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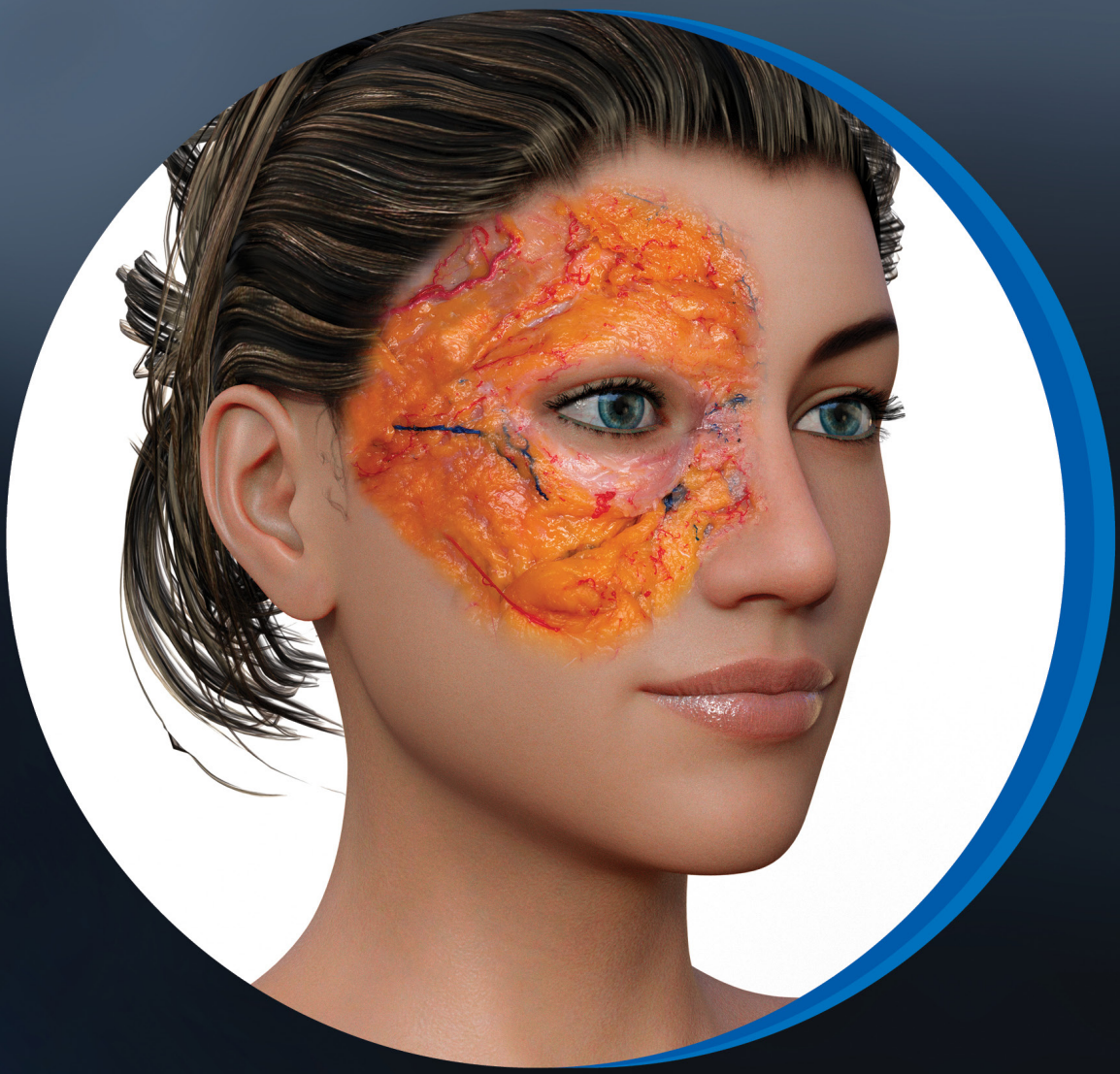
AESTHETIC FACIAL ANATOMY

ESSENTIALS FOR INJECTIONS



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WOSIAM
WORLD SOCIETY OF INTERDISCIPLINARY AESTHETIC & ANTI-AGING MEDICINE

PRIME

Aesthetic Facial Anatomy Essentials for Injections

Aesthetic Facial Anatomy Essentials for Injections is the first title of a series to be published in partnership with *PRIME Journal* and the World Society of Interdisciplinary Aesthetic & Anti-Aging Medicine (WOSIAM).

PRIME Journal is the leading authority on aesthetic and anti-aging medicine, providing industry news, insightful analysis, and key data, as well as the most high-quality research articles in the market. It's because of this that *PRIME* attracts leading authors who provide authoritative analysis on the issues that matter most to the industry. The aesthetic and anti-aging industry is a global one and deserves a dedicated international publication—a voice that will not only communicate, but educate, motivate, and inspire you with the latest, most applicable and usable information you need to do your work smarter, better, and more effectively. This is *PRIME*'s mission.

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The World Society of Interdisciplinary Aesthetic & Anti-Aging Medicine was created with a strong belief that good practice in aesthetic and anti-aging medicine must be comprehensively addressed. To achieve this, its mission is to disseminate knowledge in medical aesthetics and anti-aging medicine, as well as to federate scientific associations with shared values.

The WOSIAM is a nonprofit organization based in Paris, and membership is available to anyone who has participated in any event co-organized by the WOSIAM. Benefits of joining the WOSIAM include:

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The WOSIAM board of directors includes Dario Bertossi, editor of *Aesthetic Facial Anatomy Essentials for Injections*, as well as other core specialists with the ambition to advance aesthetic and anti-aging medicine by creating high-quality programs at leading educational events.

The WOSIAM also hosts the annual Anti-Aging & Beauty Trophy awards, which gives recognition to the companies and physicians striving to make breakthrough innovations in the field of aesthetics and anti-aging. For more information on the awards or how to enter, visit the website at https://wosiam.org.

Aesthetic Facial Anatomy Essentials for Injections

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PREFACE

Anatomy has long been the compass guiding clinicians through the astounding complexity of the human body.

Many textbooks of anatomy display the vital structures and their anatomical relationships in order to guide medical students and physicians, thus enabling them to learn and execute medical treatments.

We encountered a void in the plethora of anatomical scripts where both essential clinical anatomy and an aesthetic eye for beautification and rejuvenation need to merge. Only a paucity of mostly single-author texts exist on the essential anatomy for aesthetic medicine.

The global conference platform of Euromedicom and its network provided us with unparalleled access to the greatest minds in surgical and medical aesthetics who enjoy passing on their passion, tips and tricks in this ever expanding field.

This book by the Aesthetic Facial Anatomy group is a multi-author, cross-specialty consensus on the essential knowledge of clinically relevant anatomy and injection guidelines mandatory for safe, effective and aesthetically pleasing application of aesthetic medicine, and is encouraged to be regularly updated online by the many authors.

The men and women who allowed us to explore their anatomical structures after their passing in order for us to pass on this knowledge to our peers are the true hero educators which we should honour. It has been a privilege to work on this ongoing project.

Ali Pirayesh, Dario Bertossi, and
Izolda Heydenrych

FOREWORDS

"We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time…"

—from TS Eliot, "Little Gidding", *Four Quartets*,
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The ancient art of anatomy, which has long fascinated the human mind, has in recent years been considerably expanded by the field of aesthetic medicine. This book beautifully demonstrates the fascinating detail beneath the surface of our everyday work and should form an invaluable practical resource for those passionate about the field of medicine.

This initiative is aimed at elevating both procedural safety and clinical excellence.

I am proud to be part of it.

Mauricio de Maio, MD

During my 40 years of practice, I have trained many residents, some of them who are now masters in the field of facial aesthetics, where they are witnesses of the impressive growth this field has undergone during the last few decades. As a teacher, my role has always been to accurately evaluate the international scientific production. As I received the first draft of this comprehensive book, I realized that its impact on the medical aesthetic field will be great as it will provide the reader a solid scientific knowledge and a practical tool for beginners as well as for the advanced injectors.

I wish for all readers to understand the deepest meaning of this work. If culture and learning are made to light up our minds before our hands, the result has been achieved.

Pierfrancesco Nocini, MD

Fillers and toxins have proven to be affordable and safe treatments for the aging face. Injectables continue to gain popularity and are by far the most sought after cosmetic treatments worldwide. With this increase in demand and popularity, there arises the need for appropriate training; a need to assure safety as well as efficacy of results.

I congratulate the editors Dr Pirayesh, Dr. Bertossi and Dr. Heydenrych for bringing together such an illustrious group of thought leaders to share their knowledge and expertise in this book which is designed to improve results and enhance safety.

The most feared and devastating complication of injectables is intra-arterial injection of fillers leading to tissue necrosis and vision loss. The chapters organized by facial regions accurately describe the anatomy in minute detail, with beautiful medical illustrations and immaculately clear cadaver dissections which highlight the location and course of blood vessels at risk. The risk to blood vessels in each location is outlined and safe injection techniques are recommended that reduce risk.

This book will be invaluable not only to the novice eager to perfect their injection technique but also to those of us who have had years of experience. As someone with a long career as a surgical educator and proponent of patient safety, I plan to put this book in the hands of all our trainees.

Foad Nahai, MD FACS FRCS (Hon)

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A AESTHETIC REGIONS OF THE FACE

Alessandro Gualdi, Michele Pascali, Heidi A. Waldorf, Rene van der Hulst, Philippe Magistretti, and Dario Bertossi

FOREHEAD

The superior forehead margin lies at the hairline, whilst the lateral border is formed by the temporal crest where the frontalis and temporalis muscles fuse. The glabella, frontonasal groove (central), and the eyebrows overlying the supraorbital ridges form the inferior boundary (Figure A.1). The forehead does not demonstrate overt ethnic variations, but is usually shorter in South American and Asian patients whilst Caucasians and Africans have a higher, yet variable forehead height.

Figure A.1 The frontal area.

During the aging process, the forehead surface increases due to progressive hairline recession and widening of the orbital rims, with subsequent descent of the eyebrows. The lateral forehead aspect remains relatively unchanged.

Insightful understanding of the forehead and glabella is of great clinical importance. The frontalis is a very superficial muscle which may demonstrate several anatomical variants which need be taken into account for effective treatment with neuromodulators. The corrugator, one of the most important targets for neuromodulator treatment, lies at the medial orbital rim. Its medial origin is deep on bone, after which it courses superolaterally to insert into the skin over the lateral brow. Here it fuses with inferior frontalis fibers. Procerus is a vertical, medial muscle lying deep at the radix of the nose. The supratrochlear and supraorbital vessels are the major vessels in this area. They are delineated by overlying creases, and knowledge of their anatomical depth is of paramount importance as communications between internal and external carotid circulations pose a high risk for blindness after inadvertent intravascular filler injection. Nerves and vessels generally follow an adjacent course.

It is important to note that a deep branch of the supraorbital nerve runs approximately 1 cm medial to the temporal crest. To minimize pain or nerve damage, it is advisable to avoid injecting this region with sharp needles.

TEMPORAL REGION

The temporal region is a well-defined region extending from the temporal crest to the zygomatic arch (Figure A.2). The orbital margin forms the anterior and hairline the posterior limit. There is little ethnic variation in the extent of the temporal region, but in African skulls, the temporal bone is very thick, making temporal hollowing uncommon. The temporal area contributes to the aging process due to widening of the lateral orbital margin and concomitant underlying bone resorption, thus causing a hollowed, aged or diseased appearance. The temporal artery courses from deep to superficial through the temporal fossa. It passes close to the ear, near the root of the helix, before running in the temporoparietal fascia to pass approximately 2 cm lateral to the brow. It may anastomose with the supratrochlear and supraorbital vessels, thus comprising another danger zone for potential blindness after inadvertent filler injection.

The temporal area contains important veins, the most important and dangerous of which is the middle temporal vein. This is a very large vein draining retrogradely to the jugular vein and inadvertent injection may cause embolism and death. The middle temporal vein anastomoses with the sentinel vein. Injections should be either very deep or very superficial, and done with knowledge of the course of the middle temporal vein, which runs 1–2 cm above the zygomatic arch.

Figure A.2 The temporal area.

EYE AND PERIORBITAL REGION

The periorbital region extends from beneath the eyebrow to the zygomatico-malar ligament, and lies between the nasojugal sulcus and lateral aspect of the orbicularis retaining ligament (Figure A.3).

The periorbital region is the area demonstrating the most pronounced age and ethnic variation. In African skulls, the orbits are wider and more rectangular, and demonstrate earlier onset of bone resorption. The scant subcutaneous fat and protruded superior orbital margin causes a hollow-eyed look due to significant retraction of the periorbital tissues. Although the bone structure in Asian patients is similar to Caucasians, the tendon structure differs and the upper eyelid forms an epicanthic fold.

During the aging process, underlying bone resorption leads to progressive widening of the orbit. The

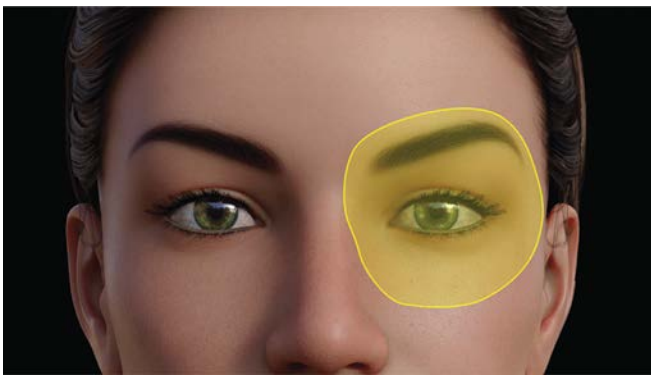

Figure A.3 The periorbital area.

eyebrows descend, and eyelid skin laxity may cause blepharochalasis and ptosis, thus impairing vision. The site for the neuromodulator injection is usually in the lateral preseptal orbicularis oculi muscle where there is no vascular danger zone. The use of neuromodulators in the upper eyelid is not recommended, because of the high risk of upper eyelid ptosis. The upper lid is a highly dangerous zone for filler injections as connections between the supratrochlear, medial palpebral and ophthalmic arteries may lead to blindness after inadvertent intravascular filler placement. It is thus imperative to have insightful anatomy knowledge and to use a cannula when treating the A-frame deformity of the upper eyelid.

NOSE

The nose is ethnically distinct, with variable bone structure and cartilage development.

It extends from the radix superiorly, to the nostrils and the columella inferiorly, and naso-jugal grooves laterally (Figure A.4).

The nose represents a vascular danger area. Above the modiolus, the facial artery superficializes and branches in two.

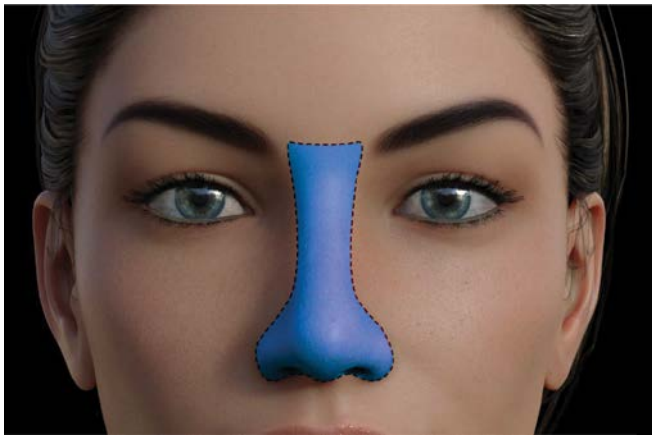

Figure A.4 The nasal area.

