonly

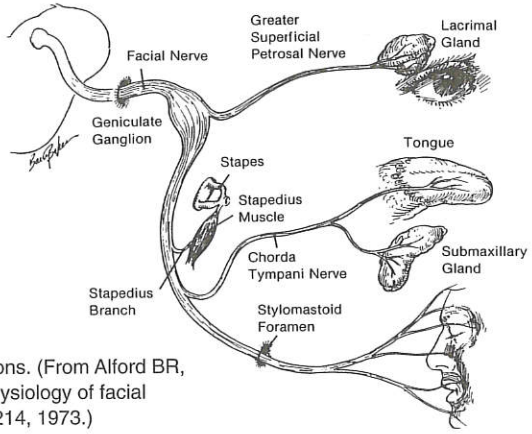

Fig. 37-1 Facial nerve main divisions. (From Alford BR, Jerger JF, Coats AC, et al. Neurophysiology of facial nerve testing. Arch Otolaryngol 97:214, 1973.)

2. **Tympanic segment**
   - 8-11 mm long, from geniculate ganglion to bend at lateral semicircular canal
   - Midtympanic canal is second region of fallopian canal: Narrowest cross-sectional area
3. **Mastoid segment**
   - 9-12 mm long, from bend at lateral semicircular canal to stylomastoid foramen
   - Widest cross-sectional area
   - **Three nerve branches**
     - Nerve to stapedius: Motor function for stapedius muscle, allows for dampening of loud sounds; cell bodies of this motor nerve not located in facial nucleus, therefore not affected by Möbius' syndrome
     - Sensory branch to external auditory canal: *Hitselberger's sign:* Hypesthesia of external auditory canal
     - Chorda tympani: Final intratemporal branch, joins lingual nerve to provide parasympathetic innervation to submandibular and sublingual glands; special sensory afferents from anterior two thirds of the tongue travel with chorda tympani

TIP: In children, the ratio of facial nerve diameter to fallopian canal diameter is less than in adults, which decreases the likelihood of facial nerve entrapment.

The facial nerve in the fallopian canal lacks sufficient identifiable topographic orientation to be clinically useful in selective fascicular nerve grafting.

3. **Extratemporal**
- Starts where facial nerve exits **stylomastoid foramen;** nerve is protected by mastoid tip, tympanic ring, and mandibular ramus
- **Nerve is superficial in children less than 2 years old**
- Travels along a course anterior to the posterior belly of the digastric muscle and along the styloid process to the posterior edge of the parotid gland
- Facial nerve trunk 1 cm deep, just inferior and medial to the tragal pointer
- Provides motor branches to the posterior belly of the digastric, stylohyoid, superior and posterior auricular muscles, and the occipitalis muscles
- Interconnections between extratemporal facial nerve and trigeminal, glossopharyngeal, vagus, spinal accessory, hypoglossal, and nearby parasympathetic and sympathetic nerves
- **Arborization begins in substance of parotid gland**
  - Nerve first divides into superior and inferior divisions that ultimately give rise to **frontal, zygomatic, buccal, mandibular,** and **cervical branches.**
    - Davis dissected 350 cadaveric halves and identified six branching patterns (Fig. 37-2).[1]
    - Baker and Conley[2] studied 2000 parotidectomies and found facial nerve trunk trifurcation, sometimes with direct buccal branch; the zygomatic was most robust, and the marginal mandibular was the smallest.
    - Frontal branch of nerve is the terminal branch of superior division.
    - Cervical and marginal mandibular branches derive from an inferior division.
    - Buccal branch always receives some innervation from inferior division and occasionally from superior division.
    - Connections exist between major facial nerve divisions in 70%-90% of patients, *except for the frontal and marginal mandibular branches.*
    - Nerves lie just deep to the subcutaneous musculoaponeurotic system (SMAS) layer.

