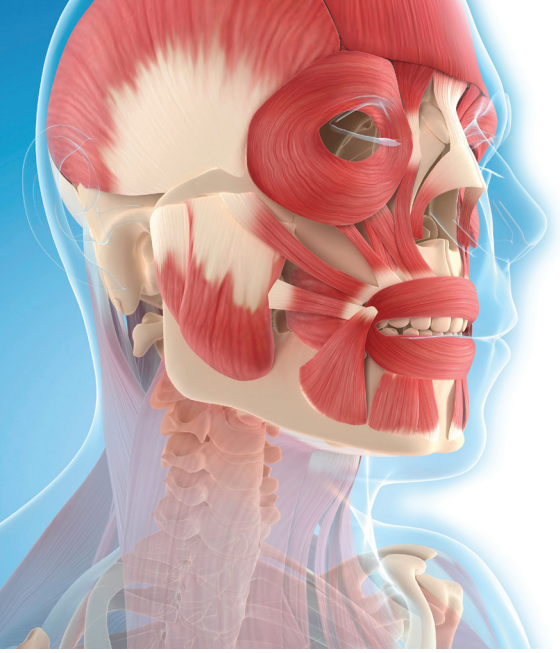

Anatomy

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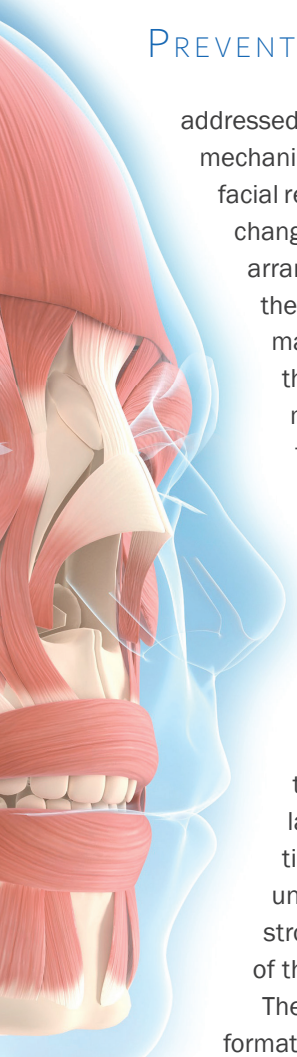
The demand for minimally-invasive aesthetic procedures for facial rejuvenation has soared in the past decade, leading to a strong increase in the number of neuromodulator and soft-tissue filler injections.[1] Simultaneously, the absolute amount of complications has risen ranging from mild to moderate and severe, with detrimental outcomes such as blindness, caused by intraarterial injection of soft-tissue fillers, retrograde advancement of the product within the ophthalmic artery circulatory system, and consecutive occlusion of the central retinal artery, being reported.[2]

Subsequently, in order to increase the safety, efficiency and efficacy of facial aesthetic treatments, efforts to increase awareness and understanding of the underlying facial anatomy have gained momentum. The anatomy of the face is extremely complex and delicate. Its bony structures protect the brain and provide stability for the overlying structures, muscles of facial expression facilitate communication, both verbally and non-verbally, via the expression of emotion and articulation, and muscles of mastication allow processing of food during the first steps of digestion. At the same time, due to its exposed visibility in social interaction, the appearance of the face reflects an individual's age by displaying several signs of ageing. Facial features are often employed during categorization of individuals into age groups.

Prior to performing aesthetic procedures in the face, physicians should acquire a profound understanding of facial anatomy and knowledge of the pathophysiology involved in facial ageing. Analysis of the underlying anatomy should be an elemental part of patient assessment prior to treatment. This chapter provides an overview of facial anatomy, the age-related changes of the face, and presents the clinically relevant anatomy for procedures for facial rejuvenation, based on facial regions.