The deep subcutaneous branch divides close to the alar nasal sulcus to form the lateral nasal and angular arteries. In Africans, short noses with large nostrils and tips are characteristic. The central maxilla is well developed and protrudes anteriorly. The nasal dorsum is usually flat and the radix is located slightly above the intercanthal line. Asian patients have a flat nose, low radix and underrepresented dorsum. The nostrils are thin, and the tip is usually very short and rounded. With aging, the nasal cartilage enlarges and the nasal bone cavity widens. The cartilage becomes thinner and the tip falls downward. Although the bony dorsum does not change in older patients, it may become thinner, with a “sharper” edge. The lateral nasal vessels run above the alar groove to provide vascularization to the tip of the nose, together with an artery coming from the superior labial artery and passing through the columella. The tip is highly vascularized, especially in the superficial plane.

The radix of the nose is also a dangerous area due to the arborization of vessels. It is important to inject on the periosteum to avoid embolization or compression of especially the dorsal branch of the supratrochlear artery. Close to the radix, just below the medial canthus, the angular and facial veins anastomose before draining into the cavernous sinus, making this an important danger zone. It is advised that injections are placed from lateral to medial, with massage toward the more medial location. Using a cannula may prevent complications. The mid-third dorsal aspect of the nose is considered the safest injection area.

CHEEK

The cheek lies in the infraorbital region, extending laterally from the ear to the nose (above) and mouth (below) in the medial aspect (Figure A.5). African patients have larger cheeks and pronounced

Figure A.5 The cheek area.

zygomatic bones, both frontally and laterally, whilst a prominent central maxilla often prevents a flat-faced appearance.

Asian patients also have pronounced cheekbones, but the flatter nose and small maxillary bones contribute to the typically flatter Asian face. The cheek fat compartment is usually well developed.

With aging, widening of the orbital and nasal cavities and thinning of bone cause soft-tissue sagging, thus enhancing the nasolabial folds, tear troughs and marionettes lines.

The facial nerve originates near the ear lobe, deep to the parotid gland, after which it divides into five branches after emerging from the anterior parotid border. The frontal nerve superficializes above the zygomatic arch, where it accompanies the superficial temporal artery. This represents a danger area.

The facial fat compartments are very well defined and may be divided into superficial and deep groups. Volumizing certain compartments ensures maximal projection, whilst injecting into others may induce sagging (see Cheek chapter). The infraorbital nerve enters the face via the infraorbital foramen which lies 6–8 mm below the infraorbital rim on a perpendicular line at the medial limbus. It is important to avoid intravascular injection by placing injections lateral to the foramen. Avoid embolization into the facial vein, which runs from the mandibular angle to the medial orbital canthus.

LIPS AND PERIORAL REGION

The perioral region comprises the lips and area corresponding to the orbicularis oris muscle (Figures A.6 and A.7).

Whilst the extent of the mouth region does not vary among ethnicities, lip proportions do. African and Mediterranean patients generally have bigger lips, while Asian, North European, and North American patients have thinner lips.

Figure A.6 The perioral area.

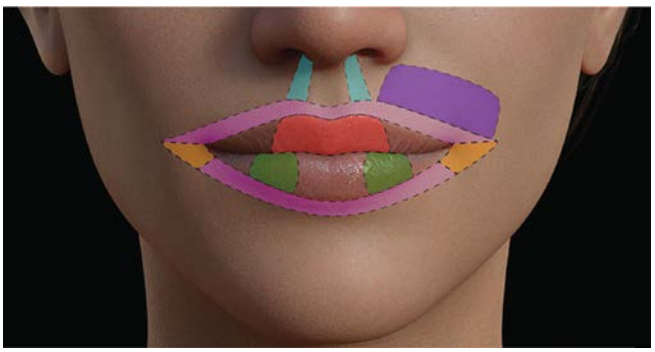

Figure A.7 The lip area.

Elderly patients also present with thinner lips. In the case of total or partial edentulism, there may be moderate to severe alveolar crest atrophy, causing a retraction of the lips and perioral tissue with shortening of the nose-chin length.

Several muscles insert into the modiolus to exert an effect on smiling. Zygomaticus major is stronger in effecting an upwards or zygomatic smile. As the elevators weaken with age, risorius may dominate to cause a more horizontal smile. Eventually, the depressor anguli oris (DAO) may dominate to cause a downwards smile. The zygomaticus minor, levator labii superioris, and levator labii superioris aleque nasi insert into the upper lip.

After passing below the commissure, the facial artery superficializes and divides into superior and inferior labial branches. The superior labial artery penetrates the orbicularis oris to enter the lip, running at the junction of the dry and wet mucosae. The inferior labial artery originates from the facial artery below the commissure, and runs from deep to superficial close to the mucosa. Inferiorly, there is more variation in morphology.

CHIN

The chin lies between the DAO (laterally), inferior margin of the orbicularis oris (superiorly) and mandibular margin inferiorly (Figure A.8). African patients have a wider chin, thicker bone, and more prominent lower maxilla.

Asians often present a retracted maxilla and smaller chin. Apart from soft-tissue sagging, aging does not affect the chin area directly. However, anterior protrusion may result due to loss of occlusion in edentulous patients. Although the chin is a relatively safe area to treat, it is important to note the emergence of the mental nerve just below the two premolars of the

Figure A.8 The chin and jawline area.

mandible. In elderly or edentulous patients, the foramen is usually closer to the alveolar ridge. Injecting the mental nerve may cause permanent dysesthesia, paresthesia, or anesthesia of the lower lip.

JAW

The jaw area extends from the DAO (anteriorly) to the temporomandibular joint posteriorly; inferiorly, it is defined by the bony margin of the jawline (Figure A.9). There are no technically specific aging changes other than soft-tissue sagging. The facial artery crosses the mandible approximately 1 cm anterior to the anterior border of the masseter. The latter is the strongest muscle in the body.

Figure A.9 The neck.

NECK

The neck is defined as the anatomical area originating anteriorly from the inferior surface of the mandible, running to the superior surface of the manubrium sterni. The posterior neck borders are bounded superiorly by the occipital bone of the skull and inferiorly by the intervertebral disc between CVII and T1. The neck is further divided into anterior and posterior triangles. The anterior triangle is bounded by the anterior border of the sternocleidomastoid, the midline of the neck, and inferior border of the mandible. The posterior triangle is defined as the area bounded by the posterior border of the sternocleidomastoid (SCM), anterior border of the trapezius and, inferiorly, the lateral third of the clavicle. The visible anterior triangle is the predominant focus of aesthetic treatments. With aging, the neck develops increased soft tissue laxity, excess skin, fat accumulation and loss of the cervicomental angle.

B FACIAL LAYERS

Eqram Rahman, Yves Saban, Giovanni Botti, Stan Monstrey, Shirong Li, and Ali Pirayesh

The face, with its diverse ability to portray emotions whilst communicating, is one of the most uniquely recognizable areas of the human body. An increasing interest in facial aesthetics, coupled with considerable research, has extended our understanding of the facial layers and the subtle physical variations resulting from underlying bone structure and genetic factors. With progressive aging, the face undergoes asynchronous changes which may present unique surgical challenges. Insightful understanding of facial anatomy as pertaining to the aging process facilitates treatment planning and predictable outcomes [1]. Traditionally the face has been divided into upper, middle and lower horizontal thirds with the upper face extending from the trichion to the glabella, the midface from glabella to the subnasale, and lower face extending to the menton.

However, Mendelson and Wong (2013) have posed that a more global understanding is facilitated by distinguishing between functional regions and considering the anatomy in terms of a layered construct bound together by retaining ligaments.

Seven major layers may be differentiated [2] (see Figure B.1):

1. Skin
2. Superficial fat
3. Superficial muscular aponeurotic system (SMAS)
4. Muscle
5. Vasculature
6. Deep fat
7. Bone

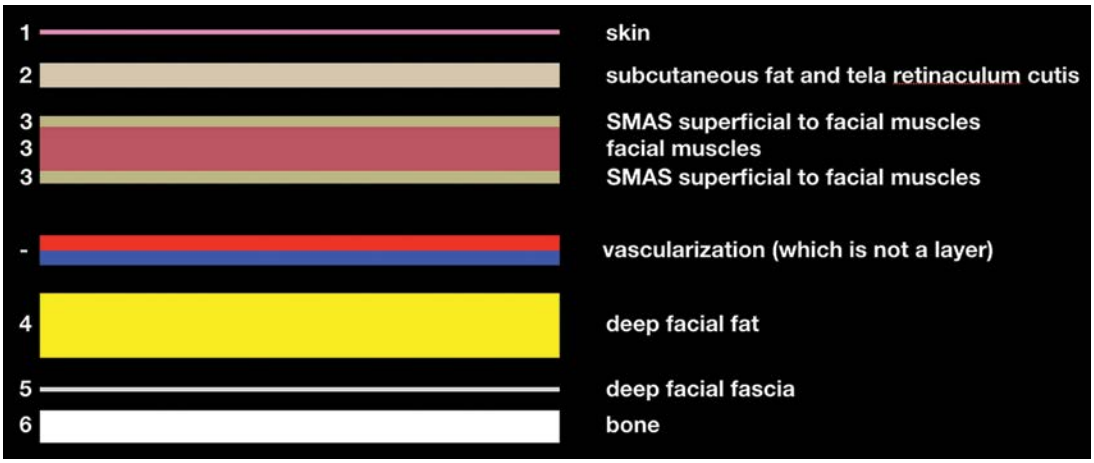

Figure B.1 The schematic illustration of the facial layers.

SKIN

The skin represents the superficial layer of the face and is an important indicator of age. In youth, the skin is smooth, firm, unblemished, and retains a uniform texture [3]. The skin may be histologically divided into epidermis and dermis, with the dermis consisting of collagen, elastic fibers, and ground substance comprising mucopolysaccharides, hyaluronic acid, and chondroitin sulphate [3].

Cutaneous aging often escalates from the fourth decade under the influence of contributory genetic, hormonal, behavioural and environmental factors [3,4]. During soft tissue aging, the two distinct processes of deflation and descent manifest as excess skin [5]. Wrinkles start to appear in the lower eyelids and lateral orbital areas, along with the development of dyschromia, textural changes, pigmentation, dryness, thinning, folds, drooping, and mimetic lines [3]. The midface is particularly susceptible to UV-induced aging, with the subsequent development of rough, wrinkled and leathery skin carrying a higher incidence of telangiectasias, premalignant conditions and malignancies. Other causes of extrinsic aging include smoking, pollution, infrared-A radiation and also visible light [3,4]. Recent advances in the understanding of volume loss as a critical component of facial aging, and the subsequent integration of volume replacement into both surgical and non-surgical treatment algorithms, arguably represents one of the most significant advances in the field of facial rejuvenation [6].

SUPERFICIAL FAT

In youth, the facial fat consists of a diffuse, balanced spread of superficial and deep fat which create the different arcs and convexities of the face. The superficial and deep layers are separated by the superficial muscular aponeurotic system (SMAS). Superficial fat is understood to be separated into unique compartments, which are divided by fascial septae containing vascular structures [2,5]. The major role of the fat layers is as a gliding plane for the facial mimetic muscles [5].

The superficial fat compartments comprise the nasolabial, medial, middle, and lateral temporal-cheek, central, middle, and lateral temporal-cheek (found within the forehead) and superior, inferior, and lateral orbital fat pads. The nasolabial fat, located medial to the cheek fat pads, plays a pronounced role in sagging of the nasolabial fold. The orbicularis retaining ligament (ORL) is situated 2–3 mm below the inferior orbital rim and forms the superior border of both the nasolabial and medial cheek fat compartments. The middle cheek fat compartment, juxtaposed between the medial and lateral temporal-cheek fat compartments, contains a superior fascial border known as the superior cheek septum [2].

The individual fat compartments age at different tempi and vary metabolically, thus contributing to segmental loss of fullness and the stigmata of aging. The periorbital, forehead, malar, temporal, mandibular, mental, glabellar, and perioral sites are prone to volume loss, whilst the nasolabial and inferior jowl compartments may hypertrophy. The infraorbital and malar fat pads often become more prominent, with anterior protrusion of the malar fat causing it to bulge against the nasolabial crease, thus emphasizing the nasal fold [6]. It is important to understand that individual fat pads behave differently after injection with fillers, with inferior displacement of the superficial nasolabial, middle cheek, and jowl compartments after injection. However, injection into the medial and lateral cheek and superficial temporal compartments lead to an increase in local projection without inferior displacement.

SUPERFICIAL MUSCULAR APONEUROTIC SYSTEM (SMAS)

The SMAS, which has been recognized since 1799, is a unique subcutaneous fascia which is continuous with the platysma below and galea above. It acts as an investing fascia for the facial mimetic muscles, thus playing an important role in facial expression [2,5]. The SMAS is firmly adherent to the parotid–masseteric fascia in the lateral aspect, where it is known as the immobile SMAS. The facial retaining ligaments, which originate from either the periosteum (zygomatic and mandibular retaining ligaments) or underlying muscle fascia (masseteric and cervical retaining ligaments) transmit through the SMAS to the overlying skin and serve as barriers between the superficial and deep facial fat compartments [12]. Neurovascular structures, or "facial danger zones," are located between these retaining ligaments [4].

Superiorly, the SMAS passes over the zygomatic arch to meet with the superficial temporal fascia [5]. The SMAS is considerably thicker over the parotid gland, but thins substantially as it courses medially. Superior to the zygomatic arch, the SMAS is known as the superficial temporal fascia where it splits to accommodate the temporal branch of CN VII and the intermediate temporal fat pad [2,7].

Degenerative changes in the viscoelastic properties and three-dimensional structure of the SMAS result in ptosis. Researchers have hypothesized that there is earlier and more progressive aging in the midface due to a decreased amount of SMAS [4]. With increasing age, retaining ligaments are at risk of weakening, thus leading to further ptosis of the masseteric SMAS and resultant jowl formation [2].

Due to the proximity of the SMAS to the temporal branch of CN VII, any dissection in this location should be performed deep to the superficial temporal fascia in order to avoid accidental denervation-related injuries [2].

DEEP FAT

The deep fat comprises the medial and lateral suborbicularis oculi fat (SOOF), and the deep medial cheek fat. Whilst the majority of the SOOF is found inferior to the lateral aspect of the infraorbital rim, it is also found underneath the orbicularis oculi muscle [7]. Other deep fat compartments include the temporal fat pad and a deep addition of this pad known as Bichat's fat pad [3]. The deep, supraperiosteal fat layer is located beneath the SMAS. Although the SMAS is sandwiched between fat layers, there are bilaminar connecting membranes or fusion zones containing neurovascular structures [7]. Compared with the superficial fat layer, the deep fat layer is composed of segmental, large white lobules containing a scant system of thin fibrous septae [3]. With aging, the deep fat layers may disintegrate and descend, resulting in a more prominent appearance of the inferior border of the orbicularis oculi which may accentuate the malar crescent and the nasojugal fold [6]. Post-menopausal changes due to decreased estrogen may cause increased fat deposition in combination with decreased superficial fat [3].