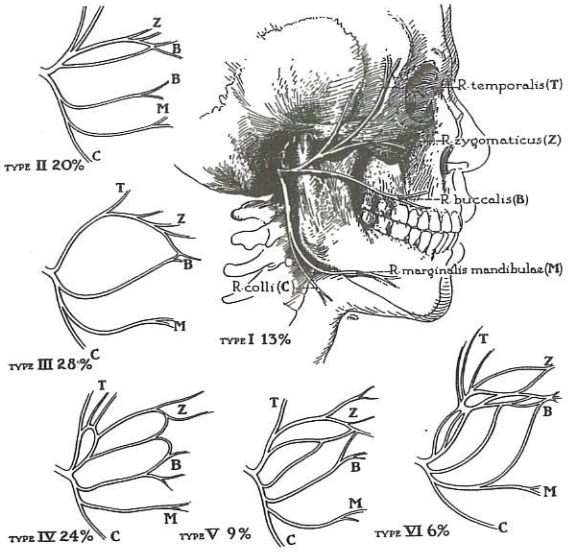

Fig. 37-2 Facial nerve branching patterns. (From Davis RA, Anson BJ, Budinger JM, et al. Surgical anatomy of the facial nerve and parotid gland based upon a study of 350 cervicofacial halves. Surg Gynecol Obstet 102:385, 1956.)

Frontal Branch Anatomy

- Frontal branch has consistent course from 0.5 cm below tragus to 1.5 cm above the lateral brow.[3]
- Frontal branch lies within temporoparietal fascia.[4]
- Frontal nerve and superficial temporal artery reside in deep aspects of temporoparietal fascia and the most posterior rami of frontal branch; may be either anterior or posterior to superficial temporal artery.[5]
  - At level of zygomatic arch, frontal branch arborizes into two to four branches.

Marginal Mandibular Anatomy (Fig. 37-3)

- Marginal mandibular is connected to other rami in only 15% of cases.[2]
- Marginal mandibular branch, posterior to facial artery, is located above inferior border of mandible in 81% of cases and below in 19%, and it is above inferior border in 100% of cases if anterior to facial artery.[6]

Facial Musculature (Fig. 37-4, Table 37-1)

- Orbicularis oris and 23 other paired muscles
- **Four layers**[7]
  - Layer 1: Depressor anguli oris, zygomaticus minor, orbicularis oculi
  - Layer 2: Depressor labii inferioris, risorius, platysma, zygomaticus major, levator labii superioris alaeque nasi
  - Layer 3: Orbicularis oris, levator labii superioris
  - Layer 4: Mentalis, levator anguli oris, buccinator

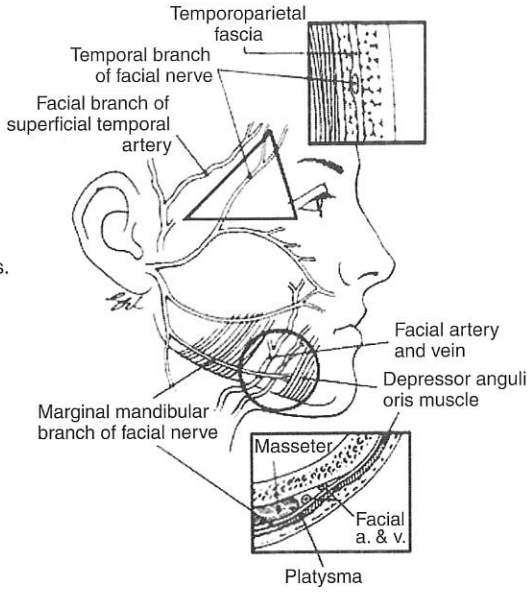

Fig. 37-3 Facial danger zones.

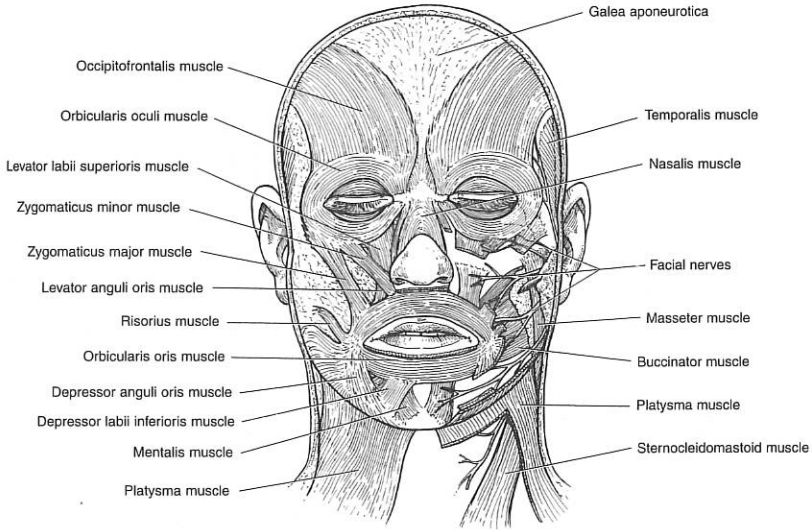

Fig. 37-4 Muscles of the face.

