

The Dynamic Microanatomy of Skin and Fascia. From the Deep Fascia to the Skin Surface.

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Abstract

The study of the structure of the skin and fascia in recent years has made important advances with respect to the "dynamic anatomy" that they present, that is, the anatomical relationships and tissue interconnections that you share through different tissues. In the same way fascias have been recognized as important sources of origin of different pathologies in the last years, so the greater knowledge of their function and structure is indispensable. The aim of this article is to review the last advances in the anatomic terminology of the soft superficial tissues as advances and recent anatomical discoveries.

Keywords: Fascia; Skin; Anatomy; Connective tissue; Fascial system.

Introduction

The skin is the largest organ of the human body, accounting for approximately 16% of total body weight. Its vital role is to prevent loss of water and other components of the body to the environment and protect the body from a variety of environmental insults. The skin also has important immune and sensory functions, helps to regulate body temperature, and synthesizes vitamin D. Human skin is composed of three distinct layers: epidermis, dermis and hypodermis, with varying degrees of specialization within each layer [1].

The epidermis is generally considered to be subdivided into 5 separate strata: basal, spinous, granular, lucid, and corneum. The vital barrier function of the skin resides primarily in the top stratum of the epidermis, the stratum corneum (SC). The SC is the barrier to the passive diffusion of water out of the skin, allowing us to live in air without suffering from dehydration, and is the barrier to other molecules including irritants into the skin. The epidermis also has immunologic functions and provides some protection of the skin from ultraviolet light via the pigment system. Every abrasion that draws blood has eroded the epidermis and entered the dermis.

Perhaps, most importantly, the dermis provides the pathways that allow the body to transport defenders to the outer wall through blood vessels and removes damaged skin and dead invaders through the lymphatics [1]. Skin also provides a 'live feed' of information of the body's systemic physiology through physical signs, such as flush, sweating and pallor, and can inform us of disease states, such as hypothyroidism, jaundice or Cushing's disease to name but a few [20]. The skin acts as an envelope to the body and is closely integrated to the underlying fascial endoskeleton through retinacular ligaments [3, 4, 5], blood vessels [6], nerves [7] and lymphatics [8].

A fascia is a sheath, a sheet, or any other dissectible aggregations of connective tissue that forms beneath the skin to attach, enclose, and separate muscles and other internal organs. Fascia is a widely used yet indistinctly defined anatomical term that is concurrently applied to the description of soft collagenous connective tissue, distinct sections of membranous tissue, and a body pervading soft connective tissue system [9].



The fascial system consists of the tridimensional continuum of soft, collagen-containing, loose and dense fibrous connective tissues that permeate the body. It incorporates elements such as adipose tissue, adventitia and neurovascular sheaths, aponeuroses, deep and superficial fasciae, epineurium, joint capsules, ligaments, membranes, meninges, myofascial expansions, periosteal, retinacula, septa, tendons, visceral fasciae, and all the intramuscular and intermuscular connective tissues including endo/peri/epimysium. The fascial system interpenetrates and surrounds all organs, muscles, bones and nerve fibers, endowing the body with a functional structure, and providing an environment that enables all body systems to operate in an integrated manner [9].

The retinacular system or fascial system has these functions: the venous return [10], dissipation of tensional stress concentrated at the sites of entheses [11], etiology of pain [12,13], interactions among limb muscles [14-17] and movement perception and coordination [18- 22], due to their unique mechanical properties and rich innervation.

The aim of this article is to review the last advances in the anatomic terminology of the soft superficial tissues as advances and recent anatomical discoveries.

The fascial endoskeleton or retinacular system [23] is important in determining the limits of skin movement. Specific tethering points from this retinacular system define the appearance of skin; The key concept is that the connections between fascia and skin act as a continuum for finite movement. Undermining these ligaments can be used to restore form with facial rejuvenation surgery [24]. This anchoring system is therefore also fundamental to the appearance of skin.

The study of the structure of the skin and fascia has been done in static form and generally in two dimensions. In most cases it is assisted by histology and histopathology samples or by *in vitro* experimental studies. However, in the last years there have been done several descriptive and functional studies using MRI, electronic microscopy and tridimensional digital reconstruction which have permitted the increment the knowledge about the microanatomy of the skin and fascia as the complex anatomic and biomechanical relations between them.

Surgeons [25, 26] are all looking for accurate and realistic means of predicting the behavior of soft tissues. Although different objectives have been pursued in each case, the main problem has been that of modeling a heterogeneous three-dimensional structure showing complex mechanical behavior [27]. The SSC includes the skin, the subcutaneous fat and connective means of union between the skin and the deep plane.