MUSCLE

The facial muscles can be categorized as periocular and perioral and broadly organized into four layers, where CN VII runs between the deepest and third layer. The first, superficial layer consists of the orbicularis oculi, the zygomaticus minor, and the depressor anguli oris. The second layer contains the levator labii superioris alaeque nasi, the zygomaticus major,

the risorius, the depressor labii inferioris, and the platysma. The third layer includes orbicularis oris and levator labii superioris. The final, deepest layer consists of the buccinator, the levator anguli oris, and the mentalis [8]. Whilst the major function of facial muscles relates to facial movement, they also play a significant role in maintaining soft-tissue support. The SMAS unites and advances the facial muscles, especially the zygomaticus major and orbicularis oris [2,5].

The mimetic muscles of the cheek are separated into a superficial and deep layer. The superficial layer consists of zygomaticus major and minor, levator labii superioris, risorious, depressor anguli oris, orbicularis oculi, and the orbicularis oris. The deep layer contains the levator anguli oris, buccinator, depressor labii inferioris, and the mentalis [5].

Muscular aging can cause prominent changes such as declining muscle mass and strength. An example of this can be seen in the midface, where the orbicularis oris thins with age while the orbicularis oculi does not. Extensive investigations of facial MRIs at different ages have shown that the midface muscles start to shorten and straighten simultaneously. Researchers have hypothesized that this, in addition to a lifetime of facial contractions, may cause prolapse of the deep midfacial fat compartments [4].

VASCULATURE

Three major arteries originating directly from the external carotid artery or subsequent branches provide arterial supply to the face: the facial, transverse facial, and infraorbital arteries [7,9]. The facial artery, which is the largest, crosses the inferior border of the mandible just anterior to the masseter, where its pulsation may be felt, after which it travels in a coiled fashion towards the pyriform fossa [9]. It runs from deep on the mandible, over the buccinator, beneath risorius and zygomaticus major, under or over zygomaticus minor, crosses the nasolabial fold from medial to lateral at the junction of the proximal third after which it becomes the angular artery which anastomoses with the superficial temporal artery (STA).

The ophthalmic artery is the major artery supplying the orbit. Originating from the internal carotid artery in the middle cranial fossa, this artery traverses the optic foramen and subdivides into numerous branches inside the orbital cavity [7].

The superficial temporal artery represents the final branch of the external carotid artery. This artery arises inside the parotid gland at the point where the maxillary artery branches off the external carotid artery. Bilaterally, this artery supplies a large area of facial skin, including the lateral forehead, the temple, the zygoma, and the ear. One prominent branch that stems from the superficial temporal artery includes the transverse facial artery (also originating from the parotid gland) [7].

The forehead is supplied by the supraorbital and supratrochlear arteries (branches of the ophthalmic artery). The nose has a particularly intricate vascular network of tiny arteries within the alae, tip and columella. Most of this is supplied by the lateral nasal artery (originates from the facial artery) or superior labial artery (also originates from the facial artery). The upper lip is supplied primarily by the superior labial artery, while the lower lip is supplied by three labial arteries. The chin's main vasculature is the mental artery (branch of the inferior alveolar artery) [7].

The majority of veins are located close to the similarly named arteries. After crossing the inferior mandibular border with the facial artery, the facial vein takes a direct path to the medial canthus. The lateral forehead and temporal/parietal regions usually drain via the superficial temporal vein, while the middle forehead and upper eyelid drain via the angular or ophthalmic veins within the cavernous sinus. Venous

drainage of the midface is via the infraorbital vein and pterygoid plexus; certain structures, such as the lips and cheeks drain into the facial vein [7].

The location, size and origin of the major arteries may vary between individuals and races [7,9]. With aging, random degenerative changes can occur in individual vessels, including increased diameter, decreased elasticity, and arterial hypertension. These changes can result in elongation and further tortuosity of these arteries [9].

The facial artery crosses the inferior border of the mandible just anterior to the masseter, where its pulsation may be felt, after which it travels in a coiled fashion towards the pyriform fossa [9]. It runs from deep on the mandible, over the buccinator, beneath risorius and zygomaticus major, under or over zygomaticus minor, crosses the nasolabial fold from medial to lateral at the junction of the proximal third after which it becomes the angular artery which anastomoses with the superficial temporal artery (STA).

NERVES

Cranial nerve (CN) VII—the facial nerve—is the main motor innervation of the facial muscles, with damage to CN VII being one of the most dreaded (but rare) complications of surgery. After exiting the stylomastoid foramen, an upper and lower division develops as it passes through the parotid gland before travelling to the facial muscles [3]. This nerve harbors significant clinical implications during facial surgery [5]. Another significant clinical consideration during a mandibular block (CN VII), is potential hemifacial paralysis, otherwise known as Bell's palsy [7].

Other important innervations include CN V (trigeminal nerve), which has three branches as well as additional branches from the cervical plexus.

The greater auricular nerve is found approximately 5 cm inferior to the external auditory meatus, running deep within the superficial cervical fascia. The mental nerve, a branch of the inferior alveolar nerve, exits the mental foramen where it can be seen and palpated when the oral mucosa is stretched. This nerve provides innervation to the lower lip and the mandible. The buccal mucosa and the skin on the cheek is innervated by the buccal branch of the mandibular nerve, while the anterior two-thirds of the tongue is innervated by the lingual nerve (a branch of the mandibular division of the trigeminal nerve) [2].

Face transplants have rapidly blossomed into a feasible management for patients with extreme disfigurements. To help repair damaged facial expression muscles and preserve their function, it is vital also to understand that these muscles do not contain proprioceptive receptors, compared with mastication muscles (which are innervated by the trigeminal nerve and thus contain proprioceptors) [7].

BONES

Youthful features have been said to be optimally present at a point in time when a specific set of skeletal proportions are ideal for their soft-tissue envelope. The skeletal framework forms the basis on which unique facial characteristics are built, rendering underlying bone vital in providing and preserving ideal soft-tissue relationships.

Important facial bony constituents include the frontal, maxillary, zygomatic, palatine, nasal, temporal, lacrimal, ethmoidal and mandibular bones. Bone provides structural support and attachment sites for the muscles of facial expression and mastication, and also protects certain structures such as the eyes.

The facial skeleton undergoes both expansion and selective resorption throughout life, with the pyriform

and orbital apertures being particularly susceptible to age-related resorption. Maxillary recession and a 10° decrease in the maxillary angle have been noted after 60 years of age [11]. Midface skeletal involution also occurs from the sixth decade, occurring more frequently in women than men [4]. Skeletal regression of particularly the inferolateral orbital rim and alveolar ridges, contributes to loss of midfacial support and also loss of overall facial height.

Age-related changes within the nasal aperture, paired nasal bones, and ascending processes of maxillae may lead to prominent changes, including nasal lengthening, sagging of the tip, and posterior displacement of the columella and lateral crura [11].

Selective resorption of the upper jaw may lead to a subsequent loss of dentition, with Bartlett et al. [13] demonstrating that decreasing height of the maxilla and mandible correlate strongly with eventual loss of dentition.

Loss of teeth generally affects the mandible more than the maxilla, with women at a higher risk of this loss [4].

Individuals with prominent bony features, including a supraorbital bar, strong cheekbones, and prominent jawlines have been said to age more favorably [11].

CONCLUSION

The face is unique in its profound ability to communicate, express emotion and masticate. As a result of this intricate functionality, it is imperative that medical practitioners have an insightful understanding of applicable anatomy. Each facial layer is morphologically and clinically distinct and may be differentially affected by the aging process. This layered structure provides an intricate canvas, adding to the functional and artistic imagery required during aesthetic treatments.

By first breaking the anatomy down into basic layers, it is easier to visualize the integral structural an functional components before attempting to brainstorm novel aesthetic solutions.

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C AGING OF SKIN, SOFT TISSUE, AND BONE

Daria Voropai, Steven Dayan, Luis Fernando Botero, Chiara Botti, Leonard Miller, and Ali Pirayesh

Facial aging is a complex, multifactorial process involving multiple facial layers. Changes in the skin, skull, and soft tissues play contributory roles. Loss of collagen and elastin, combined with epidermal thinning, contributes to the appearance fine rhytides. Distributional changes in the superficial and deep fat pads, in addition to bone remodeling, constitute key morphological factors and result in the characteristic inverted heart shape of the aging face. Understanding these multifactorial aging pathways facilitates effective aesthetic treatments.

The main function of the facial skeleton is to protect the brain and important sensory organs of smell, sight, and taste, and to provide a foundation for the face. The skull is subdivided into two main parts: the cranial vault, which protects the brain and houses the middle and inner ear structures, and the facial bones, which form the support for the soft tissues of the face, the nasal cavity, the eyeballs, and the upper and lower teeth.

The adult skull comprises 22 separate bones, of which only one, the mandible, is mobile and not fused as a single unit. In order to understand the aging process of the skeletal base, it is of great importance to know the relationships between the different bones, transitions, and landmarks.

The face may be divided into thirds (upper face, midface, and lower face) in order to identifying important bony and soft tissue landmarks (Figure C.1).

The upper face consists of mainly the frontal bone, which forms the upper third of the anterior adult skull giving the forehead an aesthetically pleasing curvature. The frontal bone can be divided into three parts (see also Chapter 1, Forehead):

1. Squamous part of the frontal bone
2. Glabella and nasion
3. Supraorbital ridge

The important aesthetic landmark of the upper third is the nasion, defined as the suture between the frontal and nasal bones in the midsagittal plane. Together with the nasion, the glabellar angle (the line connecting the maximal glabellar prominence with the nasofrontal suture, as compared to the horizontal or nasal-sellar line) is used

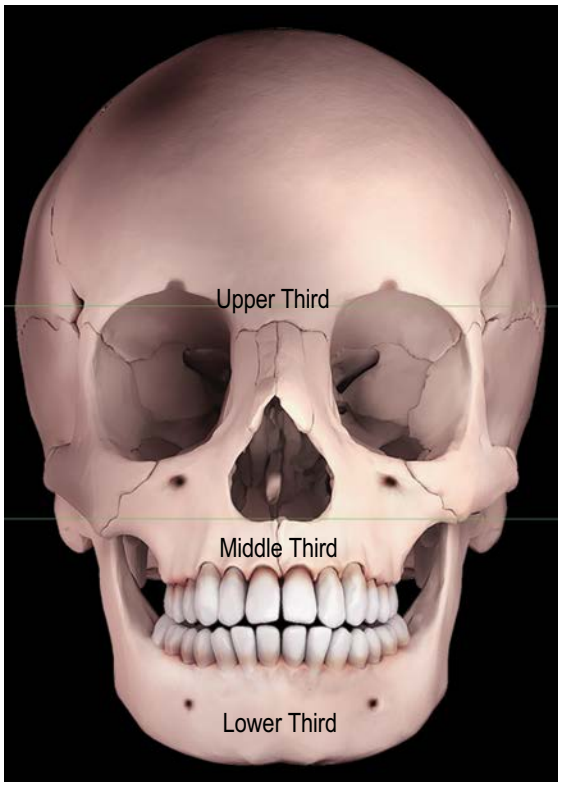

Figure C.1 Facial bone sutures.

as an anthropometric measurement in facial and cephalometric analysis.

There is no clear understanding as to which aging changes occur in the cranium and the upper face. A well-researched change is the decrease in glabellar angle [2,3]. However, Cotofana et al. [1] studied computed tomographic multiplanar scans of 157 Caucasian individuals between the ages of 20 and 98 years and found significant results, which complemented the results of Yi's [8,9] study looking at aging changes of the frontal eminence and the concavity of the forehead (however, limited to the Korean population). Yi's study concluded that in both genders, aging was associated with increasing length of the concavity (Figure C.2). Cotofana [1] documented a decrease in sagittal diameter in men (−2.24%), an increase in transverse diameter in both women and men (1.97% vs 2.22%), and a decrease in calvarial volume in men and women (5.4% vs 5.1%) (Figure C.2). Furthermore, lateral expansion of the skull [1] could also contribute

Figure C.2 Skeletonized facial features.

to the more skeletonized appearance of the face of the older individual, hence the prominent lateral orbital rims, temporal crest, and zygomatic arch.

Soft tissue changes in the aging upper face are also of note. A well-accepted theory is that of volume loss due to lipo- and muscle atrophy [3]. Foissac et al. [11] looked at magnetic resonance imaging scans of 85 female Caucasians (age 18 to >60 years) to analyze the volume and distribution of the central forehead and the temporal fat compartments. They concluded that there is an increase in fat volume in the older group, with an increased basal expansion of the compartments (central fat compartment increasing by 155% and temporal fat compartment by 35.5%). Combinations of these findings result in visual aesthetic implications for the aging upper face, which include enhanced forehead concavity, brow ptosis, temporal hollowing, and a more prominent supraorbital ridge due to a decreased glabellar angle.

The midface is a merging of the following bony structures: nasal, lacrimal, ethmoid, maxillary, zygomatic, and palatine bones [5]. The main function of

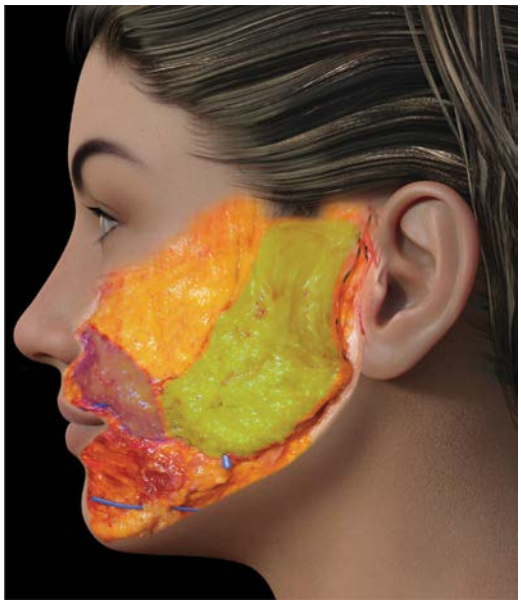

Figure C.3 Midfacial fat.

the midface is to house the eyeballs within the orbit and the teeth within the maxilla, which then transmits masticatory forces to the skull base. The midface also provides a scaffold for the main facial tissues (see Figure C.3).

One of the key points in midface analysis is the bizygomatic distance, or most exterior bilateral point of the zygomatic arch, which is widest part of the face. The midface anthropometric measurement landmarks are the maxillary angle (the angle between the sella-nasion and the line between the superior and inferior maxilla) and the pyriform angle (nasal bone to lateral inferior pyriform aperture, divergent from the sella-nasion line) [3].

Facial skeletal aging is most prominent in the midface, but the rate of bone resorption is not uniform; the maxilla is more prone to bone loss compared to the zygoma [4]. Therefore, it is helpful to analyze the important midface features separately (orbit, maxilla, pyriform aperture, and zygomatic arch).

Maxillary recession is most evident in the anterior aspect [12]. Studies found a decrease of the maxillary angle of 10° between the young (<30 years) and old populations (>60 years). This finding can be causative for the loss of support of the inferior orbital rim [2–4] and loss of projection of the maxilla. The zygomatic arch suffers a posterior and anterior remodeling, which leads to increased temporal hollowing.