Table 37-1 *Muscle Groups of the Face*

Muscle	Facial Nerve Branch	Action
Corrugator supercilii	Temporal	Moves eyebrow medially and downward
Procerus	Temporal	Moves medial eyebrow downward
Orbicularis oculi	Temporal and zygomatic	Closes eyelids and contracts skin around eye
Zygomaticus major	Zygomatic and buccal	Elevates corner of mouth
Zygomaticus minor	Buccal	Elevates upper lip
Levator labii superioris	Buccal	Elevates upper lip and midportion of nasolabial fold
Levator labii superioris alaeque nasi	Buccal	Elevates medial nasolabial fold and nasal ala
Risorius	Buccal	Aids smile with lateral pull
Buccinator	Buccal	Pulls corner of mouth backward and compresses cheek
Levator anguli oris	Buccal	Pulls angles of mouth upward and medially
Orbicularis oris	Buccal	Closes and compresses lips
Nasalis, dilator	Buccal	Flares nostrils
Nasalis, compressor	Buccal	Compresses nostrils
Depressor anguli oris	Buccal and marginal mandibular	Pulls corner of mouth downward
Depressor labii inferioris	Marginal mandibular	Pulls down lower lip
Mentalis	Marginal mandibular	Pulls skin of chin upward
Platysma	Cervical	Pulls down corner of mouth

From May M, Schaitkin BM. The Facial Nerve, 2nd ed. New York: Thieme Medical, 2000.

TIP: **Layer 4** muscles are innervated on their **superficial** surface; all other muscles receive innervation from their deep surfaces.

- Subtle movements of normal expression require a delicate balance among all the muscles. However, a few muscles create clinically significant movements that are important when evaluating facial paralysis.
  - **Frontalis:** Raises eyebrows
  - **Orbicularis oculi:** Closes eyelids
  - **Zygomaticus major and minor:** Smiling
  - **Orbicularis oris:** Purses the lips
  - **Lower lip depressor:** Keeps lip from riding up during chewing

DIFFERENTIAL DIAGNOSIS OF FACIAL PARALYSIS

INTRACRANIAL

- Vascular abnormalities, aneurysms
- Central nervous system degenerative disorders
- Tumors of the intracranial cavity
- Trauma to the brain
- Congenital abnormalities and agenesis

INTRATEMPORAL

- Bacterial and viral infections
- Cholesteatoma
- Trauma: Temporal bone fractures, penetrating trauma
- Bell's palsy
- Systemic conditions: Diabetes mellitus, HIV infection

EXTRATEMPORAL

- Malignant parotid tumors
- Trauma: Particularly penetrating
- Primary tumors of the facial nerve
- Malignant tumors of ascending ramus of mandible, pterygoid, and skin

UNILATERAL FACIAL PARALYSIS

BELL'S PALSY[8]

- Idiopathic facial paralysis (Table 37-2)
- Accounts for 85% of all cases of facial paralysis

Table 37-2 *Findings That Rule Out Bell's Palsy*

Symptom/Finding	Diagnosis	Frequency Exclusive of Bell's Palsy
Simultaneous bilateral facial palsy	Guillain-Barré, sarcoidosis, pseudobulbar palsy, syphilis, leukemia, trauma, Wegener's granulomatosis	100%
Unilateral facial weakness slowly progressing beyond three weeks	Facial nerve neuroma, metastatic cancer, adenoid cystic carcinoma	100%
Slowly progressive unilateral facial weakness associated with facial hyperkinesis	Cholesteatoma, facial nerve neuroma	100%
No return of facial nerve function within 6 months after abrupt onset of palsy	Facial nerve neuroma, adenoid cystic carcinoma, basal cell carcinoma	100%
Ipsilateral lateral rectus palsy	Möbius' syndrome	100%
Recurrent unilateral facial palsy	Facial nerve neuroma, adenoid cystic carcinoma, meningioma	30%

From May M, Hardin WB. Facial palsy: Interpretation of neurologic findings. Laryngoscope 88:1352, 1978.