The layered arrangement of the face

Anatomy of the face can best be understood when regarding its classic layered fascial arrangement. Breaking down facial anatomy to different layers provides a reliable navigation system around the facial fat compartments, muscles, fascias, ligaments and the sensitive neurovasculature. The layered arrangement of the face is continuous from upper to lower face, with regional differences that will be



addressed within respective chapters. The pan-facial connection of fascial layers has biomechanical implications which are utilized within new treatment concepts of injections for facial rejuvenation.[3-5] With regard to the medial and lateral face, the fascial arrangement changes from a strictly parallel (lateral), to a more obliquely orientated and interwoven arrangement (medial) at the so-called line of ligaments. This vertical line extends from the temporal crest (lateral to the lateral orbital rim) to the mandible and connects major ligaments of the face: the temporal ligamentous adhesion, the lateral orbital thickening (the lateral thickening of the orbicularis retaining ligament), the zygomatic ligament and the mandibular ligament.[6] These ligaments are anchored at the periosteum and branch into multiple connective tissue fibers superficially.

Generally speaking, from superficial to deep, the face is composed of the following continuous tissue layers: Skin (layer 1), subcutaneous fat (layer 2), superficial musculo-aponeurotic system (SMAS, layer 3), deep fat (layer 4), deep fascia or periosteum (layer 5). The skin is the first protective barrier of the face. It contains sebaceous glands, sweat glands, hair follicle, arrector pilii muscles as well as sensory skin appendage providing for sensation, lubrication, heat loss and environmental protection.[7] The skin has variable thickness, depending on the facial region.[8] Exemplary, the infraorbital region is especially tender, the skin being very thin and transparent, thereby allowing the underlying orbicularis oculi muscle to shine through, causing the characteristic bluish pigmentation of the area. Furthermore, the skin presents with variable adherence to its underlying layers. Deeper layers within the periorbital and perioral regions show strong attachments with the dermal underside, thus facilitating the high mobility of the region required during verbal and non-verbal communication.

The subcutaneous fat is compartimentalized by fibrous septae which results in the formation of the superficial fat compartments, including the nasolabial and jowl, as well as the medial, middle and lateral cheek fat compartments. The superficial fat compartments can be found covering most of the face, apart from the tear trough region, the zygomatic arch or the lateral orbital thickening. Moreover, the compartimentalized fat architecture does not extend inferior and medial to the nasolabial or labiomandibular sulcus.[9] These sulci mark transition lines of the subcutaneous architecture of the superficial fat in layer 2.[10, 11] Two architectural types are differentiated. According to Ghassemi *et al*., Type I fat can be found lateral to the nasolabial and labiomandibular sulcus, where it is compartimentalized by fibrous septa that enclose the adipocytes, with loose adhesions between the skin (layer 1) and the SMAS (layer 3). Type II fat refers to the tissue found medial and inferior to the transition lines at the nasolabial and labiomandibular sulcus. It is composed of a dense and interwoven mesh of collagen and muscle fibers with interposed adipocytes and strong adhesions between the musculoaponeurotic system (layer 3) and the skin (layer 1).[12]

Cadaveric studies have demonstrated high mobility of the superficial midfacial fat compartments. These show inferior displacement during ageing

or soft-tissue filler injection (nasolabial and jowl), and cranial shift during facial expression such as smiling.[9, 13] From a clinical point of view, the mobility of the superficial fat compartments needs to be considered when injecting soft-tissue fillers. The increase in volume can enforce soft-tissue descent following gravitational forces. This can, for example, increase the visibility of the nasolabial sulcus which marks the strong inferior boarder of the nasolabial fat compartment. Inferior displacement of the nasolabial fat compartment causes a prolaps of the compartment over this boarder, aggravating the appearance of the nasolabial fold instead of alleviating it.

