History corner

About muscle insertions in man (Proposal for a new nomenclature of striated muscle)

A proposito delle inserzioni muscolari nell'uomo (Ipotesi e commento per una nuova nomenclatura dei muscoli striati)

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SUMMARY

Some plastic surgeons are limited in their technical knowledge on the mimetic muscle and conversely appear to vindicate a distinct priority in the problem of surgical rejuvenation, or, in general, in the effects of ageing, always involving the mimetic muscles included in the skin. Anatomists have worked better in research on mimetic muscles that we would like to indicate as *not inserted,* free to move in a different way from that of *inserted* or *semi-inserted*. Otolaryngologists and maxillo-facial surgeons, in the practice of surgery on the salivary glands, seem to have studied mimetic muscles before and in more detailed manner than plastic surgeons.

KEY WORDS: Striated muscles • New nomenclature

RIASSUNTO

Può darsi che alcuni chirurghi plastici abbiano dato un'importanza minore di quanto dovevano alla conoscenza dei muscoli pellicciai (mimici), largamente coinvolti nei problemi della moderna chirurgia di imbellimento facciale. Gli anatomici, al contrario, sembrano avere offerto contributi importanti ed insostituibili al problema dei muscoli appartenenti al sottocutaneo che dovrebbero essere considerati elementi non inseriti, a confronto di tutti gli altri, semi-inseriti o inseriti. Gli otorinolaringologi ed i chirurghi maxillo-facciali, obbligati alla pratica sulle ghiandole salivari, hanno studiato i muscoli pellicciai (mimici) non inseriti, in modo più approfondito dei chirurghi plastici.

PAROLE CHIAVE: *Muscoli striati • Nuova nomenclatura*

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While convinced of the need of a wide range of bibliographic references, as a sequel to articles that we have published since 1987, which were based on research accomplished by Sterzi [1], in 1910, we would like to introduce a new concept, largely inspired by existing texts, related to the nomenclature of the voluntary muscles.

The anatomy of human muscle, being almost a purely descriptive science, has involved physicians.

The history of myology includes so many eminent anatomists, who were followers of Eduard Zeis [2].

Aulus Cornelius Celsus (V, 26, *De generibus noxarum quisque corporis, et primo de vulneribus*), described the structure of the heart muscle (IV, 1, *De humani corporis partibus interioribus*) [3]. Galen and Rufus of Ephesus [4], described some details of voluntary and visceral myology. Baglivi [5] described the difference between striated and *smooth* muscle (published in Latin in *Opera Omnia Medico-Practica Anatomica*, reprinted in Venice in 1761 from the texts of 1666 and 1669).

In *Dissertatio Prima De Anatomie Fibrarum, De motu musculorum ac de morbis solido rum* (p. 177-189), (perhaps one of the first illustrated descriptions, with citations on studies of Nicholas Steno [6] and Peter Borelli, he also outlined many clear expressions of the location of tendons (*omnes musculos non uno sed duplici venter praeditos esse, nec caput & caudam habere, ut opinabantur Antiqui, sed duo tendines sibi oppositos, fibrasque musculares non una, ut hactenus creditum, sed oppositas in partes nisi…*, p. 178). He advanced an original doctrine on the contractions of fibres (from *Motu cordis* of Lovvero) not produced by the *spiritum inflatione,* but by *utriusque ventris fibrarum, quae oppositus in tendines habeant contractione, et duplicis tendinis adductione: nam ut quisque musculus duplex est quodammodo, ita duplici motu per fibras in diversa se nitentes loca adducitur, annexa sibi ossa vel membra secum trait.*

Baglivi [5] established that the muscular tissue does not grow in volume when it contracts but stiffens and hardens, while the tendons remain immobile.

Berlin and Halle in the period 1816-1820, in the introduction to the Italian edition of the *Manual of Anatomy*, 1826, (edited by Constantine Dimidri), Johann Friedrich Meckel [7], in Volume I, referred to Giovanni Battista Morgagni, who was not in favour of new words and complained of the many *good anatomists, wishing too much to reform the names.* Meckel the Younger (1781-1833), discoverer of the sphenopalatine ganglion, with repeated references to anatomical dissertations of Albert Haller (1757/68), of Xavier Bichat (1800) and of Ippolito Cloquet (1823) [8], in the four volumes of his labyrinthine treatise (enriched by the thoughtful remarks of the translator), considered the organs of locomotion almost exclusively by means of histological investigations.

Haller, in his *Elementa phisiologiae corporis humani,* firmly believed that there were only three tissues: the nervous, the *cellular* and the muscular tissues. He maintained that *the fibre is to the physiologist what the line is for the surveyor*.