- **Most common** diagnosis in patients with facial paralysis: 15-40 of 100,000/yr
- Associated with **pregnancy:** 17.4 of 100,000/yr in women of child-bearing age versus 45 of 100,000/yr in pregnant women
- **Diagnosis of exclusion** is used to avoid misdiagnosis and delay of treatment.
- **Proposed etiology** is a viral-vascular insult to the facial nerve that causes edema of the nerve within fallopian canal, which disrupts neural microcirculation, thereby impairing conduction of neural impulses.
- *All patients begin to recover function within 6 months of paralysis and none remain totally paretic.*
- Recovery begins within 3 weeks in 85% of patients but not until 3-6 months in 15% of patients.
- 71% of patients with total facial paralysis recover completely without sequela.
- Completeness of recovery decreases with age.
- **Management**
  - Two studies document less denervation and significant improvement of facial grade at recovery if steroids are used within 24 hours.[9,10] The protocol involves prednisone, 60 mg/day for 5 days, tapering to 5 mg/day by the tenth day of treatment.

Trauma

Trauma is the **second most common cause of facial paralysis,** usually caused by temporal bone fracture, penetrating wound, or birthing injury.

- **Temporal bone fractures**
  - These are classified as **longitudinal, transverse,** or **mixed** according to the long axis of the temporal bone.
  - Facial paralysis is more likely with **transverse** fractures.
  - Repair requires midcranial fossa or translabyrinthine approach with end-to-end coaptation of the transected nerve.
- **Penetrating wounds**
  - In general, lacerations medial to the lateral canthus do not require repair because of nerve arborization.
  - Repair should be performed **within 72 hours** to allow identification of distal branches by nerve stimulation.

TIP: If soft tissue injury prohibits repair within first 72 hours, the nerve ends should be tagged to allow for delayed repair.

  - Peripheral injuries to the frontal and marginal mandibular branches that have resulted in significant weakness should be repaired, because of low likelihood of spontaneous recovery.

Tumors

- Paralysis can present variably: Sudden or slow progression, complete or incomplete, recurrent or single episode, possibly hyperkinesis (twitching)
- **High concern for neoplastic causes if:**
  - Unilateral facial weakness, slowly increasing for more than 3 weeks
  - Unilateral facial weakness, onset abrupt with no return of function in 6 months
  - Associated with hyperkinesis (twitching)
- **Types**
  - Primary facial nerve
  - Parotid
  - Acoustic neuroma (Von Recklinghausen's disease)

- Central nervous system
- Cutaneous malignancy
- Metastatic lesion
- Cholesteatoma (benign)
- Hemangiomas (benign)

Viral Infection

- **Ramsay-Hunt syndrome:** Varicella-zoster virus infection with facial paralysis, ear pain, and varicelliform rash in external auditory canal; accounts for approximately 12% of all cases of facial paralysis.
  - Treatment involves prednisone (1 mg/kg/day divided twice per day) and acyclovir (800 mg, 5 times/day) for 10 days[11]

Iatrogenic

- Postoperative facial paralysis after acoustic neuroma resection: Trauma, thermal injury, devascularization, edema, and reactivation of latent herpes virus infection

BILATERAL FACIAL PARALYSIS

- 0.3%-2% of all cases of facial paralysis
- **Most commonly from Lyme disease** (36% in Teller and Murphy's review)[12]
- **HIV infection** also a common cause

RECURRENT FACIAL PARALYSIS

- **Melkersson-Rosenthal syndrome:** Recurrent facial nerve paralysis, noninflammatory facial edema, and congenital tongue fissures (lingua plicata)
  - Etiology unknown, hereditary factor suspected
  - Treatment usually conservative
- **Bell's palsy** in approximately 10% of patients

PEDIATRIC DIAGNOSES

Möbius' Syndrome

- Unilateral or bilateral loss of eye abduction
- Unilateral or bilateral, complete or incomplete facial paralysis
- Facial paralysis may be accompanied by other cranial nerve palsies or congenital defects
- Primary developmental defect of central nervous system treatment, usually involves free microneurovascular muscle transfer

Hemifacial Microsomia

- Facial paralysis in small percentage of patients

Congenital Unilateral Lower Lip Palsy (CULLP)

- "Asymmetric crying facies"
- Other major congenital anomalies in 75% of affected children