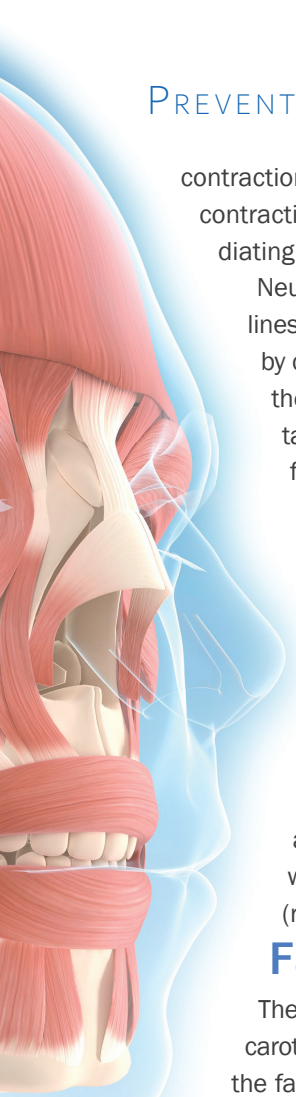
The superficial musculo-aponeurotic system (SMAS) is a continuous three-dimensional layer that separates the superficial from the deep fat. It is considered as an essential biomechanical unit that transmits contraction of the facial muscles to the skin. In addition is considered an autonomous functional unit with the ability to modulate facial expression, due to intrinsic nerve cells, vascularization and muscle fibers within the three-dimensional fibrous tissue network.[14] The superficial musculo-aponeurotic system continuously spans across the head and neck and is referred to as the superficial temporal fascia in the temple, the orbicularis oculi muscle periorbitally, the superficial musculoaponeurotic system (SMAS) in the midface, the platysma in the lower face and the superficial cervical fascia in the neck.[10]

Similar to the superficial fat in layer 2, the deep fat in layer 4 is compartmentalized and forms the deep facial fat compartments (*i.e.*, deep pyriform, deep medial cheek, deep lateral cheek, deep nasolabial, medial and lateral sub-orbicularis oculi fat). The boarders of these compartments are formed by the origin of the muscles of facial expression, by neurovascular structures enveloped in strong fascial sheets or by facial ligaments. The deep facial fat compartments provide support and projection of the overlying structures. Age-related volume loss of the deep fat compartments decreases the support, projection and stability of the overlying structures and contributes to the deflation of the face.[15] Compared to superficial fat compartments, the deep fat compartments remain stable in their position related to the underlying bone both during facial expression and facial ageing.[13, 15]

Layer 5 refers to periosteum or deep fascia, depending on facial region (*i.e.*, periosteum at the jawline or scalp; deep parotideo-masseteric fascia in the midface). The periosteum of the scalp and forehead is continuous with the deep temporal fascia in the temple and extends as the parotideomasseteric fascia in the midface until reaching the investing layer of the deep cervical fascia in the neck.[16, 17]

Facial musculature

The facial musculature can be differentiated in muscles of facial expression (*i.e.* zygomaticus major muscle) and muscles involved in mastication (*i.e.*, masseter or temporalis muscle). While the muscles of facial expression can be found medial to the line of ligaments, masticatory muscles are located lateral to it.[18] The distinctive musculature of the face allows for minute movements and manifold facial expressions. Most muscles originate deep from the bone and course superficially, intersecting different fascial layers and investing within the SMAS, with the dermal underside (*i.e.*, perioral region), or with each other to form complex muscle systems (*i.e.*, orbicularis oculi muscle complex).[19] The skin surface reflects the underlying muscle movements. Dynamic facial lines seen at the skin surface are the consequence of contraction of the underlying musculature. With respect to the muscle fiber orientation, horizontal, vertical and radiating contraction patterns can be differentiated. Generally speaking, the orientation of the rhytids on the skin surface is perpendicular to the muscle fascicle



contraction pattern. Exemplary, horizontal lines are caused by procerus or frontalis muscle contraction, vertical lines by corrugator supercilii muscle contraction, and peripherally radiating lines by orbicularis oculi muscle contraction.[20]

Neurotoxin injections are frequently applied to alleviate age-related glabella or frown lines. They inhibit the release of acetylcholine at the neuromuscular junction and thereby cause muscle paralysis.[21] Adverse events of neuromodulator treatments are often the consequence of paralysis of muscles that were not the intended primary injection target. Knowledge of the underlying musculature and their contraction axes is therefore vital to predict outcomes and to avoid collateral damage.