But Cloquet, in 1815, established the existence of no less than eleven classes of tissue. Considering the recent description, by Yves Saban and Roberto Polselli (2009) [9 10], of a third *zygomaticus* muscle, we may explain why in 1966, Testut and Latarjet [11] (L. Testut had published the *Traité d'Anatomie Humaine* in Paris, in 1889), definitely believed that it was not possible to verify the exact number of units, because of *the difficulties encountered, at every moment in determining whether a body muscle can be considered separately or considered as a simple bundle of a neighbouring muscle.*

Chaussier listed 368 muscular items, Strambio [12] lists 374 in men and 346 in women; Theile 346 and Sappey 501, the same number as in Romiti's, eighteen pages of *general myology* (1897).

In 1904, Giulio Chiarugi [13] described only skin and skeletal muscles. In 1966, Testut and Latarjet, likewise, confirmed the division into two broad categories: superficial and deep muscles (sub-aponeurothics).

With a sort of *invasion of the field*, encouraged by the favourable comments of Jorge Psillakis (1994) [14], Lorenzo Mir y Mir (1994) [15] and some others of their level, we have considered, between 2000 and 2006, the theme of muscle insertions.

In reality, the mimetic cutaneous muscles do not seem to be provided with any tendinous or aponeurotic intermediaries, as they are directly attached at each end, and may be free to contract within the superficial fascia which invest them and the two layers of subcutaneous fat.

Herewith, an alternative classification is offered, recognizing three categories of human muscles: *inserted*, *semi-inserted* and *not inserted*.

In the first group, we would include those muscles with a tendon at both ends: in the second, those with the tendon at one proximal end, in the third, the *superficial mimetic facial muscles* (*pellicciai* in Italian expression), without tendons. Apart from the description of the fine structure of striated fibres [16-18], on their innervation [19-28] and their blood supply, attention, in our study, has been focused here on the *entheses* (capacity as tendon junctions), as a guideline for a general overview [29] of the so-called point of insertion of the muscle bundles [30].

Concerning some notions regarding the nature of the muscles, it is worthwhile pointing out that as observed by Latarjet-Testut, somatic muscles are of mesodermal origin, starting from myomer, with special differences from the muscles of the head [4 11]. The "fleshy body" of the muscle or the *muscular body* (supplied with a perfect elasticity) consists of striated fibres. The striated fibre should be considered a plasmodium in the shape of a long cylinder with a variable diameter of approximately 200 microns, and a length of a few centimetres [17 18]. The typical disc [4] is clearly visible using polarized light (field of Conheim).

Bairati recalled the structure of the sarcolemma and sarcoplasm, as an undifferentiated cytoplasm containing mitochondria (sarcosoma).

We should also mention the telofragma (Z lines) and the mesofragma (Stria M) discovered by Romiti in Amici G.B. [4] perhaps ancestors of the filamentary elements seen by Hodge and Huxley with the electron microscope, and the identification of polypeptide spiral chains of actin and myosin, to contribute to the formation of *encapsis*, chosen by Haidenhaim in 1911 as a base of the muscular system unit [17 18].

The substance of the muscle is of soft consistency, flexible and elastic.

Even when it is at rest *is in a state of active contraction albeit weak, or in a state of tonicity.*

The muscles (congeners are those that contribute to the movement itself) perform a mechanical action according to the principles of the lever, fulcrum and resistance.

As for their work, it should not be forgotten that the skull rotates on the fulcrum of the vertebrae like a scale (^---- ▼ ----^) i.e. as a first degree lever, the foot acts as a second degree lever (^ ▼ ------------^), while the arm (humerus and ulna) act as a third-degree lever (^------------- ▼ ^). The neuromuscular spindles (FNM) are elongated structures, parallel to the muscle fibre axis, with intra-fusal fibres innervated by γ motor fibres (ending in particular endplates, *synapses*), with annular-spiral endings, submitted to the primary law of *everything or nothing* [17 18]. The muscle-tendon of Golgi's organs (tendon spindle) [31], (OMTG) consists [4] of bundles of tendon enclosed in a fibrous capsule that is penetrated by one or two myelinic afferent fibres.

The OMTG are the proprioceptors responsible for the tone, in particular of the antigravity muscles (*postural*). The OMTG, unlike the FNM, are placed in series with the contractile muscle fibres.

An OMTG can be put under tension by external stretching (passive tension) or by active contraction, whereas the voluntary contraction of the muscle is in a permanent state of physiological tone [27].