The results of a 3T MRI study on subcutaneous tissue showed the existence of a common pattern of organization of the skin-subcutaneous tissue complex in the various parts of the body studied. The superficial and deep adipose tissue was found to be clearly separated by an intermediate layer called stratum membranosum or superficial fascia. This continuous layer covered all the anatomical parts of the body examined. It was found to have several components in the trunk and limbs and to form a continuous layer with the superficial muscular aponeurotic system in the face. A retaining connective network consisting of superficial and deep retinacula cutis detected in all the

regions investigated sometimes formed more densely packed structures playing the role of skin ligaments. This general model is subject to quantitative variations and tissue differentiation processes promoting the sliding or contractility of the supporting tissue. Three-dimensional reconstructions were obtained by post-processing the MRI images and will be used to perform pre-surgical simulations by setting a generic model that can be adapted to the different localization of the human body in a procedural way [28].

Between the two different kinds of the skin covering the body, the glabrous skin is found only on the palmo-plantar surface because of its rather simple function to protect the underlying living tissue with its remarkably thick stratum corneum (SC) from strong external force and friction. Thus, its barrier function is extremely poor. In contrast, the hair-bearing skin covers almost all over the body surface regardless of the presence of long hair or vellus hair.

In regard to its SC, many dermatologists and skin scientists think that it is too thin to show any site-specific differences, because the SC is just present as an efficient barrier membrane to protect our body from desiccation as well as against the invasion by external injurious agents. However, there are remarkable regional differences not only in the living skin tissue but also even in such thin SC reflecting the function of each anatomical location. These differences in the SC have been mostly disclosed with the advent of non-invasive biophysical instruments, particularly the one that enables us to measure transepidermal water loss (TEWL), the parameter of the SC barrier function, and the one that evaluates the hydration state of the skin surface, the parameter of the water-holding capacity of the SC that brings about softness and smoothness to the skin surface.

The SC of the facial skin is thinner, being composed of smaller layers of corneocytes than that of the trunk and limbs. It shows unique functional characteristics to provide hydrated skin surface but relatively poor barrier function, which is similar to that observed in retinoid-treated skin or to that of fresh scar or keloidal scars. Moreover, there even exist unexpected, site-dependent differences in the SC of the facial skin such as the forehead, eyelid, cheek, nose and perioral regions, although each location occupies only a small area.

Moreover, these features are not static but change with age particularly between children and adults and maybe also between genders. Among various facial locations, the eyelid skin is distinct from others because its SC is associated with poor skin surface lipids and a thin SC cell layer composed of large corneocytes that brings about high surface hydration state but poor barrier function, whereas the vermilion borders of the lips that are covered by an exposed part of the oral mucosa exhibit remarkably poor barrier function and low hydration state. Future studies aiming at the establishment of the functional mapping in each facial region and in other body regions will shed light on more delicate site-dependent differences [29].

Organization

From the skin to the muscular plane, there are usually three fundamental fibrous connective layers in the human body: superficial fascia, deep fascia, and epimysium, apart from all the visceral fasciae.



This distinction of the fascial layers is not always so clearly defined, since one or more layers sometimes disappear, or are strongly connected with each other, as in the palmar and plantar regions, where the adhesion of the superficial to the deep fascia forms a single connective layer called the palmar aponeurosis [20] and plantar fascia/aponeurosis respectively [30].

The anatomical descriptions available include one or several fibrous layers corresponding to the stratum membranosum (SM) usually called superficial fascia (SF) running parallel to the skin, which are crossed by fibrous septa called retinacula cutis (RC). On the surface of the SM and at deeper level, there also exist variable amounts of adipose tissue, known as superficial adipose tissue (SAT) and deep adipose tissue (DAT) [31-33].

Most of the authors have agreed that the subcutaneous tissues consist of three main components: the SAT, an intermediate membranous layer, the SM or superficial fascia which can be either fibrous and/or muscular and either single or multiple, and the DAT [31-33].

The SAT and DAT are crossed by dense fibrous septa called retinacula cutis superficialis (RCS) and retinacula cutis profundus (RCP). Inside this retaining connective network (RCN), the adipose tissue forms lobules separated by thin septa, as in a honeycomb. The structure and development of these retinacula cutis are indissociable from those of the fatty lobules. Whenever the thickness of the adipose panicle increases, these structures play a mechanical and physiological role, reinforcing the neighbouring adipocytes. They have been found to show considerable intra- and inter- individual variability [31-33].