Aging changes in the orbit are characterized by an increase in aperture and width. However, there is no uniform resorption; research has proved that the superomedial and infralateral aspects recede more [12,13]. This leads to an expansion of the orbit. A similar process occurs at the pyriform aperture, with lateral widening as the edges of the nasal bone recede with age [4] and an increase in the pyriform angle.

In the lower face, there is only one bone, the mandible, which carries the lower dentition. Important anatomical landmarks are the pogonion, the most anterior point of the chin, and the gonial angle, located at the posterior border at the junction of the lower border of the mandibular ramus.

There are numerous controversial theories regarding aging changes of the mandible. Alvero et al. [10] examined 241 forensic skulls and observed a posterior and superior bone formation in the older population, with anterior and inferior resorption. As a result of this resorption, there is an increase of the mandibular angle, where it becomes more robust compared with the acute angle of youth. Equally, the chin area undergoes changes as a consequence of bone remodeling, where the mandible loses its vertical projection and the chin becomes shorter and more oblique [10]. These processes are accelerated in edentulous individuals and apply to both maxilla and mandible.

Bony changes lead to loss of soft tissue support and therefore changes in facial aesthetics. Decreased mandibular height and length, and an increase in the mandibular angle, contribute to a loss of definition of the jawline and development of jowls.

Loss of maxillary support and projection and the mandible will result in morphological changes, and soft tissue changes also contribute to the saggy appearance in older individuals. Rohrich and Pessa [7] described a compartmentalization of the superficial and deep fat pads divided by septae, fasciae, ligaments, or muscles.

With aging, there is deflation and loss of the normal anatomic subcutaneous facial fat compartments, which give the appearance of increased skin laxity or prominent folds around the nasolabial region, periorbital region, and jowl [7]. One can use the deep and superficial fat pads as a map for facial aging: the deep fat pad of the periorbital area is affected first (the transition between the medial suborbicularis oculi fat and the superior edge of the malar fat pad is lost), which creates a concavity between the thin medial eyelid skin and thicker cheek skin, resulting in a tear trough deformity [14]. Subsequent further deflation of the deep medial cheek fat leads to ptosis of the overlying superficial malar fat pad and further deepening of the tear trough deformity with hollowing of the centromedial cheek. Wysong et al. [15] found that the most dramatic loss of facial fat occurs from the third to the sixth decade, after which depletion stabilizes.

However, there is not only volume loss but also hypertrophy. Donofrio et al. [6] found slight hypertrophy of the submental, jowl, nasolabial, and lateral malar fat pad, which aligns with morphological changes in those areas, characterized by sagging tissues and the appearance of folds (see Figure C.4).

Together with volume loss in fat pads, there is also lack of support and stability of the ligaments because of the repositioning of their points of origin, followed by ligamentous weakening due to continuous stretching. Ligaments function as a hammock for the fat compartments and promote the appearance of sagging when there is a lack of structure [14]. More detailed aesthetic implications and treatment proposals will be elucidated in the chapters to follow.

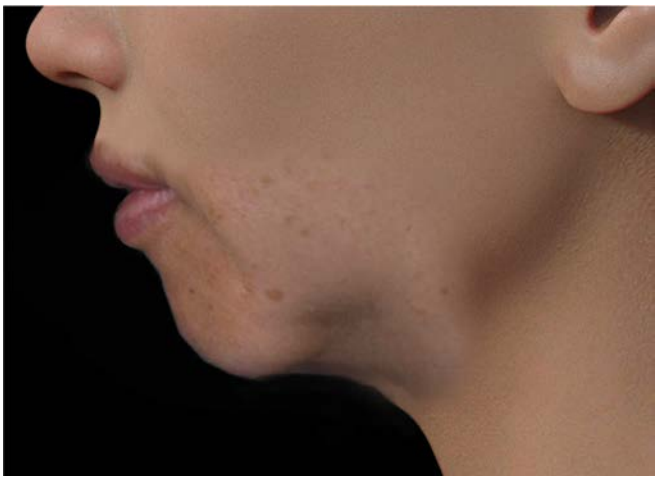

Figure C.4 Sagging submental tissues.

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D MYOMODULATION

Mauricio de Maio and Izolda Heydenrych

The definition of modulation is the exertion of a modifying or controlling influence on something.

Clinical observation over the past two decades has shown that injectable fillers may, in addition to addressing volume loss, also profoundly influence muscle dynamics. With aging, structural deficiencies in either bone or fat pads may precipitate abnormal muscle movement. As the indications for facial injectable fillers have evolved from the mere treatment of lines and folds, through three-dimensional facial volumizing, to the current sophisticated paradigm of modifying muscle movement by the use of hyaluronic acid (HA) fillers, it has become possible to consciously complement the mechanism of neurotoxins by the use of HA fillers.

Despite a paucity of literature detailing scientifically measurable muscle strength, case studies offer irrefutable evidence of the potential clinical impact of injectable fillers on muscle function in both the presence and absence of volume deficiency. It is clear that various factors may be instrumental in either facilitating or reducing muscle movement, making this a fascinating field for ongoing study [1,2].

The treatment of facial palsy and asymmetry is complex and mandates insightful, detailed mastery of both anatomy and technique in order to achieve reproducible results [3]. Developing expertise in this field often requires many years of experience, making consistent and reproducible transfer of knowledge a challenging aspect. The first publication on myomodulation highlighted the ability of injectable fillers to influence facial muscle action in a reproducible manner by addressing the muscle imbalance resulting from structural deficiencies with and without substantial volume loss [1]. The evolution of innovative treatment paradigms is offering new treatment methods—and hope—for patients with facial palsy [4].

TERMINOLOGY

The succinct new language of the MD Codes, also encompassing MD ASA and MD DYNA Codes, was conceived in order to refine and standardize description of both facial assessment and technique, and constitutes an invaluable teaching tool [1]. It is important to understand that these points should be applied according to clinical indication and expertise and, as such, constitute a set of accurately defined placement points rather than a rigid prescriptive method.

The MD Codes divide the face into structural units and depict target structures, injection technique, product choice, and danger areas in a detailed and standardized manner through the use of symbols. Placement points and symbols are briefly illustrated in order to facilitate the methodology later in this chapter (Figures D.1, D.2 and Table D.1).

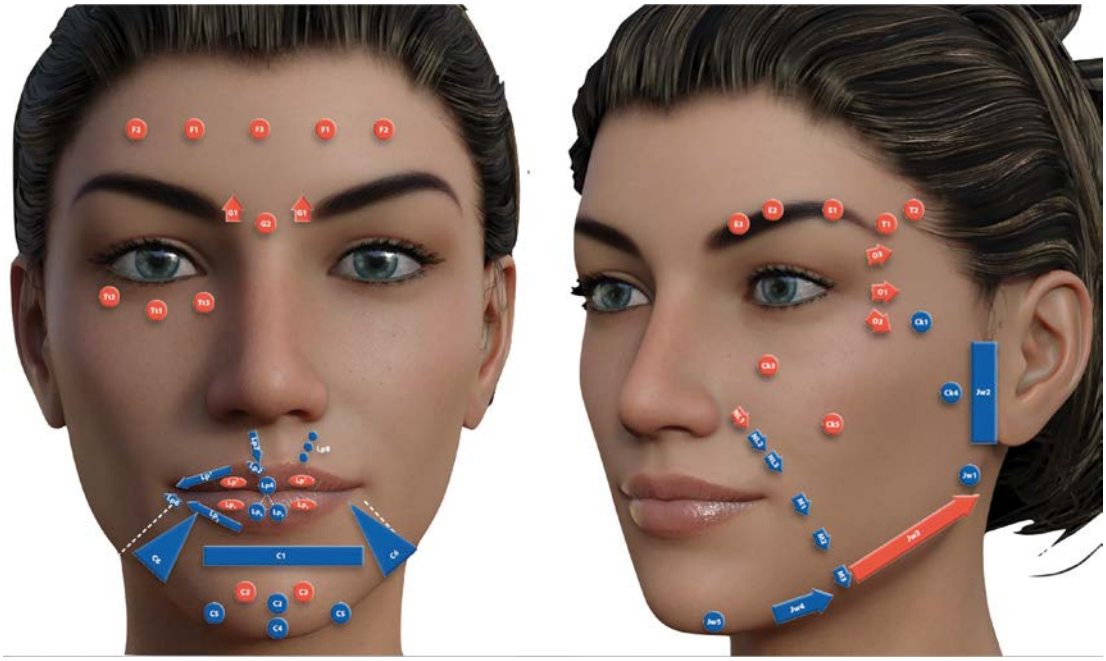


Figure D.1 Illustration of the MD Codes placement and terminology.

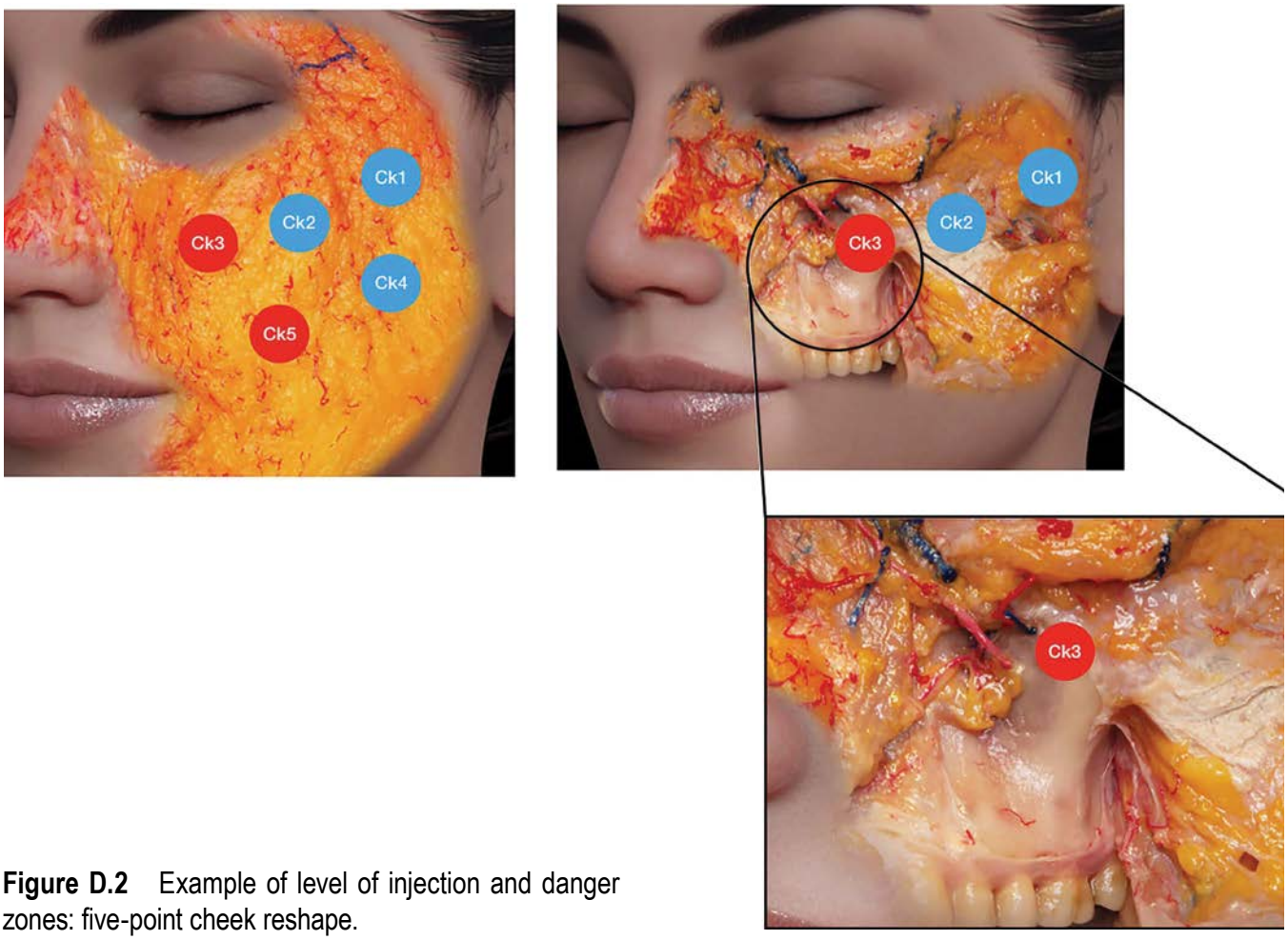


Figure D.2 Example of level of injection and danger zones: five-point cheek reshape.

Table D.1 The Five-Point Cheek Reshape: Injection Areas and Effects

Code	Injection Area	Effect of Injection	Aim
Ck1	Zygomatic arch	Lifts the cheek Gives support to eyebrow and lower eyelid	Bone structure and lateral suborbicularis oculi fat (SOOF)
Ck2	Zygomatic eminence	Provides projection of the cheek and shortening of the palpebral-malar sulcus	Bone structure and lateral SOOF
Ck3	Anteromedial cheek-midcheek	Improves the medial lid-cheek junction and softens the tear trough	Bone structure, deep malar fat pad; medial SOOF
Ck4	Lateral lower cheek/parotid area	Addresses the sunken area at the parotid level and volume loss; lifts the jawline	Subcutaneous
Ck5	Submalar	Addresses the sunken area and improves volume loss in the submalar area	Subcutaneous

The choice of injection device should be based on individual experience and preference (Tables D.2 and D.3) [5].

The targeted structures are specified as:

- Dermal
- Mucosal
- Subcutaneous
- Fat pads
- Supraperiosteal

MD DYNA Codes detail the muscles implicated in facial muscle excursion and suggest specified placement sites for both neuromodulator and/or HA filler. Accurate knowledge of muscle origin and insertion is essential, as is knowledge of the muscular anatomical plane. Insightful knowledge of functional groups and muscle synergism/antagonism is vital in planning product placement; the injector is encouraged to reflect critically on the desired effects of placement above, below, or within muscles and to define a strategy encompassing placement, product choice, and method of delivery before embarking on treatment (Figures D.3 and D.4).