Monomers are the muscles served by one nerve and the others are polymers [4].
In media texts (My-personaltrainer.it-12.11.2010), together with categories of long muscles, or the spindle-shaped, or wide, or short (in the spinal column), annular or curvilinear muscles (orifice, orbicular, sphincters) are described.
Strambio [12] in the mid-1800's, described monogastric, digastric, and polygastric elements (with an intermediate tendon), and also monoceps, biceps, tri- and quadriceps muscles. Muscles can be further divided into two main groups: superficial mimetic cutaneous muscles (*pellicciai*) and deep (*skeletal*).
The deep *skeletal muscles*, are mostly joined to bone by tendons at each end, such as cranial muscles [4] or those of the limbs. Some muscles have not only tendons [17 18] but also aponeurotic structures, mainly composed of bundles of connective tissue enveloping the muscles (such as the neck), or continuous with the periosteum.
The superficial palmar aponeurosis [4] was recognized by Louis Candiollo [32], and Gabbiani and Majno [33], as a stabilizer of the concavity of the palm of the hand; as well as favouring the adduction of the last four fingers and bending their first phalanges. All the muscles in this area, including the lumbricals, can be called *inserted*, except the *palmaris brevis* [13], also known as *cutaneous palmaris*, which stretches from the ulnar edge of the palmar aponeurosis to the ulnar cutaneous margin of the hand. It can, therefore, be considered as a *semi-inserted* muscle. It is understandable, therefore, that faced with the theme of muscle insertion, the common phraseology, in classical anatomy, does not seem to offer consistent examples. Testut and Latarjet [11] have argued that the temporal muscle is *born on the temporal line* and *extensively in the of the temporal fossa*, and also *in the upper two-thirds of the deep plane of the temporal fascia*: but the use of the verb "rise" seems to be insufficient and inadequate to indicate the precise way of insertion.
Speaking of the medial layer of fat, the meaning of subfascial fatty layer, together with that of the terms *under* and "spatial", should also be clarified. Even the phrase, *the temporal muscle tendon ends with a strong process that fits the crown of the jaw*, seems to be incomplete and insufficient to describe the intimate contact between tendon and coronoid process of the mandible. Larrabee [34] and Knize [35] do not seem to express themselves much more clearly when they write *tendon that inserts into the medial side of the ramus of the mandible and the entire coronoid process of the mandible…*
In 1912, in his chapter on myology, Dante Bertelli [36], a pupil of Romiti and colleague of Giuseppe Sterzi [1] and Giulio Chiarugi [13], carefully described the thin, continuous, connective tissue fibrillar layer, provided with many elastic fibres, called *external perimysium*. From the external perimysium new septa start, called *internal perimysium* dividing the muscle belly into bundles of fibres of different sizes. Bertelli [36] confirmed that each muscle has an "origin" and a connection called *insertion* (fixed or floating point).
The source of a long muscle is called the *head* and the distal extremity is called the *tail*. Like Romiti [4], he welcomed the further subdivision into *penniformi* and *semipennati* to indicate where the fleshy bundles are implanted on opposite sides of a tendon, or on the same side. However, in speaking of muscles acting by moving on the bones, he not think to provide an explanation regarding the mode of attachment, although he did not forget to enrich the text with a picture of the *endplate* (neuromuscular junction).
Testut and Latarjet [11], in the same Volume II, p. 50, concerning the internal pterygoid muscle, write that… *it is born high up on the whole extension of the pterygoid fossa* […] (at this level the Juvara palatine fascia is very strong…) *the external face of the maxillary tuberosity insertion* […] *shall be carried medially by a broad aponeurosis* […]? *at the other insertion is done? in part by fleshy fibers, partly by means of fiber tendons in the lower jaw* […] *bind both directly and through tabs in the thickness of the muscle tendon…*
Testut and Latarjet, do not seem to help to better understand the tendon structure. Indeed, focusing on the Juvara fascia, Testut and Latarjet, seem to omit the finer details of the topography of the *birth* of the muscle, which is presented too briefly as an element that is attached on the outer face of the tuberosity of the maxilla by means of a large aponeurosis. The question is whether we are observing the *penniformi* tendons or whether we are dealing with the general behaviour of the *wide* muscles. What also seems to be defective is a mention of the insertion of the upper bundle of the lateral pterygoid muscle, and of the pterygoid *aponeurosis,* as *entities independent of the fascia propria of the pterygoid muscle*. More! The interpterygoid aponeurosis is reported as a thin layer or leaf between the two muscles (without saying what the direct relationships are) and joins down to the medial aspect of the mandible (without saying how).
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Complaints may be made of descriptive gaps, or grossly superficial defects, even in regions far from the cephalic area, for example between the muscles of the abdomen.
In chapter 5, on page 194, of the same volume, the small pyramidalis muscle, immediately in front of the *rectus abdominis,* is described as a contractile, flattened and elongated pyramid with the base just below the upper apex on both sides of the midline. With regard of its insertion, it is only known that *it is on the body between the pubic symphysis and the pubic tubercle through short tendon fibres*, and that the upper insertion is through a series of small tendon *laminae* on the *linea alba*. Unfortunately,

this synthetic summary scarcely provides a classification of the problem of the relations between periosteum and tendons.