The term deep fascia refers to any dense fibrous sheath that interpenetrates and surrounds the muscles, bones, nerves, and blood vessels of the body, binding all these structures together into a firm compact mass. Over bones, it is called periosteum; around tendons, it forms the paratendon; around vessels and nerves, it forms the neurovascular sheath; around joints, it strengthens the capsules and ligaments. So the paratendon, the neurovascular sheath, and the periosteum can be considered a specialization of the deep fascia, not only because they are in continuity with it, but also because they have the same histological features [31, 32].

Recent research shows that there are differences between the fasciae of the limbs and of the trunk. In particular, the deep fasciae of the trunk are usually formed of a single layer of undulated collagen fibers that are continuous/ adherent with intramuscular septa, and intermixed with many elastic fibers, whereas the deep fasciae of the limbs are formed of two or three sub-layers of parallel collagen fiber bundles of densely packed collagen bundles, interspersed with thin layers of areolar connective tissue and able to slide over the underlying muscle, sharing only a few myofascial connections with it [20].

Variable	Dorso	Extremities
Number of layer	1	3-Feb
Collagen fibers disposition	Ondulated	Parallel
Conections with the muscle	Yes	No
Loose tissue presence	No	Yes
Collagen fibers' size	Small diameter	Wide diameter
Amount of elastic fibers distributed in the tissue	Vast	Scarce

There is deficit of transmission electron microscopy investigations of cellular components of both superficial and deep fascial structures. Telocytes are relatively recently discovered cells involved in a number of essential biological processes. They are present in the interstitial space of many human and animal tissues forming within the stromal compartment a unique, complex and integrative three dimensional network [36].

Through this close contact, telocytes actively contribute to the maintenance of tissue homeostasis and play a role in tissue regeneration and repair. Moreover, they are involved in intracellular signalling by both formation of intracellular junctions as well as via a paracrine mode of action (secretion of soluble mediators such as interleukin-6, VEGF and nitric oxide). Recent studies have determined that telocytes are found in the fascia lata [36], we suspect that these types of cells could be present in the whole fascial system.

Role of the different structures in wounds and disease

Following injury, fascia heals by recruiting inflammatory cells and fibroblasts. Stewart et al. showed that in serial cultures of cells isolated from incised rat fascia, macrophages composed 84% of total cells on postinjury day 1 and declined steadily thereafter to 15% of total cells on postinjury day 28 [37]. Fibroblasts displayed an opposite trend, comprising 2% of total cells on postinjury day 1, rising to 65% of postinjury day 7, and peaking at 820 of total cells on postinjury day 28. Historically, fascial healing was believed to be slower than dermal healing [38-40]. However, recent studies have established that rectus fascial healing is greatest during the first 7 days postinjury and that fascia regains tensile strength more quickly than skin. On postinjury day 7, fascia showed an average tensile strength of 0.3 MPa vs. 0.16 MPa for dermis. However, by postinjury day 21, both fascia and dermis recovered to tensile strengths of approximately 0.6 MPa. Changes in fibroblast populations mirrored this data, with significantly more fibroblasts in fascia on postinjury day 7 but similar fibroblast numbers in both fascia and dermis on postinjury day 21 [41].

Surgical considerations

Regarding plastic reconstructive surgery and soft tissue injury, surgeons can optimize fascial healing by using continuous nonabsorbable sutures and by excising rather than imbricating fascia when possible [42].

In aesthetic plastic surgery, dissection of the midface in the sub-SMAS/deep plane creates advantages that allow for significantly improved outcomes in face lifting. This approach enables direct lysis of the zygomatic cutaneous ligament, which is the major facial retaining ligament; direct assessment and treatment of issues such as pseudoherniation of buccal fat and its influence on jowling; and mobilization of most of the facial fat. Additionally, the deep-plane dissection confines tension to the platysma/SMAS fascia, allowing for a tension-free skin closure, minimizes complications, and results in a natural rejuvenation [43].

Conclusions

In the last years there have been important advances in the terminology and knowledge of the structure and function of the skin and fascia as in the interactions between them.



It is important to understand and recognize the elements that conform the microanatomy of the skin and the fascia in order to understand the morpho and physiopathology of the changes that occur in them with age as in pathological subjacent processes. This is also important to consider in rejuvenation procedures and pre-surgical conditions in aesthetic and plastic reconstructive surgery, as fascia and skin are strongly related both anatomically and in post-surgery outcomes.

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