The zygomaticus major muscle deserves some special attention. It originates from the zygomatic bone, travels infero-medially until it inserts at the modiolus at the angle of the mouth directly beneath the skin. It is connected to the alveolar and zygomatic process of the maxilla via a strong connective tissue band – termed the transverse facial septum – thus forming the inferior boarder of the deep medial and lateral cheek fat compartments. Contracture of the zygomaticus major muscle causes an increase of tension within the transverse facial septum, increasing the projection of the midfacial fat compartments.[22] Prior to soft-tissue filler injections, patients should therefore be assessed dynamically, also during facial expressions such as smiling, to prevent overfilling of this region which becomes visible only after contraction of the zygomaticus major muscle (referred to as facial overfilled syndrome or “apple-cheeks”).

Facial vasculature

The head and neck have a rich vascular system, supplied by the internal and external carotid artery, with several anastomoses between the internal and external system in the face.[23] Major complications of soft-tissue filler injections result from intraarterial injection and consequent occlusion of terminal arterial branches, causing tissue hypoxia and ischemia. The ophthalmic artery is a branch of the internal carotid artery, supplying major vessels to the glabella (supraorbital and supratrochlear artery) and nose (dorsal nasal artery). Injection of a soft-tissue filler bolus into one of these arteries can cause devastating complications. If the pressure applied when injecting overcomes the arterial systemic blood pressure, the bolus is advanced retrograde through the ophthalmic artery circulatory system. Once the pressure is then released from the plunger, the product can advance forward and cause occlusion of the central retinal artery – a branch of the ophthalmic artery – causing blindness in short time due to ischemia of the retina.[24] While the glabella and nose are considered most high-risk areas for the advent of blindness, this complication is not only limited to direct intraarterial injections into the aforementioned vessels in these regions, but can also result from injections into the facial or angular arterial system anywhere else, due to the rich amount of anastomoses between the external and the internal carotid circulatory system.[23] The course of the facial vasculature within the respective fascial layers will be highlighted in the anatomical overview of the different facial regions below.

Facial ageing

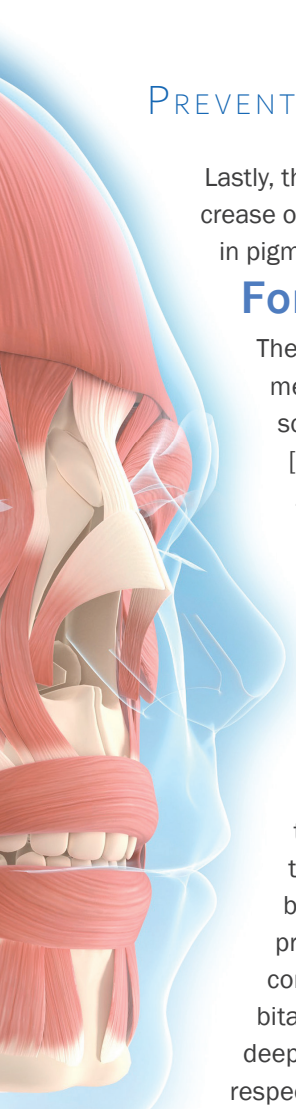
Age-related changes of the face include the increase of skin laxity (eye-lid hooding), the formation of static lines (*i.e.*, forehead, frown, glabella, periorbital and perioral), deflation of facial fat tissue causing hollowing (*i.e.*, periorbital, temporal) and a skull-like appearance, the descent of facial fat compartments (*i.e.*, nasolabial, jowls) increasing the prominence of the nasolabial and labiomandibular fold, as well as the formation of jowls. These changes seen at the surface of the face are the result of a series of multi-factorial processes involving the skin, fat, ligaments, muscles and bone.[10]

The facial bones play an imminent role in providing stability and structure to all overlying tissues, as many of the fascial and ligamentous structures are attached to it. Studies have revealed changes of the facial skeleton with increasing age, both of the neuro- and viscerocranium. Bone remodeling leads to loss of calvarial volume in the sagittal axis, irrespective of gender, in turn ultimately influencing the position of all overlying structures,[25] as the calvaria is the most superior attachment point for the continuous fascial layers. Following the downward pull of gravity, the change in the structure of the bony fundament facilitates the inferior displacement of the soft-tissue structures. In addition, age-related loss of midfacial height and anterior maxillary projection following rotational changes of the midfacial skeleton in the viscerocranium, supports caudal displacement of midfacial soft tissue with increasing age.[26] Finally, loss of alveolar height and dentation in the lower face reduces support to the lips and jowls.