Muscles with a single point of insertion are designed in different ways for the movement of organs such as the ear (external), intestine, lung, tongue, larynx, pharynx, lips, anal perimeter and cremaster…

The muscles of the tongue are extrinsic and intrinsic muscles, supported by three special *fixed* sites consisting of hyoid bone, the hyo-glossal membrane and the medial septum [11].

The genio-glossus muscle is inserted in the jaw, and ends at the apex of the tongue on the deep surface of the mucosa; the palato-glossal muscle or glosso-staphyline, from the lower surface of the soft palate end nearby across the margin of the tongue…

The two pharyngo-glossal muscles, derived from the superior constrictor of the pharynx, are included within the borders of the tongue.

The amigdalo-glossal muscle extends from the pharyngeal aponeurosis to the midline of the tongue. The upper and lower lingual bellies, branch off from the little horns of the hyoid bone (the upper one also passes the median glossoepiglottidean fold) to the mucosa near the apex of the tongue.

The transverse muscle originates from the two sides of the septum, ending on the lingual mucosa of the margins of the tongue, tenaciously fixed to the subjacent muscles, with a minimum and sometimes less grip when the submucosal layer consists of loose connective tissue [4 16].

Lingual muscles, such as the *orbicularis oculi* of the eyelids, could be more accurately indicated as *tendinal* or *commessural semi-inserted.*

Taxonomic uncertainty persists with regard to eye muscles with one proximal fixed point of attachment to *move* the ocular globe: it may represent an intermediate quality, very unique, between *inserted* and *semi-inserted* muscles.

Speaking specifically of the *tendon,* some general information can be gathered [17 18] on this star of muscle function, composed of inextensible bundles of connective tissue. The muscle, cylindrical or flattened, long or short, bicaudal or polycaudal (with many tendons), or digastric (with intermediate tendon) and also doubled or tripled (such as the *zygomaticus* muscle) ends at the surface where its insertion is found. Its fleshy fibres, surrounded by the perimysium, are covered by a tendon or aponeurosis that acts as extension of its point of attack.

Some tendons take the form of a large membrane (*enveloppe capsulaire* of Chaussier) or aponeurosis (*linea alba*), formed by strips of connective bundles [17 18].

The muscle insertion can be *mediated* [4] in a union of tendon bundles "embedded" in the periosteum or perichondrium; the *immediate*, is directed towards a bone surface with an obtuse or acute angle, with direct setting but without intermediate periosteum (bony eminences and depressions), in other words, without aponeurotic tendon intermediaries.

Strambio [12] considered the aponeurosis as thin insertion tendons.

In the hand, the fibrous tendon sheaths [17 18] are applied to keep their pipes, flowing freely, sometimes acting as reflection of pulleys.

Synovial folds surrounding the vessels are mesotendons stretched from the parietal to the visceral plane. In the anatomical texts the muscle has been constantly regarded on account of its role, as *producer of movement*, usually achieved through its attachment to the various skeletal elements, by means of tendons or ligaments, placed at the two extremities of the contractile body.

In some muscles, when tendons and fascia are weak and are not visible microscopically, the contractile part seems to be inserted directly into the muscle [17 18]. Tendons and aponeuroses (in their varying forms: ribbon-like or spindle-like) long, broad and laminar, consist of collagen compacted fibres, presenting in primary, secondary and tertiary bundles, held together by loose connective sheets, referred to, in their complex, with the term *peritenomio* [37].

The muscle connection through tendon or aponeurosis, can be found exclusively in the proximal fleshy body, and consequently the remaining end of the muscle is free to move, as in the tongue and ocular globe.

The mimetic muscles invested by the superficial fascia within the subcutaneous tissue and without tendon or aponeurosis, have obviously a different behaviour. In an overview on the relationship between bones and joints, Francesco Pellegrini (2010), together with reliable findings on the joints, osteoblasts, osteocytes and the osteoclasts, and, in parallel (A. Kölliker, 1850, J. Tomes, C. De Morgan, 1852) [38], on the bone structure, have been established (*Generalità sulle ossa e articolazioni,* on www.ilguerriero.it) the function, typically osteogenic, of the periosteal membrane.

The periosteum is lacking only in the area of attachment of tendons and ligaments and some areas covered with articular cartilage.

According to Cooper et al. [39] only a few research workers have studied the traditional microscopic tendon and ligaments.

Many years after the report by Clopton Havers, on the bony canal, in the *Osteology Nova* printed in London in 1691 [16] Sharpey et al. announced, in 1856, the existence of penetrating fibres, with a special expression reproduced in many texts (Romiti had been talking about bundles of calcified connective, identical to the *clavicles* of Gagliardi).