PATIENT EVALUATION

- History of weakness: Onset, duration, progression
- Grading facial nerve function
  - **House-Brackmann scale**[13]: Gross scale, most commonly used for reporting (Table 37-3)
  - **Burres-Fisch system,**[14] **Sunnybrook scale**[15]: Objective scales, used to limit subjectivity of evaluation
  - **Other scales include**[16]: Botman and Jongkees, May, Stennert, Pietersen, Janssen, and Yanagihara

Table 37-3 *House-Brackmann Scale*

Grade	Description	Characteristics
I	Normal	Normal facial function
II	Mild dysfunction	Gross: Slight weakness on close inspection, normal at rest Motion: *Forehead,* moderate to good; *eye,* complete closure with minimum effort; *mouth,* slight asymmetry
III	Moderate dysfunction	Gross: Obvious but not disfiguring, normal asymmetry and tone at rest Motion: *Forehead,* slight to moderate; *eye,* complete closure with effort; *mouth,* slightly weak with maximum effort
IV	Moderately severe	Gross: Obvious weakness with disfiguring asymmetry at rest Motion: *Forehead,* none; *eye,* incomplete closure; *mouth,* asymmetric with maximum effort
V	Severe dysfunction	Gross: Only barely perceptible motion, asymmetry at rest Motion: *Forehead,* none; *eye,* incomplete closure; *mouth,* slight movement
VI	Total paralysis	No movement

From House JW, Brackmann DE. Facial nerve grading system. Otolaryngol Head Neck Surg 93:146-147, 1985.

DIAGNOSTIC STUDIES

Most cases of facial paralysis are Bell's palsy; therefore a **3-week period of observation** is acceptable before undergoing an extensive diagnostic workup.

Tests for Etiologic Factors

- **Serologic tests:** Syphilis and diabetes
- **CT scan:** Good for evaluating tumors and bony detail of the fallopian canal
- **MRI:** Good for evaluating pathologic and nonpathologic conditions of the nerve

Prognostic Tests[8]

- **Nerve excitability test (NET)**
  - Subjective
  - Determines energy required to stimulate the nerve
  - Difference of 3.0 milliamps or more between sides is abnormal
- **Maximal stimulation test (MST)**
  - Assesses facial movement with stimulus level that creates discomfort
  - Becomes positive before NET does in lesions of facial nerve

- **Electroneurography (ENoG)**
  - Apply current to stylomastoid foramen region and record maximal muscle action potentials at nasolabial fold
  - **Most accurate and reproducible test to determine prognosis**
  - When ENoG reveals 75% to 95% degeneration within 2 weeks of onset, facial nerve decompression surgery may preserve the remaining axons.[11]
- **Electromyography (EMG):**
  - Measures muscle activity
  - Does not become positive until 14-21 days after onset of paralysis
  - Useful for late prognosis in complete nerve paralysis

Topographic Tests

Attempt to localize the intratemporal site or extent of involvement.

- **Schirmer's test:** Assesses lacrimation
- **Stapedial reflex:** Assesses function of nerve to stapedius muscle
- **Taste testing:** Assesses chorda tympani function

GOALS OF SURGICAL TREATMENT

- Normal appearance at rest
- Symmetry with voluntary motion
- Corneal protection
- Symmetric, dynamic smile
- Restoration of oral, nasal, and ocular sphincter control
- Symmetry with involuntary motion and controlled balance when expressing emotion
- No loss of other significant functions

TREATMENT PLANNING

- Aim for realistic expectations of functional facial movement after intrinsic muscle reinnervation.
- Typically, **3 years** is considered to be the period after which denervation atrophy of facial muscles precludes their usefulness for further reconstruction.[17] However, presence of **fibrillations on EMG** is considered evidence of facial muscle viability and therefore indicates potential for useful function after reinnervation.