Table D.2 Considerations in the Choice of Injection Device

 Cannula	May minimize risk of intravascular injury and bruising Recommended for use in danger zone areas
 Needle	May be preferred for fine, controlled injections Ideal for bolus at the supraperiosteal level

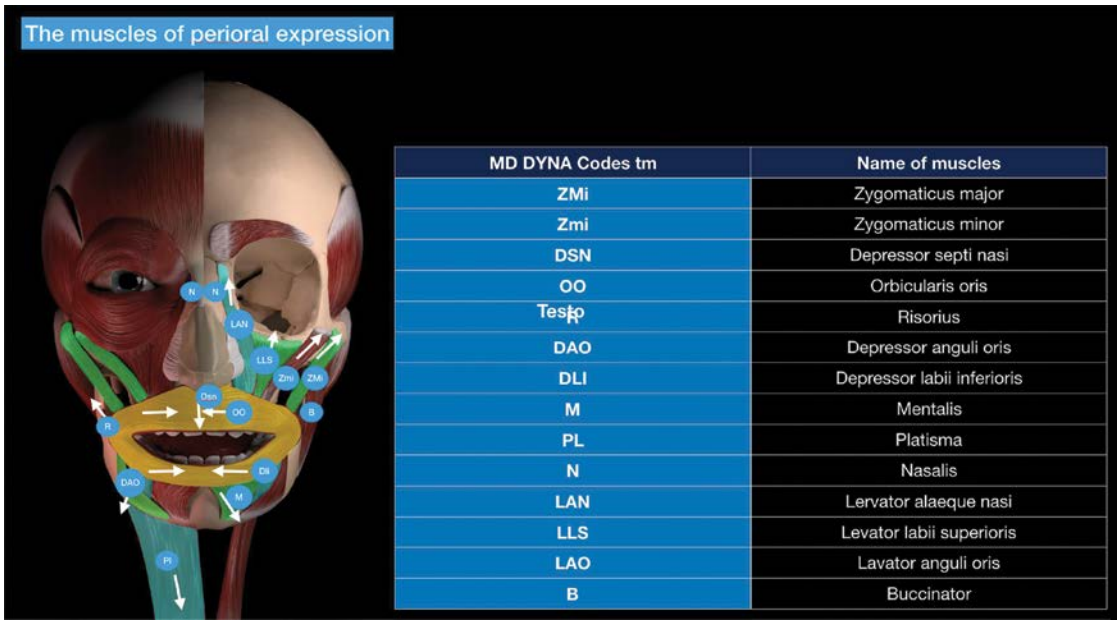
Table D.3 Details of Injection Delivery

Microaliquot 	Very small droplet of injectable (0.01–0.05 mL per point)
Aliquot 	Static injection of a small amount of injectable (0.1–0.2 mL)
Small bolus 	Static injection of injectable (0.1–0.3 mL)
Linear 	Anterograde or retrograde
Fanning 	Multiple linear injections via a single-entry site creating a fan-like pattern with needles or cannulae

MECHANISMS

The factors influencing the effect fillers may exert on muscle action (mechanical myomodulation) (see Figure D.5) include:

- Functional muscle groups
- Agonist and antagonist pairs
- Tissue resistance
- Volume loss



MD DYNA Codes tm	Name of muscles
ZMi	Zygomaticus major
Zmi	Zygomaticus minor
DSN	Depressor septi nasi
OO	Orbicularis oris
Testo	Risorius
DAO	Depressor anguli oris
DLI	Depressor labii inferioris
M	Mentalis
PL	Platisma
N	Nasalis
LAN	Lervator alaeque nasi
LLS	Levator labii superioris
LAO	Lavator anguli oris
B	Buccinator

Figure D.3 The MD DYNA Codes detailing the specific muscles implicated in facial muscle excursion.

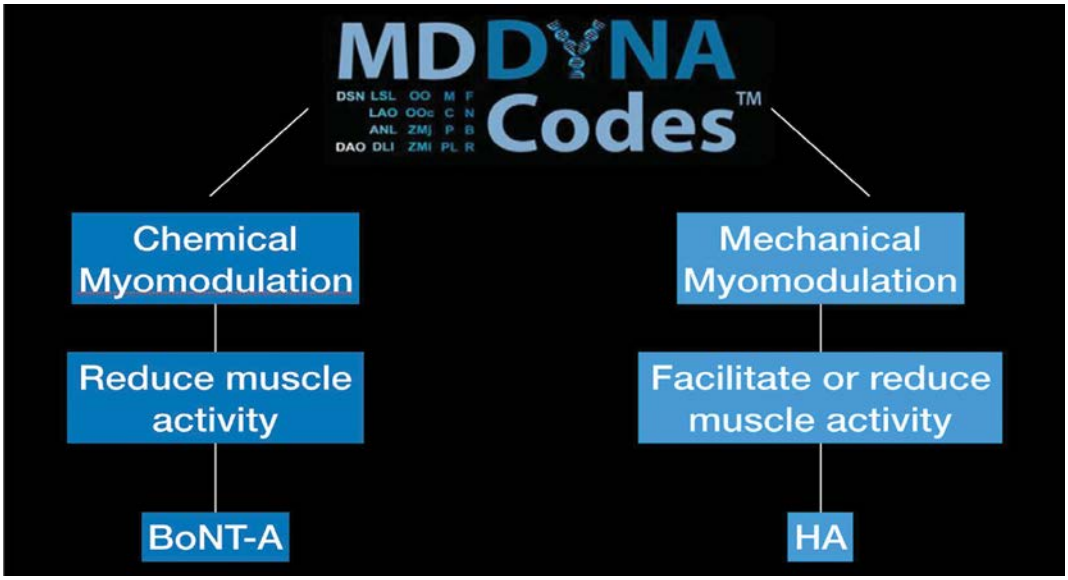


Figure D.4 The MD DYNA Codes differentiating chemical and mechanical myomodulation.

- Superficial muscolar aponeurotic system (SMAS) expansion

Factors potentially inhibiting muscle strength include:

- Adding tissue resistance above the muscle
- Injecting directly into the muscle to create a muscular block

Factors potentially facilitating muscle strength include:

- Injecting beneath a muscle to create a “pulley effect”
- Increasing tensile strength by stretching the muscle
- SMAS expansion

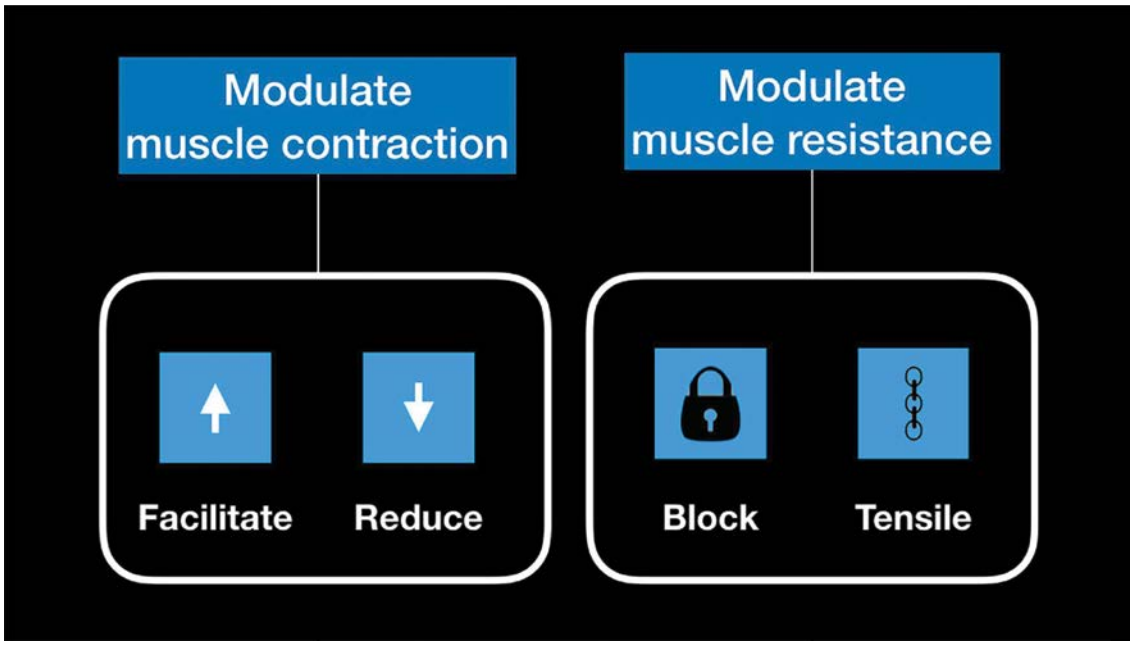


Figure D.5 Mechanisms of myomodulation.

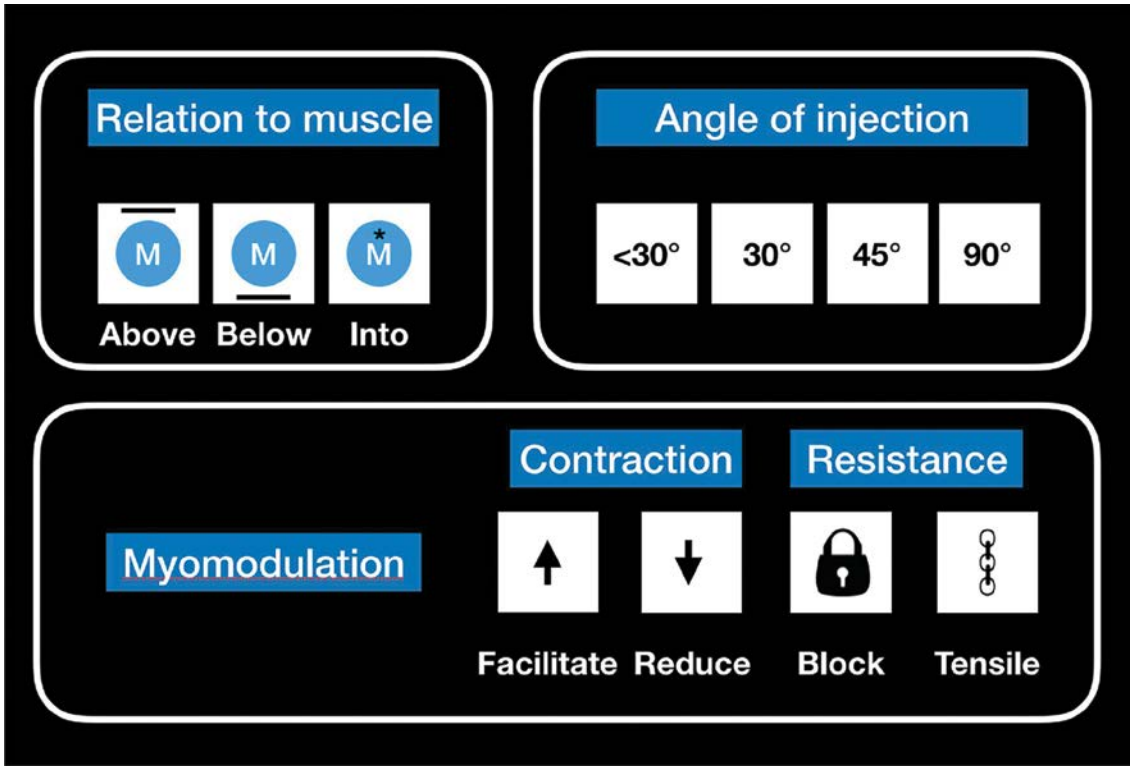


Figure D.6 Language of the MD DYNA Codes specifying placement relative to muscle, angle of injection device relative to skin and proposed mechanism of action: M, muscle.

The MD DYNA Codes specify both the placement for the desired mechanism (above, below, or in the muscle) and required technical details (angle of needle or cannula to the skin) (Figure D.6).

FUNCTIONAL ANATOMY

It is important to know the origins and insertions of the facial muscles (see Tables D.4–D.6) [6].

The skull insertion points [10] are shown in Figure D.7.

It is imperative that the injector have knowledge of anatomical layers and an understanding of the differential effect of injecting above or below a muscle. This is especially important in the midface, where incorrect placement may negatively impact animation and upper-lip length. The layers of the midface comprise:

- Skin
- Subcutaneous fat
- Orbicularis oculi
- SOOF
- Levators of upper lip
- Deep malar fat pad
- Bone

Functional Muscle Groups

Agonist and antagonist groups function synergistically, with levators and depressors working in opposition for normal, balanced facial expression (Figures D.8 and D.9) [11]. Levator strength generally predominates in youth, thus maintaining the position of soft tissue structures and counteracting downward gravitational pull and depressor antagonists. In youth, this balance may be disrupted by underlying structural deficiencies, while loss of bone and/or soft tissue become an increasing problem during

Table D.4 Muscles of the Upper Face [7]

Muscle	Origin	Insertion	Function
Temporalis	Temporal lines on the parietal bone of skull and the superior temporal surface of the sphenoid bone	Coronoid process of the mandible	Functions to elevate and retract the mandible
Elevators			
Frontalis	Galea aponeurotica along the coronal suture	Superciliary skin, where it interdigitates with the brow depressors	Inferior: elevates the brow Superior: causes descent of anterior hairline
Depressors			
Procerus	Periosteum of the nasal bone near the medial palpebral ligament	Glabellar or mid-forehead dermis; merges with frontalis	Depressor of brow with two contraction patterns 1: Lowers lateral end of brow 2: Produces lateral eyelid crow's feet
Depressor supercilii	Nasal portion of the frontal bone	Dermis beneath medial head of brow	Moving and depressing brow
Corrugator supercilii	Medially and deep along nasofrontal suture/supraorbital ridge of frontal bone	Interdigitating with frontal muscle and inserting in the midbrow skin	Approximation and depression of brows; creating vertical glabellar lines
Orbicularis oculi	Medial orbital margin, medial palpebral ligament, anterior lacrimal crest	Preseptal segment inserts into dermis of upper eyelid and brow	Thick orbital part closes eyelids tightly; thin palpebral part closes eyelids lightly

Table D.5 Muscles of the Midface [8]

Muscle	Origin	Insertion	Function
Levator labii superioris alaeque nasi (LLSAN)	Upper frontal process of maxilla, medial infraorbital margin	Skin of lateral nostril and upper lip	Dilates nostril, elevates and inverts upper lip "Elvis muscle"
Levator labii superioris	Broad sheet, medial infraorbital margin; extending from side of nose to zygomatic bone	Skin and muscle of upper lip	Elevates upper lip
Zygomaticus minor	Lateral part of zygomatic bone medial to zygomaticus major	Skin of lateral upper lip; extends to nasolabial sulcus	Pulls the upper lip backward, upward, and outward Aids in deepening and elevating the nasolabial sulcus
Zygomaticus major	Temporal process, anterior zygomatic bone	Temporal process, anterior zygomatic bone	Elevates and draws angle of mouth laterally
Risorius	Pre-parotid fascia	Modiolus	Draws back corner of mouth

Table D.6 Muscles of the Lower Face [9]

Muscle	Origin	Insertion	Function
Depressor labii inferioris	Line of mandible between mentonian symphysis and mental foramen	Orbicularis muscle and skin of lower lip	Depresses lower lip
Depressor anguli oris	Oblique line of the mandible and mandibular tubercle	Modiolus	Depresses corners of mouth
Mentalis	Upper mentonian symphysis and mental fat compartments	Orbicularis oris and skin of lower lip	Elevates and projects lip outward
Platysma	Deep fascia of upper thorax	Lower border of mandible	Depression of mandible

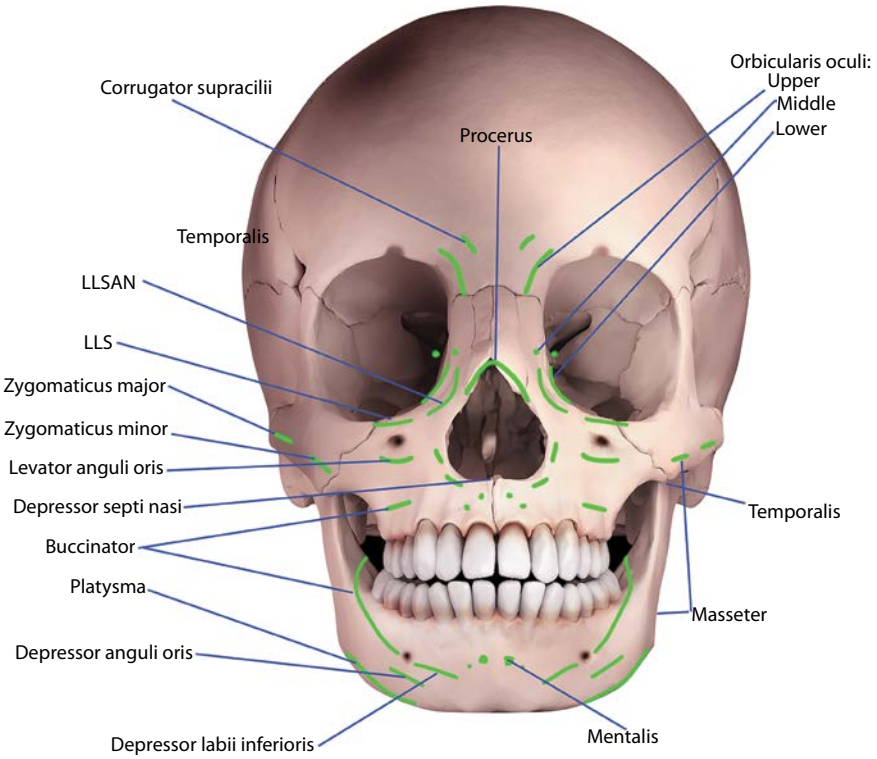


Figure D.7 Points of muscle insertion on the skull.