In 1849, Sharpey described crossed reticular fibres together with the source of the bone lamellae, crossed by the perforating fibres, like a pricking nail perpendicularly, and argued that the periosteum added stability to the liga-

ments and tendons at the point of their contact with the bone.
Ranvier [4] found that, at the point of insertion, the tendon fibres, penetrate the bone as perforating fibres.
Later, the eponymous *perforating fibres of Sharpey* would have been disappearing, as a kind of artefacts.
Kölliker, the great friend of Waldeyer and Romiti, in 1853, described the tendons and their insertions, but only in 1929, Dolgo-Saburoff [40], in the cat, patellar ligaments, was able to show four distinct areas: the tendon itself, the fibro-cartilage, the mineralised fibro-cartilage and the bone. In these areas of transition between tendon and fibro-cartilage, Dolgo-Saburoff discovered a blue line, as a dark streak, *positioned transversally.* The finding would seem to create a boundary between the fibro-cartilagineous zone and the calcified cartilage. Indeed, at this level, the tendon itself would begin.
Nearly 30 years later, Vis [41] stated that a tendon could be inserted through transition in the peri-osteum or directly into the bone. In Italy, Amprino et al. [30] had reported on tendon insertion in relation to age, Hirsch and Morgan [42], almost contemporary (1939), were measured in 1 or 2 mm extension of the fibro-cartilage in children, compared to a few microns of the adult; Bairati, studying the microscopic structure of muscle (including cardiac muscle), had also investigated the role of ATP (adenosine tri-phosphoric acid) in the so-called Huxley actin and myosin bridge.
With the enlargements of the traditional light microscope, in the patellar tendon, at the point of insertion on the tibia, Cooper et al. [39] confirmed Dolgo-Sabouroff's [40] four zones: the tendon, the non-mineralised fibro-cartilage, mineralised fibro-cartilage and the lamellar bone. The microscopic findings showed: 1) that the tendon and ligament are composed of collagen fibres more or less parallel, with elongated cells (chondrocytes); 2) that the same context of collagen continues with the fibro-cartilage, for a distance of 150-400 microns. The cells (in pairs or in rows), become round and located in areas of the extracellular matrix mixed with collagen fibres; 3) that mineralised fibro-cartilage layer, 100/300 microns in thickness, remains distinct from the blue line collagen. The collagen continues in this linear structure, differently coloured, due to the mineral matrix. Many cells surrounded by this matrix, are similar to those of the fibro-cartilaginous zone. Some cells show a vacuolated cytoplasm, with degenerated nuclei and fragments of cytoplasm; 4) the lamellar bone adapts to the irregular contour of mineralised fibro-cartilage. With the electron microscope, in the same 4 areas of investigation, Cooper et al. have made contributions of great interest. In zone 1, the collagen fibrils make up the majority of structural tendons and ligaments. The bundles of fibrils, in cross-section are separated by regions containing granular and filamentous precipitates. A second fibrous population shows ultra-structural pictures of elastic fibres, scattered among heaps of collagen fibrils close to cells at different stages of maturation. The intercellular space shows polysaccharide extra-cellular fluids as well as non-collagenous proteins and collagen in an aggregation state. The cells are represented by elongated fibroblasts containing free ribosomes. In zone 2, fibrocartilage does not possess fibrils, while the cells gradually assume the typical characteristics of chondrocytes, round or oval, often paired or arranged in rows. The cytoplasm shows a mild endoplasmic reticulum, with increasing intra-cellular lipids and lysosomes, and prominent Golgi structures. The cells are surrounded by areas of 1-2 microns, rich in filaments of 100/200 Angström (A = one hundred million of a centimeter).
The zone 3 of mineralized fibrocartilage, appears as a dense line of 350/500 Angström at the border between the non-mineralized and mineralized matrix. Two kinds of crystals, together with accumulations of elastic fibres and collagen, divide the mineralised zone in two regions. This mineral layer takes on two appearances: a granular precipitate of protein and a calcium hydroxylapatite. Some cells are in the process of degeneration (*apoptosis*) because they are surrounded by mineral tablets. In general, the chondrocytes remain active despite their immersion in the mineralized matrix.
In zone 4, the bone fibrillar matrix blends with the mineralized fibro-cartilage of zone 3. The cells of the bone matrix near the tendons are like those of normal bone. Cooper et al. [39] in tests on the dog, believe that the mode of distribution of collagen fibrils remains difficult to explain. Tendons have fibroblasts, which are able to create collagen precursors and protein polysaccharides. Elastic fibres allow the ligaments and tendons to resume their shape after each deforming function, by maintaining the position of the collagen fibrils even after twisting. Perhaps the fibro-cartilage can function as a barrier against the penetration of the mineral within the tendon. The formation and orientation of crystals, can be observed under the electron microscope, beginning from the amorphous phase to that of hydroxyapatite. Crystals, at the tendon insertion, accumulate preferentially between collagen fibrils and less (or not at all) in the bone or cartilage. Tendon cells sometimes appear to assume the function of osteoblasts and cartilage cells can become osteocytes. In 1853, Kölliker [38] said with an almost prophetic tone: *Close to the bone, tendon... contains a certain section of the delicate and isolated cells arranged in small files. I also saw some tendon fibrils at the ends, near the bone* […] *entirely encrusted with calcium salts in the form of granules, and then ossified.*
As if he had wanted to inaugurate the class of the *not inserted* muscles, Bertelli [36] described the mimetic muscles inserted under the skin, at least with one of their ends, and sometimes with both, to the deep surface of the dermis.
Concerning muscles of the head, the frontal muscle, however, was firmly considered to be covered by two layers of the galea, from its front edge to the dermis of the brow