The facial musculature experiences changes over time contributing to the appearance of an aged face. With increasing age, muscles show an increase of muscle tone in some muscles of facial expression, a decreased amplitude of movement, wasting and lengthening. Studies have investigated motor unit action potential (MUAP) by the means of surface derived non-invasive electromyography (EMG) which revealed an increase of MUAPS in the corrugator supercilii and procerus muscle, but a decrease in the zygomaticus major musculature in the elderly.[27] These functional changes contribute to the formation of rhytids (*i.e.*, glabella lines) at higher age and support the theory of diminished support for facial fat compartments due to loss of tension in bordering structures such as the zygomaticus major musculature.

Age-related changes of ligamentous structures of the face have yet to be clearly defined. First data suggest that facial ligaments also change their position during ageing.[28] Whether these changes are caused following structural changes of the ligaments themselves, are a result of remodeling of the underlying bone or caused solely by gravitational forces is yet unclear.

Independent of body mass, the overall facial fat mass decreases with age and shows deflation. This reduces facial volume, as well as support and stability of overlying tissues. Due to a lack of distinct anatomical boundaries and high mobility, the aforementioned morphologic changes of the facial tissues cause inferior displacement of the superficial nasolabial and jowl fat compartments with increasing age.[9] Inferior displacement of the nasolabial fat compartment contributes to the formation of a prominent nasolabial fold with increasing age. The fat prolapses over the nasolabial sulcus – the strong dermal depression at its infero-medial boarder, formed by the dermal insertions of the perioral/ facial musculature – and thereby increases its visibility. Inferior displacement of the jowl fat compartment leads to the formation of a further sign of facial ageing in the lower face – jowls deformity.[29] In addition, the inferior displacement of the midfacial fat compartments contributes to the formation of a more prominent labiomandibular sulcus by increasing the absolute fat tissue volume lateral it.



Lastly, the skin shows age-related changes including loss of elasticity and subsequent increase of skin laxity, loss of collagen, thinning of dermal thickness, dehydration, changes in pigmentation and skin texture.[30]

Forehead

The classic five layered fascial arrangement extends to an eight layered arrangement from the scalp to the forehead, as the galea aponeurotica (layer 3 in the scalp) splits into 3 distinct layers (supra-frontalis fascia [layer 3], frontalis muscle [layer 4], sub-frontalis fascia [layer 6]).[17] Most superficially lies the skin (layer 1), followed by the superficial frontal fat compartments (layer 2), the supra-frontalis fascia (layer 3), the frontalis muscle (layer 4), retro-frontalis fat (layer 5), sub-frontalis fascia (layer 6), pre-periosteal fat and deep fat compartments (layer 7), and periosteum (layer 8). Muscle contractions of the frontalis muscle are transmitted to the skin via a fascial sheet extending from the galea aponeurotica (supra- and sub-frontalis fascia).[17] In some patients, the muscle bellies are split by an aponeurosis, and fibers can extend lateral to the hairline. The tendon aponeurosis changes the muscle fascicle angle to a more lateral orientation, creating wavy forehead lines on the skin surface.[31] Importantly, the muscle exerts two distinct muscle functions depending on its vertical position on the forehead. While the lower frontalis fibers are the only elevator of the brow, the fibers located more cranially act as depressors of the hairline. At approximately 60% of the total forehead length, this bidirectional movement plane converges at the line of convergence (C-line).[32] The deep branches of the supraorbital and supratrochlear neurovasculature course within the retro-frontalis fat and deep to the frontalis muscle in the lower forehead, after their emergence from their respective notches or foramina at the bony orbit. During their course cranially, they change plane and travel within a more superficial layer, beneath the supra-frontalis fascia and therefore on top of the frontalis muscle, approximately 1.5-2.5 cm cranial to the supraorbital rim in the midline.[33, 34] Motor branches supplying the frontalis muscle can be found below the frontalis muscle, protected by the subfrontalis fascia.