Figure D.8 Midface levators and synergists.

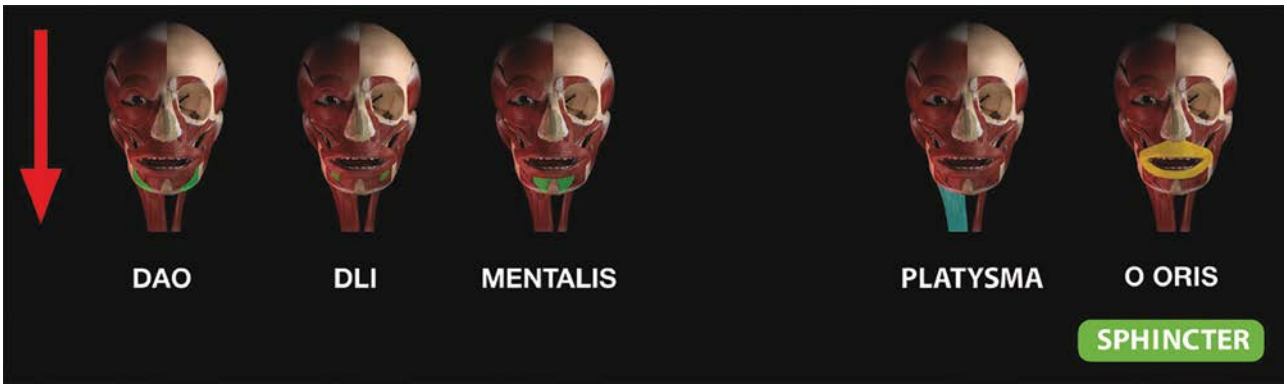


Figure D.9 Lower face depressors.

the aging process. With the loss of levator strength, depressors are more likely to predominate [12].

Factors Influencing the Angle of the Mouth/Smile

In youth, the zygomaticus major plays a critical role in tilting the angle of the mouth when smiling. When zygomaticus major lifting power is reduced due to a lack of underlying structural support, the relative role of the risorius muscle increases, producing a more horizontal smile. On further diminution of zygomaticus major lifting capacity, the depressor anguli oris (DAO) predominates with a resultant "DAO smile" (downturned angles of the mouth; Figure D.10). The lack of tissue resistance leading to a DAO smile may be age-related or secondary to structural deficiency in youth.

The Periorbital Area

As with muscles elsewhere in the face, the periorbital muscles are connected by the SMAS. Lending support to one periorbital area—for example, on the temporal bone beneath the orbicularis oculi—may therefore impact both adjacent and distant areas, thus impacting brow position and horizontal frontalis lines.

In addition, orbicularis oculi and levator palpebrae superioris function as antagonists. Supporting a weakening orbicularis oculi—for example, by placing volume on the temporal bone or lateral zygoma—may effect improved upper eyelid function, improve lateral scleral show, and reduce compensatory frontalis action. Lateral cheek support may also facilitate eye closure, thus serving great practical purpose in facial palsy patients.

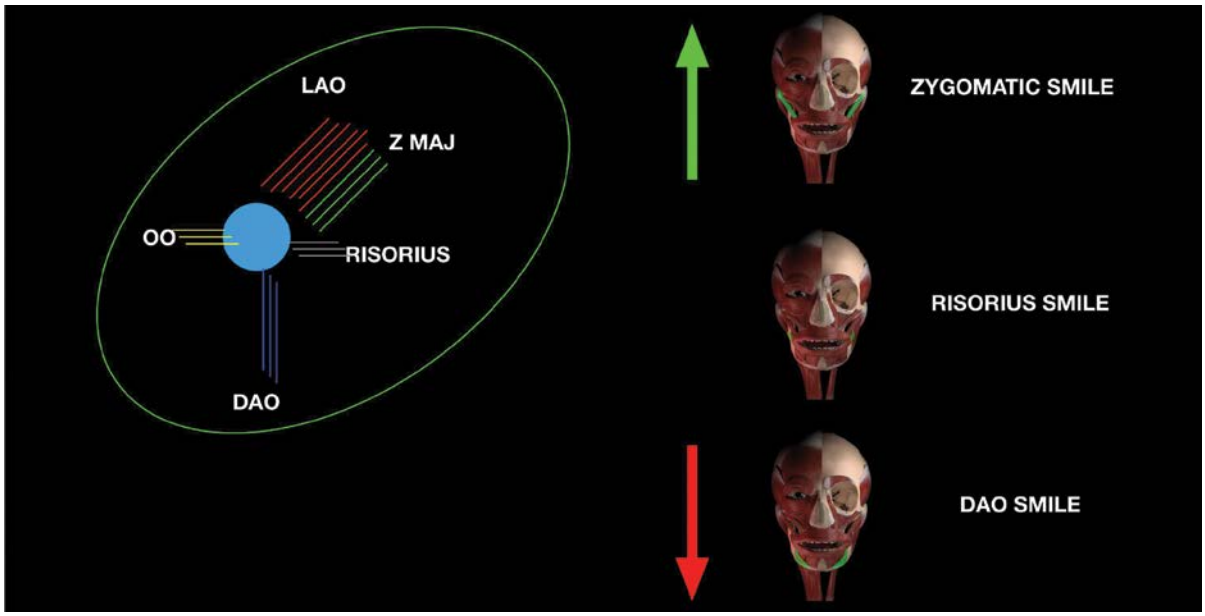


Figure D.10 Smile patterns as mediated by the relative balance of elevators and depressors. Blue circle, modiolus.

Indirect effects of treating the lateral zygoma (Ck1,2) include:

- Shortening the lid–cheek junction
- Improving the intercanthal angle
- Normalizing the position of the brow
- Enlarging eye size
- Improving horizontal forehead lines
- Improving the nasolabial fold
- Improving the jawline

See also Figure D.11.

The Perioral Area

Adding tissue resistance over the mentalis muscle (C1) inhibits upward rotation of the chin, increases vertical height and may also influence lower-lip eversion, as illustrated in a recent study detailing reduction in size of thick Asian lips by adding volume to the chin area [13]. Adding resistance over the DAO inhibits its downward traction, while layering product over the orbicularis oris and DAO are invaluable methods for balancing the perioral region in facial

Figure D.11 The indirect effect of filler placement in the deep temporal region (T1), lateral zygoma (Ck1), and lateral cheek (Ck4) on adjacent and distant muscles. Note the improvement in upper eyelid function and the reduction in forehead lines. No botulinum toxin was used. (Left) Before; (right) after.

Figure D.12 Improvement of upper lip rhytides after layering HA over the DAO and orbicularis oris. (Left) Before; (right) after.

palsy patients where asymmetry on smiling and phonation may drastically reduce quality of life. Adding resistance over the orbicularis oculi may inhibit upper lip rhytides (Figure D.12).

The upper lip levators function as a synergistic group. Strengthening zygomaticus major and minor function by adding support in the lateral cheek (Ck1,2) may thus indirectly improve a gummy smile by inducing relaxation of the LLSAN.

When treating the upper cutaneous lip (Lp8), also treat Lp[1] where indicated to provide deep support and prevent undue flattening of the vermilion lip.

When balancing a "joker's smile" (overactive zygomaticus major):

- Treat Ck4 to stretch the risorius, thus improving its tensile strength.
- Place Ck1 points posterior to the bony suture, facilitating less strengthening of the zygomaticus major.

HOW I DO IT

For chin wrinkling/expressing disappointment, see Figure D.13.

For gummy smile, see Figures D.14–D.16.

For perioral lines, see Figure D.17.

For the treatment of facial palsy with toxins:

- Document meticulously with photographs and videos both at rest and in animation.
- Assess for underlying residual facial nerve function on the palsy side, e.g., platysma, zygomaticus major.
- Treat the hyperdynamic side of the face with toxins in order to counter the Hering-Breuer reflex; proceed conservatively in the perioral area to minimize functional discomfort.
- Follow up at 2 weeks for possible top-up with toxins.
- Caution that phonation and chewing may initially be affected and warn against inadvertent lip biting and drooling.

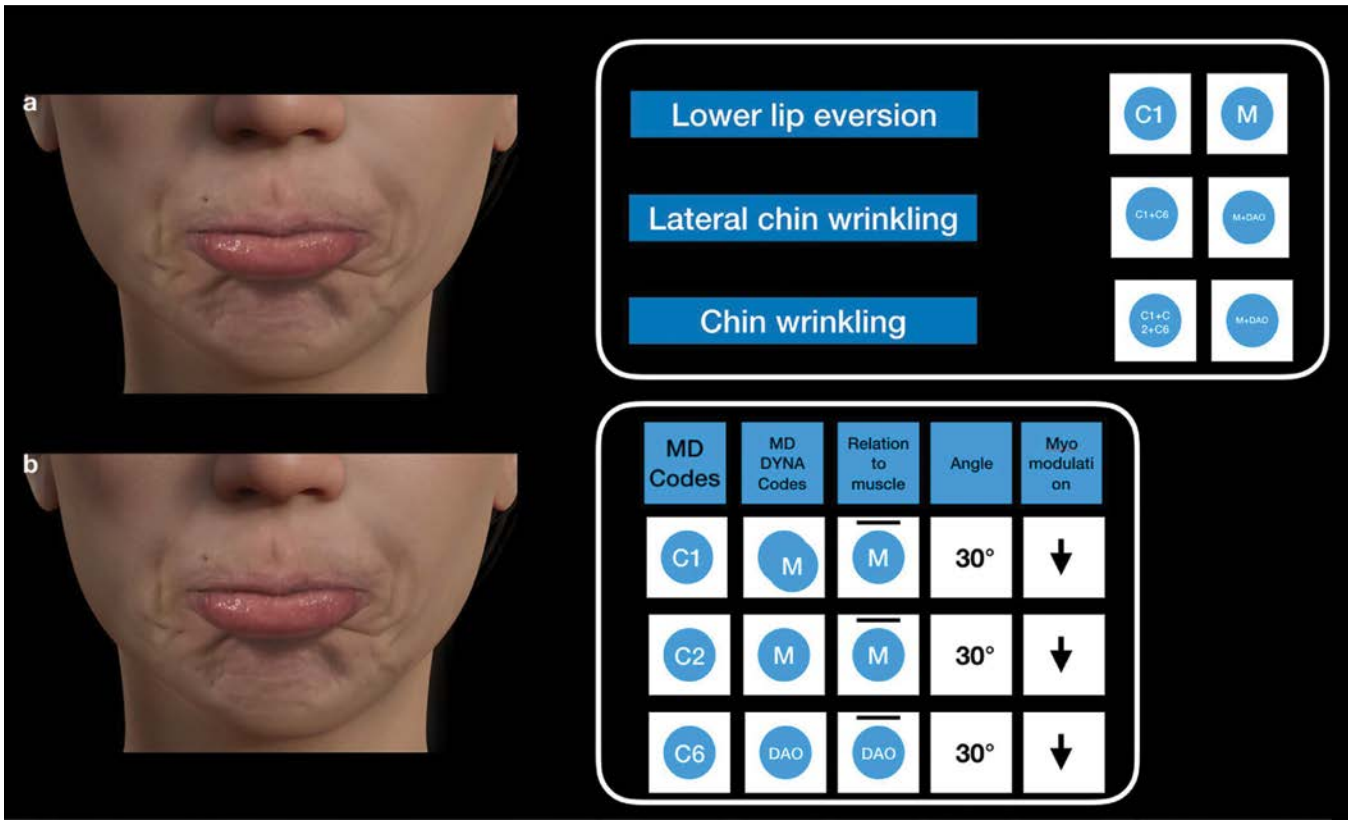


Figure D.13 (a) Codes; (b) technique.

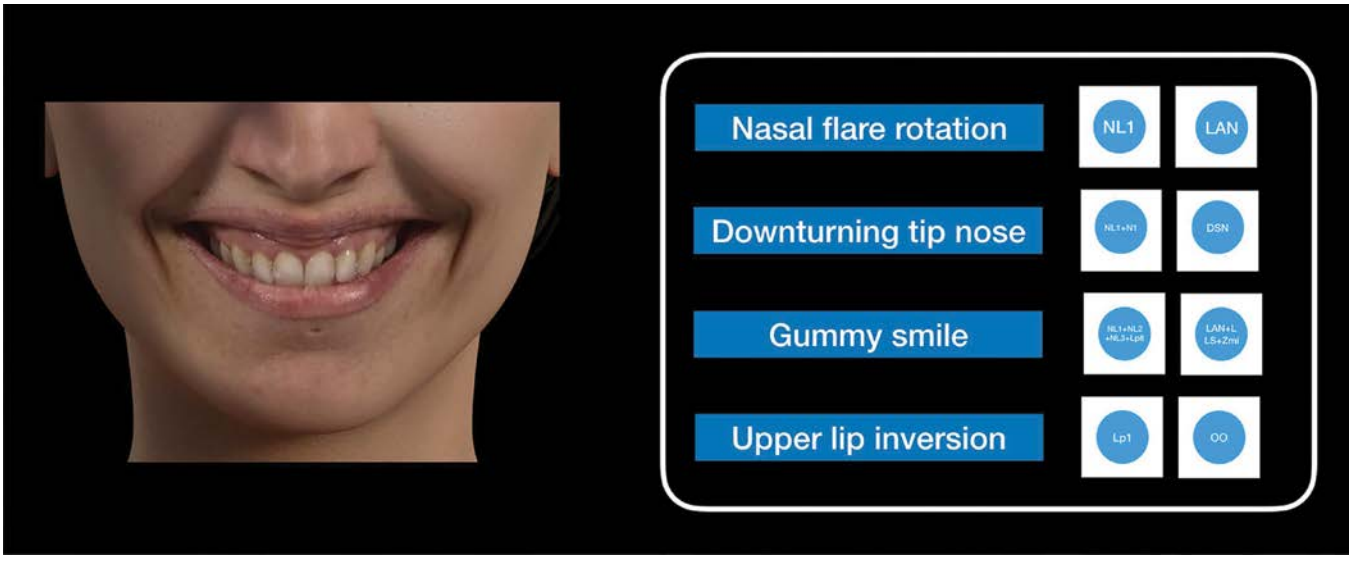


Figure D.14 Codes for gummy smile.