TREATMENT TYPES (Table 37-4)

Reinnervation

- Primary nerve repair (intracranial, intratemporal, extratemporal)
- Interpositional nerve graft
- Cross-facial nerve graft
- Hypoglossal-facial nerve transfer
- Hypoglossal-facial jump graft

Table 37-4 *Algorithm for Management of Facial Paralysis*

Facial Paralysis: Temporal Branch	
Deformity	**Treatment**
Brow ptosis	Brow lift
Dermatochalasis	Upper blepharoplasty
Lagophthalmos	Gold or platinum weight eyelid spring
Lower lid ectropion	Canthoplasty or lid shortening
Facial Paralysis: Zygomatic, Buccal, and Marginal Mandibular Branches	
Time From Injury	**Treatment**
<12 months	• Nerve repair • Ipsilateral nerve graft • Cross-face nerve graft
12-24 months	• Nerve repair • Ipsilateral nerve graft • Hypoglossal-facial transfer • Hypoglossal-facial jump graft
>24 months	• Static reconstruction • Cross-face nerve graft and delayed free-functional muscle transfer • Free-functional muscle transfer with CN XII or V neurotization

Modified from Anderson RG. Facial nerve disorders and surgery. Sel Read Plast Surg 9(20), 2001.

Dynamic Reconstruction

- Regional muscle transfer
  - Temporalis
  - Masseter
- Free-muscle microneurovascular transfer with cross-facial nerve graft
- Free-muscle microneurovascular transfer with coaptation to masseter motor branch

Static Reconstruction[18,19]

- **Indications**
  - Elderly patients with significant comorbidities
  - Massive facial defects secondary to trauma or cancer resection
  - Failed microvascular reanimation
  - Techniques directed to correct functional disabilities (protect cornea, improve nasal airway, and prevent drooling) and improve symmetry at rest
    - ▸ Browlift for brow ptosis
    - ▸ Upper eyelid gold-weight placement, eyelid spring
    - ▸ Lateral and medial tarsorrhaphy, Kuhnt-Szymanowski lower eyelid shortening and suspension, medial canthoplasty, or lateral tarsal strip procedure
    - ▸ Lateral and superior repositioning of nasal alar base with a maxillary periosteal flap
    - ▸ Shortening and thickening of paralyzed upper and lower lips with preservation of oral commissure
    - ▸ Suspension of oral commissure with fascia lata, tendon, or alloplastic materials
    - ▸ Rhytidectomy and stabilization with dermal flaps

Adjunct Procedures

- Botulinum toxin to weaken contralateral side to improve symmetry
- Repositioning of the lateral ala to improve airflow resistance
- **Physical therapy:** Neuromuscular rehabilitation critical to success of any treatment

Direct Nerve Repair and Grafting

- Ideally performed at time of injury
- Better results reported when repair within 1 year, but good results reported up to 3 years after injury
- Nerves regenerate at rate of **1 mm/day**
- **Source of nerve graft**
  - Branches from the cervical plexus, ipsilateral, or contralateral nerves
  - Great auricular nerve
  - Sural nerve

Cross-Face Nerve Grafting (Fig. 37-5)

- Procedure is indicated when proximal ipsilateral facial nerve stump is unavailable for grafting, a distal stump is present, and facial muscles are capable of useful function after reinnervation.
- Sural nerve grafts are used to connect healthy peripheral nerve branches to corresponding branches of specific muscle groups on paralyzed side.
  - Some recommend using branch that produces maximum zygomaticus major activity for coaptation to cross-facial nerve graft; others recommend using distal buccal branches.
  - **One-stage:** Repair both ends at the same time.[20]