Glabella and eyebrow

The layered arrangement of the forehead continues within the eyebrow and glabella region. Here, also eight fascial layers can be identified, including skin (layer 1), subcutaneous fat (layer 2), supra-frontalis fascia (layer 3), the frontalis/ orbicularis oculi muscle (layer 4), pre-septal and retro-orbicularis oculi fat (layer 5), deep fascia in continuation of the subfrontalis fascia (layer 6), pre-periosteal fat (layer 7), as well as periosteum (layer 8).

The mobility of the eyebrow and glabella region is determined mainly by the orbicularis oculi muscle complex, including fibers of the procerus, the corrugator supercilii, the orbicularis oculi, as well as the frontalis muscle which form a biomechanical unit.[20] The muscle fibers of the orbicula-

ris oculi complex are strongly connected to the overlying skin, allowing for meticulous movements. The eyebrow position is at balance between two antagonistic muscle groups, the eyebrow elevators (only frontalis muscle) and depressors (corrugator supercilii, procerus and orbicularis oculi muscle). Injection of neuromodulators in the glabella region will not only paralyze the targeted muscle or muscle groups, but also disturb this equilibrium and affect the position of the brow. Exact knowledge of the course of the targeted muscles is therefore required to reduce unpleasant results. The procerus muscle originates at the nasal bone in the midline. It courses cranially and inserts into the skin at the upper margin of the brow. The corrugator supercilii muscle also has a bony origin. It extends from the superciliary arch of the frontal bone and inserts the skin in the middle third of the eyebrow.[19] Terminal fibers of the frontalis muscle invest into the orbicularis oculi, corrugator supercilii and procerus muscle at the upper margin of the brow. Eyebrow ptosis, caused by paralysis of the eyebrow elevating portion of the frontalis muscle (injections placed too high, paralyzing frontalis fibers), "Spock" brow formation, caused by lateral hypercontractility (paralysis of medial muscle fibers only), and upper eyelid ptosis, caused by product migration through the supraorbital foramen with subsequent paralysis of the levator palpebrae superioris muscle (deep injections at the cutaneous insertion of the corrugator supercilii muscle).[19,20] Injection techniques to target specifically the muscle origins in the glabella region, to reduce collateral damage, have previously been defined.[35]

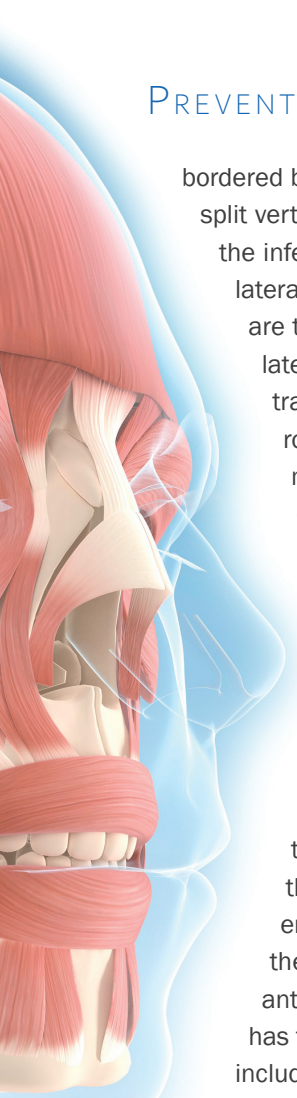
After emergence from the bony orbit, the supraorbital and supratrochlear neurovasculature travel within the ROOF caudally and the retro-frontalis fat more cranially, before they perform the change of plane.[34] Due to the rich vasculature in the glabella region, it is considered a high-risk region for soft-tissue filler injections.