and glabella and nasal bones. (…*fits on the deep surface of the skin*…). Today, after a Century, Bertelli it is still very modern when saying that, in the galea, the deep fat layer, is transformed into a loose connective tissue layer, as argued by Sterzi.

Bertelli, despite having ignored the problem of insertion of the *procerus* muscle, reinforced Sterzi's statement, and seemed to herald the research of Saban et al. (2008).

Bertelli wrote that part of the transverse nasal muscle is transformed into aponeurosis (which is fixed to the bridge of the nose and is joined to the opposite side), and equipped with a wing portion inserted into the skin dermis. In the group of muscles inserted into the dermis, he has included the muscles of the lips, the zygomaticus muscle, the square of the upper lip, the canine, the buccinator, the *risorius Santorini*, the triangular, the square of the lower lip, the *mental*, the upper incisor, the inferior incisor and the orbicular of the mouth.

Only the external portion of the *orbicularis oculi* muscle of the eyelids was described as being inserted onto the lateral palpebral raphe (lateral canthal tendon).

By acceptable comparison, Larrabee [34], in Chapter V of his atlas, seems to "revise", the concept of a superficial musculo- aponeurotic system (SMAS) launched out [21] (between 1967 and 1987) by Gasser [43], Mitz and Peyronie [44] and Jost [45-47].

Mitz and Peyronie, in 1976, moving from Gray's anatomy (1949), proposed the SMAS *in the parotid and cheek areas*, and used the Latin term *fascia superficialis.* They considered the fascia *belonging to the cervicocephalic fascia continuous from the head to the neck.* Gray, ignoring Sterzi's study of 1910, mentioned the *superficial fascia* as *tela subcutanea*; in the head that fascia *invests the facial muscles* [48]. Concerning the relationship between the SMAS and muscles, Mitz et al. wrote: *the SMAS invests and extends into the external part of the superficial facial muscles – involving fibre of the risorius, the frontalis, the platysma and the peripheral part of the orbicularis oculi.* Mitz et al. never spoke about muscle tendon or aponeurosis, but consider the SMAS *an "amplifier" of the contractions of the facial muscles.*

The Italian term "*muscoli pellicciai*", in Mitz et al., become simply *superficial facial muscles.*

Larrabee [34] is in favour, indeed, regarding the concept of splitting *galea aponeurotica* to invest the *frontalis, occipital, procerus* and auricular muscles, and declares that, in the temporal region, the superficial temporal fascia is equivalent to the temporo-parietal fascia.

Larrabee seems to consider the SMAS coinciding with the superficial fascia of the subcutaneous tissue which *acts as a network to interconnect the facial muscles and the dermis*, almost a prelude to our concept of *not-inserted* muscles.

In the legend of Figure 5.2, p. 44, Larrabee repeats the old data on the derivation of the SMAS lower plastysma, which would have a limited bony insertion, and, in the illustration 5.3, writes that the corrugator *arise from the medial orbital muscle and the skin of the eyebrow*, with an inadvertent contribution to its quality of *non-inserted* muscle.

Concerning the soft tissue of the nose, Larrabee seems to fully accept Sterzi's idea, writing *the skin and the soft tissue envelope (fat, nasal mimetic muscles, fascia) should be elevated in one layer and preserved*, although he considers the *procerus* muscle (p. 50), arising from the nasal bone in the glabellar region and inserting into the forehead skin, without any elucidation on the histological significance of that verb *inserting*.

As far as concerns this paradigm, Saban and Polselli [9] [10] seem to be more generous when unhesitatingly consider *procerus une expansion nasale du muscle frontalis qui vient prendre insertion sur le nez.* Saban and Polselli included the *procerus* in the SMAS without tendons with the task of *pilier médian* of the *frontalis* muscle and invested in the same way, however, in the SMAS as a nasal ligament (p. 200).

Testut and Latarjet [11], advised readers to consider the aponeurosis as tendon developed in the surface for large muscles, and finally seems to be forced to accept Sterzi's dictates on *the superficial fascia interposed between the deep and the superficial fat layer of skin*.