- Encourage chewing on the weaker side in an attempt to recruit muscle strength.
- Myomodulation with fillers may be attempted at 1 month after toxin treatment. See also Figure D.18.

Fillers may be used to rebalance the face in cases of facial palsy, thus contributing significantly to quality of life. Figure D.19 illustrates salient clinical observations over a 6-month period before and after a single

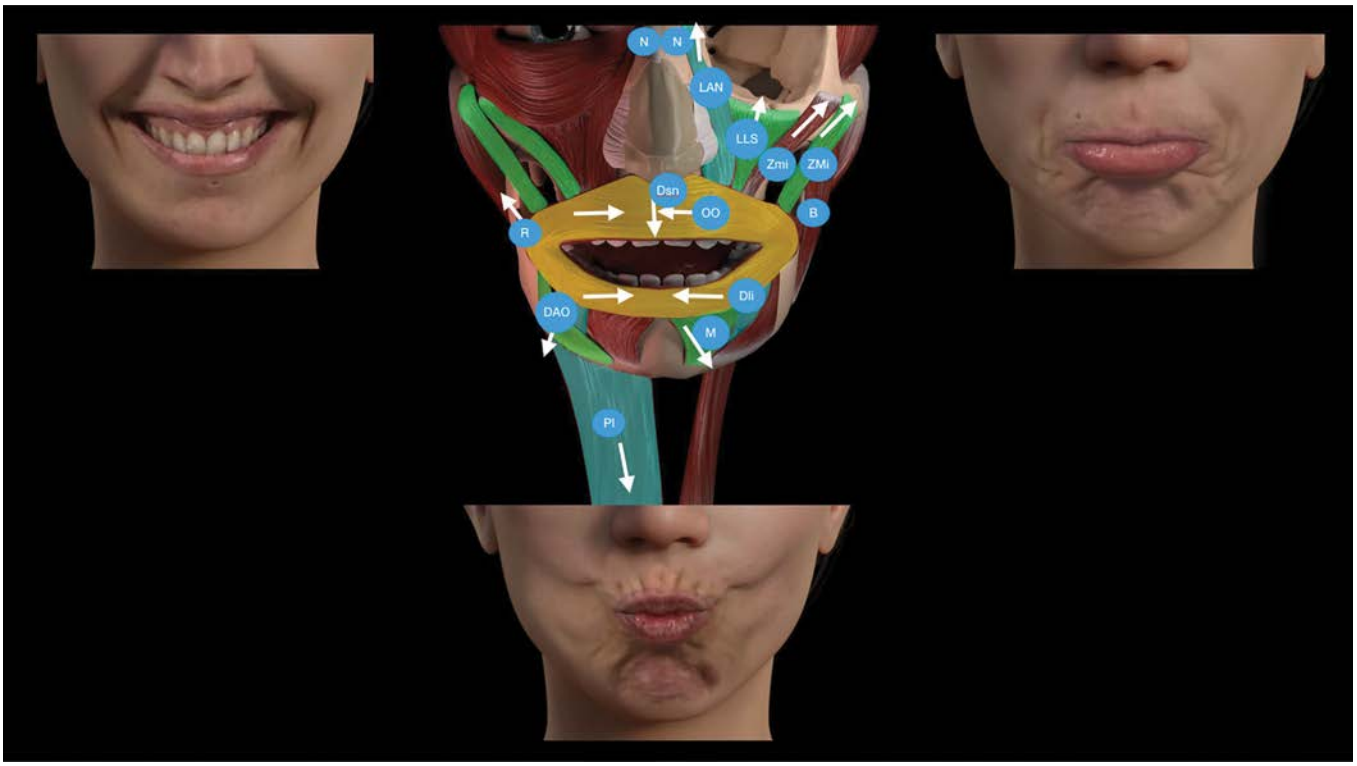


Figure D.15 Muscle vectors to consider when treating a gummy smile.

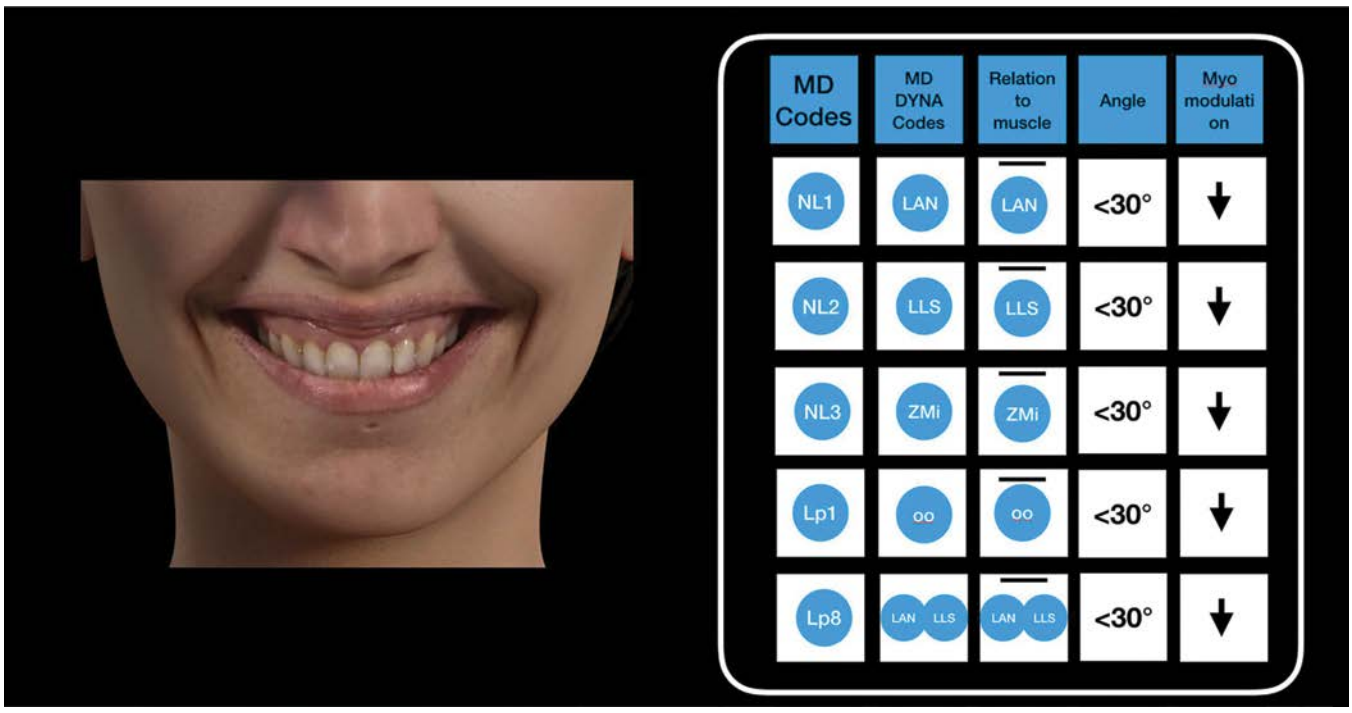


Figure D.16 Treatment Codes for addressing a gummy smile.

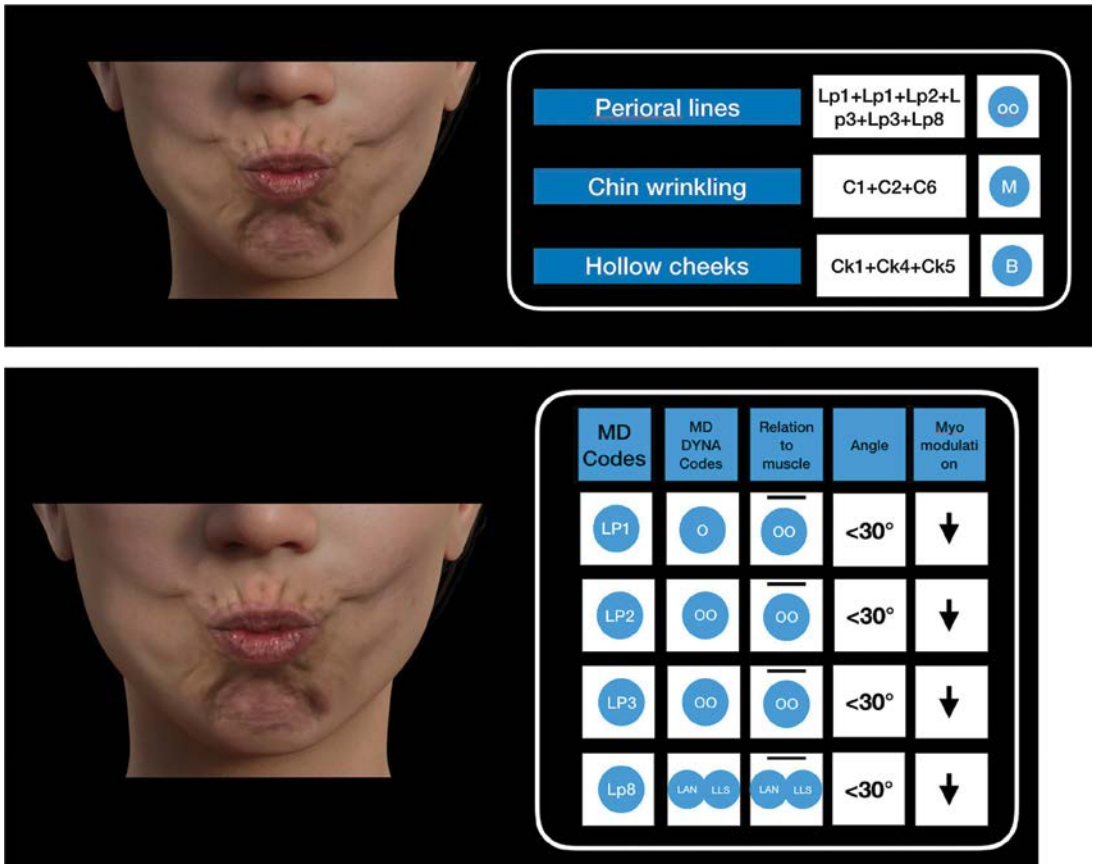


Figure D.17 Codes and technique for perioral lines.

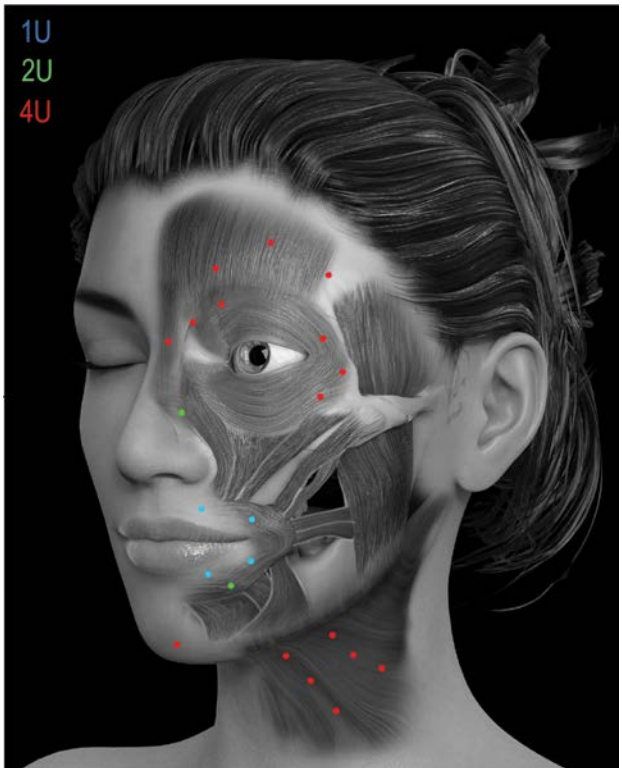


Figure D.18 Potential botulinum toxin treatment areas in facial palsy.

treatment with fillers based on myomodulation principles. Note that no toxins were used.

The main details before treatment are shown in Table D.7.

Treatment was according to the principles of myomodulation (Figure D.20).

The main details after treatment are shown in Table D.8.

COMPLICATIONS

- Injecting filler above the upper-lip levators may lead to an undue lengthening of the upper lip, especially in patients with structural deficiencies and a lengthened upper lip at baseline.

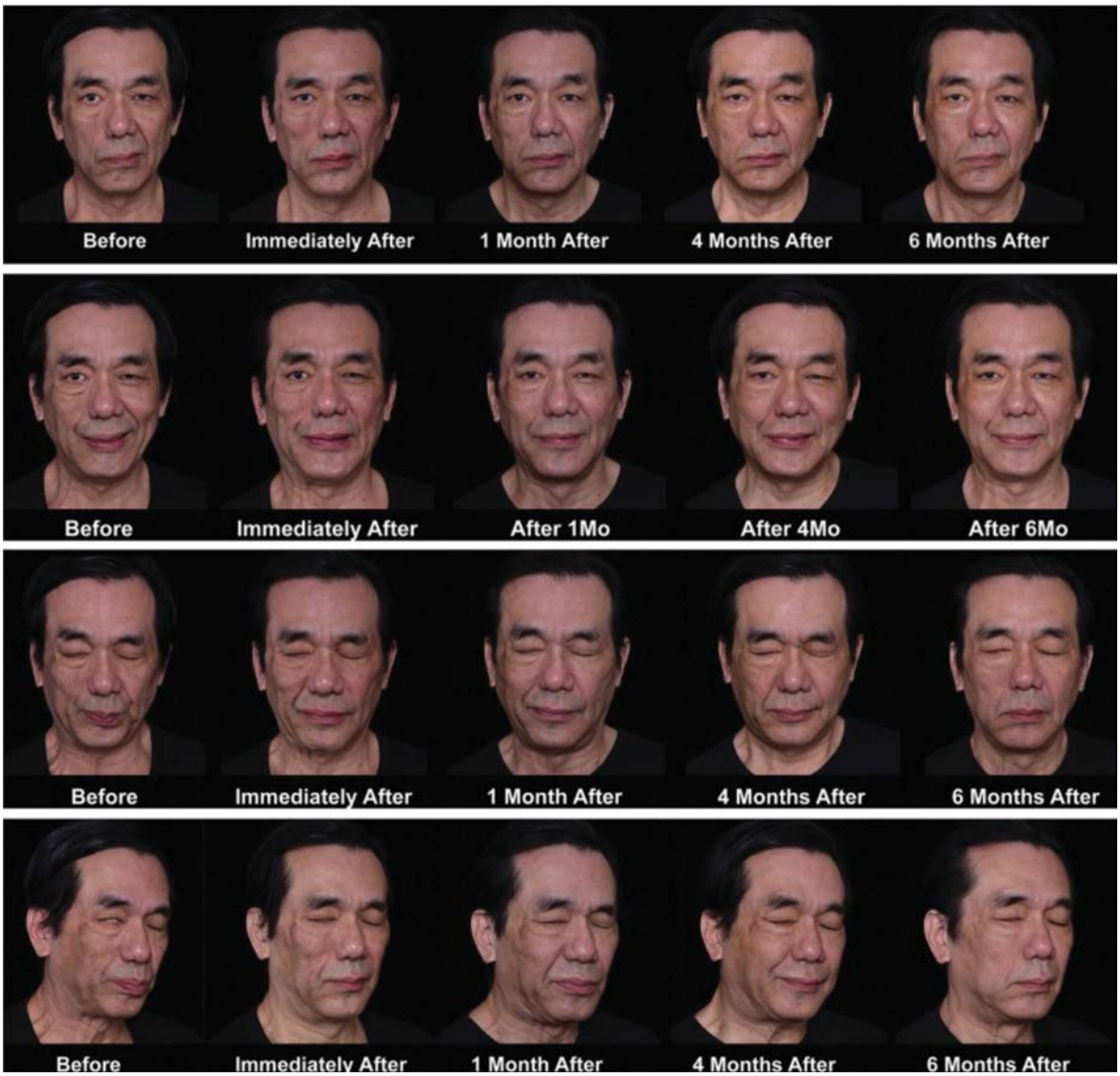


Figure D.19 The evolution of facial symmetry and muscle function upon smiling during the 6 months following treatment with mechanical myomodulation in a patient with facial asymmetry post-surgery for an acoustic neuroma.