Temple

A total of 13 distinctive layers determine the anatomy of the temple. These include: Skin (layer 1), subcutaneous fat (layer 2), superficial lamina of superficial temporal fascia (layer 3), deep lamina of superficial temporal fascia (layer 4), deep temporal fat (layer 5), innominate fascia (layer 6), loose areolar tissue (layer 7), superficial lamina of the deep temporal fascia (layer 8), superficial temporal fat pad (layer 9), deep lamina of the deep temporal fascia (layer 10), deep temporal fat pad (layer 11), temporalis muscle (layer 12) and periosteum (layer 13).[36] Notably, the deep temporal fat pad is the extension of the buccal fat pad of Bichat. Injection of soft tissue filler within this plane can cause product migration into the midface via this connection and cause masticatory pain. The neurovasculature courses within different levels in the temple. The superficial temporal artery can be found between the sheets of the superficial temporal fascia which provide a protective barrier. It emerges anterior and superior to the apex of the tragus and travels toward the forehead in a 45° trajectory. The deep temporal artery, however, courses beneath the muscle fibers of the temporalis muscle and can be injured during deep soft-tissue filler injections. The deep temporal fat protects motor branches of the facial nerve. The sentinel vein courses within the loose areolar tissue beneath the innominate fascia and can be injured when performing injections using the interfascial filler injection technique.[3]

Midface

The middle face is a highly delicate and complex region with defined anatomical boundaries. Superiorly, it is bounded by a line that connects the lateral canthus and the superior tragus. Inferiorly, it is



bordered by a line connecting the oral commissure and the inferior tragus. In addition, it is split vertically by the line of ligaments.[18] The medial midface is thus bound superiorly by the inferior orbital rim, by the lateral side of the nose medially, by the line of ligaments laterally, and the nasolabial sulcus inferiorly. The boundaries of the lateral midface are the zygomatic arch superiorly, the line of ligament ligaments medially, the tragus laterally, and the line between the oral commissure and the inferior aspect of the tragus at its inferior aspect.[18] In addition, the midface is further divided into the parotideo-masseteric and buccal region in the lateral midface, as well as the central midface medially.[11] This subdivision facilitates an increased understanding of the complex structures within the defined regions.

The parotideo-masseteric region includes five distinct layers. Most superficially it is composed of the skin (layer 1), followed by the subcutaneous fat compartments (superficial middle and lateral cheek fat compartments, layer 2), the SMAS (layer 3), deep spaces (inferior, middle and superior premasseteric spaces, layer 4) and finally the parotideo-masseteric fascia (layer 5).[37] Beneath layer 5, the parotid gland lies on top of the masseter muscle. In addition, branches of the facial nerve emerge beneath the parotideo-masseteric fascia protected within connective tissue sheets on their course medially, where they then connect to the SMAS. The fat pad of Bichat (buccal fat pad) can be found even deeper, below the masseter muscle, within the masticatory space. The facial vein canal, which envelopes the facial vein on its course superiorly, marks the anterior boarder of the masticatory space. The buccal space (layer 4 of the buccal region) is located anterior to the masticatory space (posterior boarder is the facial vein canal) and, has the facial artery travelling through it. The buccal region itself has 6 fascial layers, including skin (layer 1), subcutaneous fat (layer 2), SMAS/ platysma, (layer 3), buccal space (layer 4), buccopharyngeal fascia (layer 5) and the buccinator muscle (layer 6).[37]

The central midface, located medially, is composed of skin (layer 1), superficial subcutaneous fat compartments (superficial nasolabial and medial/malar cheek fat compartment, layer 2), SMAS (layer 3), deep nasolabial fat compartment (layer 4), levator labii superioris alaeque nasi muscle (LLSAN, layer 5), deep pyriform space, deep medial and deep lateral cheek fat compartment (layer 6) and periosteum (layer 7).[37] As stated previously, the deep fat compartments have strong borders, formed by the origin of facial muscles, neurovascular structures or by facial ligaments. The infraorbital neurovascular bundle emerges from the infraorbital foramen and marks the lateral border of the deep pyriform space and the medial boarder of the DMC. The angular vein forms the lateral border of the DMC and the medial border of the DLC. The zygomaticus major muscle borders the DLC laterally and forms the inferior border of both the DMC and DLC. Superiorly, the DMC and DLC are bound by the zygomatico-cutaneous ligament. Studies have found the angular artery to travel at various depth with the medial midface, however, its location was determined to be cranial and lateral to the nasolabial fold.[38]