Sterzi firmly believed that the subcutaneous tissue was mainly composed of a deep fat layer and a superficial layer sometimes separated by a fibrous membrane (having a very important morphological meaning), called *superficial fascia*, splitted to invest a cutaneous muscle, "simple or differentiated into several layers". Backer et al. [49] wrote: *the mimetic muscles commonly overlap one another and have been described as being arranged in four anatomic layers.* As a consequence, Backer et al. consider "superficial" and "deep" mimetic muscles which originate *within the SMAS itself.* Backer et al. hold that SMAS coincides with split of the *superficial facial fascia,* probably ignoring (p. 149) Sterzi's concept of "investiture" of the mimetic muscle by the *fascia superficialis.*

On the contrary, as already observed, Sterzi held that the deep fat layer may have the function of a true sliding layer, or sub-tegumental layer.

Sterzi even focused on the nervous system of vertebrates, examined with the same perseverance the subcutaneous tissue in different regions of the human body, starting from the head, in the frontal area, supra-orbital, parietal-occipital, temporal, auricular, mastoid, nasal, labial, mental, eyelid, orbital, buccal, zygomatic arch and masseteric. The neck regions were divided into suprahyoid, hyoid, sub-hyoid, parotid, sternocleidomastoid and supraclavicular.

We consider the use of the expression "Sterzi system" equivalent to the term superficial musculo aponeurotic system (SMAS).

A few years before, Tillaux [50] considered cervical aponeurosis an *anatomical Proteus* because of "a certain confusion in describing it, because each Author brings together these layers in their own way, putting them together, and interpreting them according to special criteria".

Allan Burns [50] is recognized as having the primacy of the first analysis, in 1811. In the subclavian triangular region and in the suprahyoid area (p. 432-4, Part II), Tillaux had totally ignored the existence of the *superficial fascia*, and, on page 492, in the section of "general arrangement of the layer soft cell layer", wrote that the neck is wrapped in a kind of subcutaneous superficial *lamina aponeurortica*. There is not a clarification on the linguistic difference between "subcutaneous", as a noun or an adjective.

Zide et al. [51] with the beautiful images of 1985, Figs. 2-4 of page 15, wrote, that the corrugator muscle eyebrow, *born* medially from the frontal bone near the medial superior margin of the orbit, beneath the *frontalis* muscle, is inserted *in the skin* of the medial half of the eyebrow.

Knize [35], implicitly follows Sterzi's data and pays him reverential homage when speaking on galea's relationship and when he writes *glide plane space formed by layers of the deep galea plane*.

Letourneau and Daniel [52], in 1988, studied the superficial musculoaponeurotic system of the nose in 30 fresh cadavers: the fibromuscular layer *consists of intertwined fibrous and musculature tissue. A distinct fibrous layer is present seen histologically as a condensation of collagenous bundles into a sheet that envelops the nasal musculature. The fibrous layer usually bifurcates, forming a superficial and a deep fascia for each nasal muscle. Thus the nasal muscle and its attendent fascia function as one unit.* The eight muscles of the nose seem to be interconnected with a complete sheath referred as *aponeurosis* that behaves like the "fascia superficialis". Saban et al. [53], with some dissections, described, in 2008, the anatomical structure of the transverse *nasalis* muscle, the *procerus*, the compressor *naris major* and *minor* and also on the *levator labii alaeque nasi* and the *dilator nasi*.

Saban et al. [53] demonstrated the continuity with the *frontal SMAS,* consisting of the *frontalis* muscle. They do not describe how the muscular body is inserted. However, Saban et al. believe that it is *possible and reliable to propose a unique and complete anatomical vision of the nasal SMAS.* In their unified vision of the nasal muscles, they do not mention tendon or aponeurosis, indeed, speaking about *dilator nasi* they have demonstrated that its fibres, in the supratip area intermingle with dermal SMAS. Saban and Polselli, in the Atlas of 2009 [10], offer to world culture hundreds of pictures of the cutaneous muscles and in Figure 1.12n, on page 39 of the first volume, show insertions of the corrugator muscle.

In the caption, like Knize [35], we discover two distinct heads of insertion of the muscle body, reaching the deep surface of the frontal skin after passing the relationships with the two neuro-vascular pedicles (supra-trochlear and supra-orbital).

Although, with the aid of Figure 1.12o, we can see the insertions of the muscle bundles, on the orbital rim, it is, nevertheless, difficult to understand whether such thin fibres go to insert in the periosteum or in the fascia, that covers it, as stated by Sterzi [1].

Conclusions

In his original investigation on the structure of the skin, (*panniculus carnosus of the ancients*), Giuseppe Sterzi [1], with essential annotations for comparative anatomy, described, with great care, the aponeurotic galea and its relationship with the forehead muscles.

As elegantly pointed out by Psillakis [14], he had magnificently established the behaviour of the *fascia superficialis* (enveloping the mimetic musculature) included between the two fat layers (superficial and deep). The deep one must be considered as a tissue special arrangement, bordering with the cranial periosteum (*pericranium*).