Table D.7 Clinical Details of Patient's Left and Right (Palsy) Sides Before Treatment

Left Side	Right Side (Palsy Side)
• Deviation of mouth/oral commissure to L • Prominent nasolabial fold • Narrower eye	• Scleral show as patient tries to close eyes • Excessive activation of orbicularis oris and platysma activity on attempting to close eyes • Some platysma activity on smiling, signaling residual VII activity

- Injecting below the upper-lip levators may increase muscle action, aggravating a gummy smile.
- Injecting over the muscles of phonation (DAO, depressor labii inferioris, mentalis, and upper-lip levators) may initially influence speech; it is prudent to warn patients beforehand.
- Large volumes placed above the upper-lip levators may lengthen the upper lip or induce an unnatural smile.

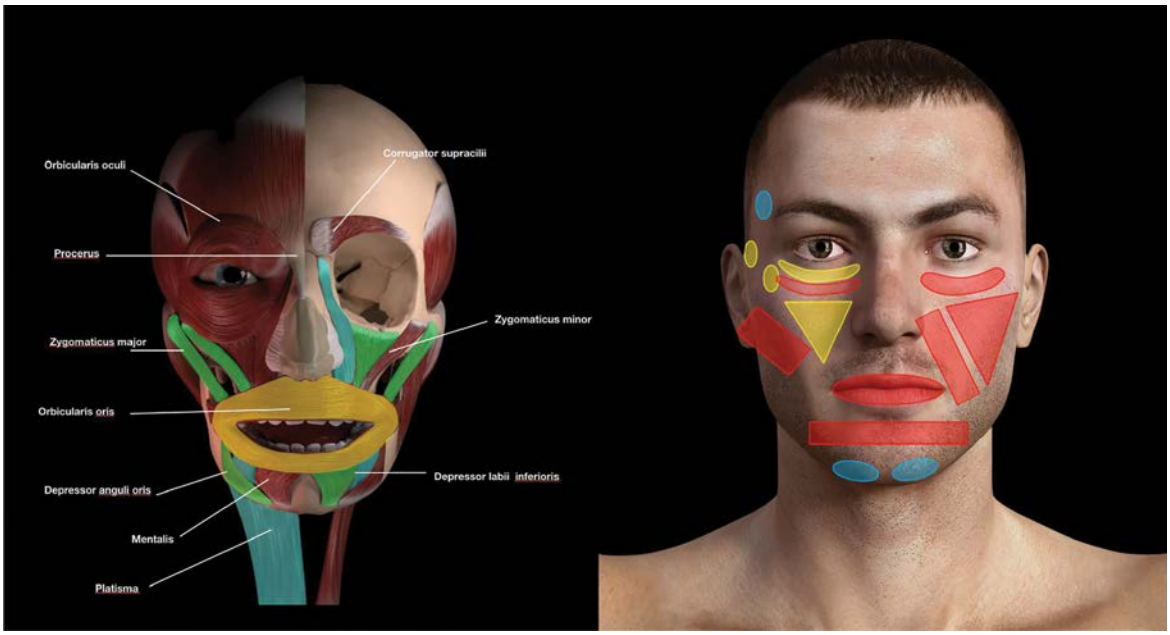


Figure D.20 Treatment areas and target muscles. Injection depth is indicated by red (superficial to muscle), yellow (under muscle), or blue (structural injections).

Table D.8 Clinical Details of Patient's Left and Right (Palsy) Sides After Treatment

Left Side	Right Side
• Reduction in the upper lateral excursion of the zygomaticus major muscle on his left side • Improved facial symmetry • Oral commissures more balanced	Immediately after treatment • Better positioning of the oral commissure, upper and lower lips • Deeper NLF on R due to increased lever effect on Upper lip levators • Less scleral show • Better alignment of the oral commissures One month after treatment • Contraction of zygomatic muscles facilitated • Less recruitment of platysma At 6 months • Closing eye with less recruitment of zygomaticus major

- Treating NL1 and Lp8 will block levator anguli oris (LAO), thus improving a gummy smile, but lengthening the upper lip in patients with a long upper lip.
- Placement below the upper-lip levators will strengthen muscles, thus elevating and everting the upper lip, but may worsen gummy smile.

TOP 10 TIPS

1. In complex asymmetry, consider using HA fillers as an adjunct to treatment with botulinum toxin.
2. Fillers may either facilitate or reduce muscle activity, thus differing from botulinum toxin, which promotes a temporary flaccid paralysis.
3. Always treat the lateral vectors (Ck1, Ck4) first in order to mitigate the gravitational sagging which weakens elevators, thus facilitating depressor action.
4. Work consciously with the concept of synergists and antagonists.
5. The upper-lip elevators function synergistically. Strengthening one muscle (e.g., zygomaticus major) may induce relaxation of others

(e.g., LAO), thus improving a gummy smile by treating the lateral cheek vectors first.

6. Boluses injected with a needle on bone usually facilitate muscle movement via a lever or pulley effect.
7. Fanning with a cannula above muscles in the subcutaneous zone usually reduces muscle movement by stretching fibers and adding tissue resistance. However,
8. Exceptions to this rule include
   - Muscle block with needle on bone in LLSAN, e.g., when treating a gummy smile.
   - Increasing tensile strength of risorius when fanning over buccinator.
9. Be aware of the angle of needle/cannula when applying myomodulation principles.
   In the midface,
   - A ∼30° cannula angle to skin will lead to placement in the SOOF (i.e., superficial to upper-lip levators).
   - A ∼60° cannula angle will facilitate deposition in the deep malar fat pad (i.e., deep to upper-lip levators).
10. Respect your learning curve; do not attempt treatment of facial palsy patients unless you are able to correct asymmetry in normal patients. This holds true particularly for addressing the smile.

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E BOTULINUM TOXINS

Massimo Signorini, Alastair Carruthers, Laura Bertolasi, Neil Sadick, Wolfgang G. Philipp-Dormston, and Dario Bertossi

MOLECULAR STRUCTURE AND MODE OF ACTION

Clostridium botulinum is an anaerobic, gram-positive bacterium that secretes an extremely large neurotoxic molecule (900 kDa), which produces food poisoning or botulism. It is now also used in medicine to treat diseases according to Paracelsus's paradigm that the difference between a poison and a drug lies in the dose. Although seven different serotypes of the bacterium (A to G) are known, type A is the one mostly used for the production of clinical formulations. Type B also has clinical applications for those patients who may have developed clinical resistance to type A, but this is seldom the case in aesthetic treatments.

Of the 900 kDa natural molecule, only the central 150 kDa segment (the neurotoxic core) is responsible for its biological activity. The surrounding portions have no pharmacological activity and simply act as a protective shield ensuring unchanged toxin absorption from the host's gastrointestinal tract. These surrounding molecules are named accessory proteins and are both hemagglutinin and non-hemagglutinin in nature. Once the toxin has entered the host by ingestion or injection, the biological role of the accessory proteins is largely terminated and the 150 kDa neurotoxin comes into play. Here again, the structure is complex and each portion of the segment plays a relevant role.

The 150 kDa neurotoxic protein is divided into a 100 kDa heavy and a 50 kDa light chain. The heavy chain has a two-fold action. The first part (binding domain) links to the specific receptors at the level of the axonic presynaptic endings; the second (translocation domain) then carries the light chain through the membrane and into the actual nerve ending. Once there, the light 50 kDa chain accomplishes its task by cleaving a group of proteins, named SNARE, which are responsible for the release of the neurotransmitter acetylcholine. Inhibition of acetylcholine release impairs muscular contraction and flaccid paralysis ensues. The effect of botulinum toxin is only temporary, and within a few months neuromuscular efficacy is spontaneously reestablished.

The details of this process have not been fully elucidated. For the purposes of this chapter, however, it should be made clear that regeneration always and completely occurs.

Interruption of neuromuscular transmission is not the only medical application of the drug. Indeed,

receptors for botulinum toxin are widespread in the human body and reach far beyond only neuromuscular junctions. Accordingly, the indications for the treatment have widened tremendously since its introduction 30 years ago. However, it is beyond the scope of this chapter to examine the present status of botulinum toxin in medicine, and from here onward, only aesthetic applications will be considered.

THE MUSCLES OF FACIAL EXPRESSION

With few exceptions, these muscles, often defined as mimetic, are the target of our treatments. Their role is to animate the face, thus allowing communication of feelings and emotions to the outside world. Most mimetic muscles feature a bony origin and a cutaneous insertion. During muscle exertion, the skin is tractioned toward the skeletal origin, causing wrinkles, lines, and furrows to appear on the surface with repeated contraction. Other mimetic elements have both origin and insertion on the skin, but here again, contraction generates surface irregularities. Muscles seldom function independently and more often interplay synergistically and variably with other muscles. This determines the unlimited nuances of facial expressions. Mimetic muscles are divided into two functional groups: elevators and depressors.

How does botulinum toxin step into the field? The answer is simple. In youth, the skin has full elastic properties and recovers promptly after each contraction, and the wrinkles and lines generated by the muscles of facial expression are accurately defined as dynamic. Over time, however, skin elasticity, strength, and resistance decrease, and muscle action eventually produces wrinkles, lines, and furrows that remain at rest. A static component thus becomes increasingly visible, harboring increasing aging.

Botulinum toxin treatment of mimetic muscles, also termed chemodenervation, requires a thorough knowledge of muscle anatomy. While routine aesthetic practice may require treatment of 20 to 30 muscles, treatment of patients with facial palsy may require treatment of additional muscles. The closely adjacent facial muscles lie mostly within the superficial muscolar aponeurotic system (SMAS) of the face and have a distinct three-dimensional structure and orientation. Precise injections of the drug are therefore essential in maximizing efficacy and minimizing complications. The dose is equally important. The injected units should ideally saturate the specific target receptors, leaving no unbound molecules free to move to nearby unwanted muscles. The clinician needs to understand that delivering suboptimal doses will negatively affect duration of result, although not giving rise to complications. Conversely, higher-than-recommended doses may significantly increase the rate of side effects.

Precision in botulinum toxin treatments is key to success. The injector must know the exact localization and depth of the target muscles and the ideal dose for combining efficacy and result. Another extremely important safety-related issue is diffusion rate. Ideally, the formulation with the lowest diffusion potential would guarantee the highest safety margin. In Europe, North America, and many countries, only three different formulations are available. Each of them has a robust literature claiming similar or better performances than its competitors, including the lowest diffusion profile. However, most of the papers are company sponsored and may lack objectivity. Although highly experienced injectors all have personal preferences, it is fair to state that these are often based on subjective impressions only and that to date there is no clear-cut superiority of one formulation over the others in terms of general performance. This is especially true when it comes to the diffusion rate. As long as a licensed product is preferred and correctly administered, efficacy and safety are guaranteed.

RECONSTITUTION

Presently, all licensed formulations are supplied as powders and require reconstitution with saline immediately prior to use. Although physicians are free to dilute according to personal preference, there are well-tested and universally accepted company recommendations. In Europe, licensed formulations are marketed in 50 U vials (Allergan's Vistabel and Merz's Bocouture) and in 125 U vials (Galderma's Azzalure). This raises the vital point that botulinum toxin units are not interchangeable between companies because the biological potency assay tests differ. This is an unfortunate confusion factor for novice injectors. However, there is general agreement that Allergan and Merz dosage units are reasonably comparable (1:1), and that Galderma units are equivalent to Allergan and Merz units in a 2.5:1 ratio. Thus, the Azzalure vial containing 125 U is more or less equivalent to the 50 U vial of Vistabel and Bocouture. Company recommendations from Allergan and Merz suggest diluting the 50 U vial with 1.25 mL of plain saline. This yields 4 U per 0.1 mL of solution. Galderma, on the other hand, has historically recommended a dilution of 0.63 mL per 125 U vial, thereby rendering a solution twice as concentrated as its competitors. It is beyond the scope of this chapter to discuss this rationale. It is fair to state, however, that the double concentration requires considerable extra care for dose precision and may thus obviate an otherwise excellent product. Recent literature has compared the efficacy and safety of Azzalure diluted at 0.63 mL versus 1.25 mL. The results with the 1.25 mL dilution have been as good, if not better, than with the double concentration. This allows the injector to dilute all three formulations with 1.25 mL of saline and to consider the potential of the resulting solution comparable to the others.

A few words should also be spent discussing injection pain. Although generally well tolerated, delivery of the drug may be unpleasant. In part, this is due to the needle, and the thinnest possible gauge size will help to minimize this component. While many injectors use a 30G, the 31–33G sizes may be preferable, although they dull quickly and require frequent changes. However, it is the solution that is mostly responsible for pain during injections. Some authors recommend nerve blocks, but these are possibly more aggressive than necessary. If available, preserved saline (NaCl 0.9% + benzyl alcohol 0.9%) should be used for dilution because the solution is almost pain-free without losing any of its pharmacological properties. Another option is to use plain saline + lidocaine for dilution. This will not impair the effect of the treatment and does reduce pain to some extent; however, preserved saline seems to be the best option.

Although companies recommend keeping the reconstituted solution at 4°C and injecting within 24 hours, both clinical experience and significant literature suggest that the solution remains active for weeks.

MANAGING PATIENT EXPECTATIONS

Careful patient assessment clarifies both the possibilities and limitations of individual treatments. Matching clinical assessment with realistic patient expectations is key to successful practice as careful pretreatment explanation will be generally well accepted, while belated explanations may be construed as excuses. Although botulinum toxin may lead to drastic improvement of facial lines, there may not always be complete eradication. Repeated treatments have been documented to enable longer-lasting results. Patients with very deep or resting frown lines should be realistically informed during initial consultation, and adjunctive treatments, such as careful intradermal injection of hyaluronic acid microdroplets, discussed upfront. Honest and straight-forward physician information helps to establish trust and develop sustainable patient relationships.