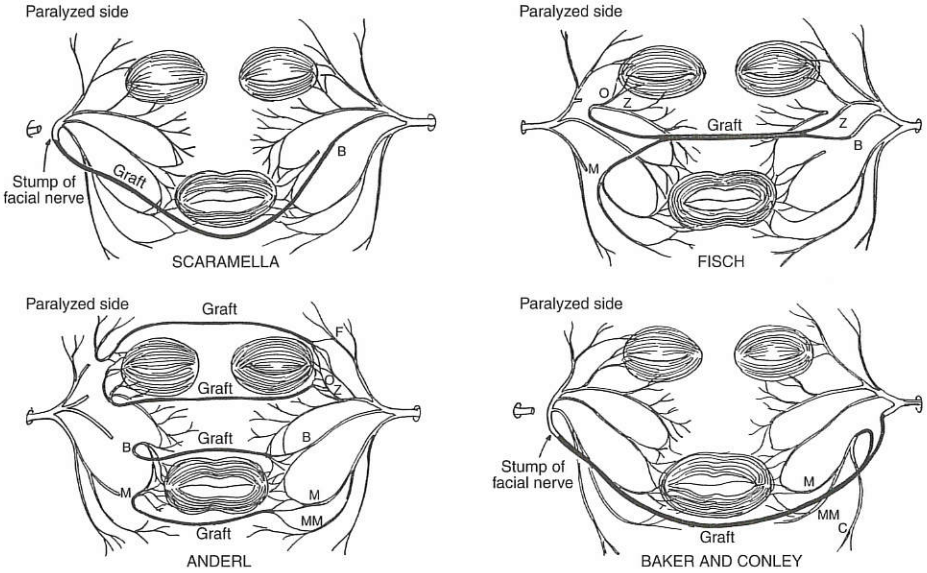

Fig. 37-5 Techniques of cross-face nerve grafting. (From Baker DC, Conley J. Facial nerve grafting: A thirty year retrospective review. Clin Plast Surg 6:343, 1979.)

- **Two-stages:** Repair healthy end, then resect neuroma to verify graft success. Once nerve fascicles grow through graft, repair paralyzed side; perform second stage 9-12 months later, after positive Tinel's sign at distal end.

Nerve Crossover

- Indicated when proximal ipsilateral facial nerve stump is unavailable for grafting, a distal stump is present, and facial muscles are capable of useful function after reinnervation
- Facial nerve stump anastomosed to hypoglossal, glossopharyngeal, accessory, or phrenic nerves
  - Requires only a single suture line: A powerful source of reinnervation
  - Sacrifices donor nerve function and often results in difficulty coordinating facial movement, mass movement, and grimacing

Hypoglossal Nerve Transfer

- Most common
- Best for immediate reconstruction of proximal facial nerve during tumor extirpation
- Provides excellent tone and normal appearance at rest
- Protects eye and permits intentional movement of face, no spontaneous facial expression
- Paralysis and atrophy of the ipsilateral tongue, usually well-tolerated unless ipsilateral low-cranial nerve (CN) dysfunction is present (CNs: IX, X, XI)

Hypoglossal-Jump Graft

- Same as hypoglossal nerve transfer, except involves partial sectioning of the hypoglossal nerve, thereby preserving ipsilateral hypoglossal function
- Indicated for patients who have ipsilateral low-cranial nerve dysfunction or for those unwilling to accept tongue dysfunction

Regional Muscle Transfers

- **Indications**
  - Absence of mimetic muscles after long-standing atrophy with no potential for useful function after reinnervation
  - Adjunct to the mimetic muscles to provide new muscle and myoneurotization
- **Masseter transfer**
  - Suited to give motion to the lower half of face
  - Three muscle slips sutured to dermis of the lower lip, oral commissure, and upper lip
  - During radical parotidectomy, transposing masseter with interdigitation into freshly denervated mimetic muscle provides maximum myoneurotization
- **Temporalis transfer**
  - More frequently performed than masseter transfer because greater excursion of movement and adaptability to orbit
  - Can transfer and suture muscle with its fascial extensions to eyelids, ala of nose, oral commissure, and upper and lower lips

Free-Functional Muscle Transfer[21,22]

- Indicated when facial muscles will not provide useful function after reinnervation
- Microneurovascular muscle transfer combined with cross-face nerve graft, ipsilateral nerve graft (facial nerve of motor nerve to masseter)
- Provides new, vascularized muscle that can pull in various directions

- **Ideal donor muscle characteristics**
  - Excursion equal to normal side of face.
  - Reliable vascular and nerve pattern of a size similar to that of recipient.
  - Removal of muscle leaves no functional deficit.
  - Location is distant enough from face to allow two operating teams to work simultaneously.
- **Gracilis muscle most commonly used**
- Other potential muscles: Extensor digitorum brevis, pectoralis minor, serratus anterior, latissimus dorsi, rectus abdominis, and platysma

Key Points

- Bell's palsy is a diagnosis of exclusion and should be treated empirically during workup.
- Successful reanimation involves addressing orbicularis oculi, zygomaticus major, orbicularis oris, and depressor anguli oris function.
- Static procedures are useful for restoring facial symmetry in repose, but they do not address dynamic function.
- Free-functional muscle transfers are the best option to restore dynamic function.
- Successful free functional muscle transfer involves postoperative physiotherapy.
- Lower lip depressor function is difficult to achieve; to achieve symmetry, contralateral depressor myomectomy may be beneficial.

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