The timing of this significant relationship (Micheli-Pellegrini) [19 21 23 24] could be essentially represented by the transformation of the deep fat layer in the *loose connective tissue layer* as an entity belonging to the galea. In this regard, Psillakis wrote: *histologically, the deep fat layer cannot be found with fat cells in many parts of the body because it changes to a loose, thin fibrous tissue. Consequently, the "superficial fascia" is closest to the deep fascia of the skeletal muscles.*

Mitz and Peyronie had never explained in detail, the term "muscle-aponeurotic" when referring to the so-called SMAS.

The question is: have the connections between mimetic muscles and aponeurosis been demonstrated? Surprisingly, Jost and Levet have proposed the term *fibrous platysma* to explain the behaviour of the *fascia superficialis* after investing the platisma.

In the Knize text and particularly in the more recent ones [10 48], the observations of Sterzi are confirmed, even if in an indirect way.

The dermal insertion of the corrugator and *frontalis* muscles seems to offer us the opportunity to continue to use the term *not inserted* for these muscle structures. Concluding these remarks, we are convinced that of the human muscles, the "skeletal" muscles are in the majority, and perhaps the first to be observed and studied in history, on account of the typical ability to contract to produce body movements.

Every muscle of this type can carry out its task by way of connection structures with bones. These points of attachment between muscle and bone, located mostly at the two ends of the muscle belly, are represented (Wikipedia, 2010) by tendons and aponeuroses, with the result of a synkinetic complex, especially active in the limbs. We consider these contractile elements as *inserted.* In a numerically small proportion, the tendon junction element, between muscle and tendon to bone is only one end of the muscle belly, and, therefore, firmly coincides with the point of its origin, as in the tongue. When an element is provided with only one insertion, it can be classified as *semi-inserted.*

Apart from the fibre and the long list of heart "smooth" muscles, a distinctive title for the mimetic muscles in humans, almost exclusively in the areas of the head and the neck [21 28] need not be inserted. The mimetic muscle, for facial expressions, are included in the subcutaneous layer of the skin and act in peculiar ways, free to contract without any intermediary or braking aponeurotic tendon.

We have good reasons, not at all simplistic, but derived only from their anatomical reality, to consider such muscles without aponeurotic insertion.

The aponeurosis of mimetic muscles seems to be identifiable with the *fascia superficialis*. In a comprehensive thesis on the structure of the Achilles tendon [37], the finest characteristics of tendon structures have been reported as transmitters of the muscular strength to the skeletal levers.

In that immense study, each item, macro- and microscopic, concerning muscle-tendon-bone and bone-tendon joints, was made clear.

The tendon attached to the structure of collagen fibres, the histology of ultramicroscopic tenoblast of Golgi tendon organs, considered protective receptors of the muscle-tendon complex have been studied in detail. Attention needs to be focused on the elastic fibres, which are considered a minority component of the extra-cellular matrix of the tendon, and are most abundant in areas of fibro-cartilage and calcified fibro-cartilage of the tendon junction. Our proposed classification, could possibly be confrmed following an investigation to demonstrate the complete lack of tendons in the mimetic cutaneous muscles. The clear evidence, or the crucial test, could be the absence of fibro-cartilage, or calcified hydroxy-apatite in the junction area of any muscle in this series, too often referred to only generically with uncertain terms such as "the muscle originates from" "or insert on" this bone, covered or not by a *periosteum,* in turn banded, by the transformed deep layer of the subcutaneous tissue. *Some anatomical problems are not entirely new to the world, and his or her elders may have already attempted to solve* [54]. As far as we know, some plastic surgeons could demonstrate a degree of carelessness in relation to the structure of subcutaneous.

Giorgio Sperati and Dino Felisati (medical history experts) [55-59] seem to be right when arguing that many plastic surgeons are limited in their technical knowledge on the mimetic muscles and conversely appear to vindicate a distinct priority in the problem of surgical rejuvenation or, in general, in the effects of ageing, the inevitable process of transformation of the integument of the face, always involving the mimetic muscles included in the skin. Anatomists have better worked as far as concerns research on mimetic muscles that we would like to indicate as *not inserted*, free to move in a different way from that of *inserted* or *semi-inserted.* Indeed, skeletal muscles seem to be unable to move as worms, as mimetic muscles, such as the procerus, or as the platysma with simultaneous contractions.

In performing surgery on the salivary glands, otolaryngologists and maxillofacial surgeons, have preceded plastic surgeons in studying mimetic muscles. Today, the practice of botulinum neurotoxin injection or injectable non-invasive treatments requires the finest experience regarding the topography of the mimetic muscles with electro-diagnostic monitoring of their position to ensure a safer surgical programme.

Inspired by the significance of the *Nomina Anatomica,* approved as International Anatomical Nomenclature, in Mexico City, 1980, we are firmly convinced of the importance of every anatomical explanation, even if only adopted to simplify the nomenclature.

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