

Functional morphological characteristics of the interdigital sinus in the sheep

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The present paper describes two distinct morphological features of ovine interdigital sinus, which were examined by means of scanning electron microscopy. In the sweat glandular component, acini with epithelial cells exhibiting a paved appearance and apocrine secretion were observed. In the same gland, other acini with cells exhibiting different luminal surfaces and simultaneous apocrine and merocrine secretion were recorded. The numerous hairs embedded within the waxy material of the sinus exhibited two types. The first type, with a round profile, had a special leaflet structure on the tip, whereas the second type had a convex profile. The comparative differences and probable functional relations of these integumentary structures are discussed. The mixed picture of the epithelial cells of the sweat glands suggests the release of different products. The hair microstructure correlated with the mechanism of hold and release of the secretory material of the interdigital sinus. (Folia Morphol 2010; 69, 2: 107–111)

Key words: sweat gland, apocrine, merocrine, hair, scanning electron microscopy

INTRODUCTION

The interdigital sinus is a unique anatomical structure, which is mainly found in ruminants. The sinus is a socket-like invagination of the skin with special structure and function. Light microscope studies have indicated that these anatomical structures are composed mainly of a sweat and a sebaceous component as well as of hairs.

The histology of these specialized structures was described in the red deer *Capreolus capreolus* [10, 14], reindeer *Rangifer tarandus* [15], red duiker *Cephalophus natalensis* [13], black-tailed deer *Odocoileus hemionus columbianus* [20], pronghorn *Antilocarpa americana* [16], Japanese serow *Capricornis crispus* [3], Formosan serow *Capricornis crispus swinhoei* [4], deer *Odocoileus virginianus* [19], Rocky Mountain mule deer *Odocoileus hemionus hemion-*

us [21], moose *Alces alces andersoni* [5], and fallow deer *Dama dama* [18]. The authors tried to explore the morphology in various mammals in order to clarify the function of these glands in relation to ethological sexual functions.

The microanatomy of the interdigital sinus in the sheep has been briefly and segmentally recorded [12]. Prenatal and postnatal developmental changes in the interdigital sinus of Yankasa sheep were studied microscopically by Sivachelvan et al. [22]. The anatomical positions and histological structures of the ovine interdigital sinus have been described and figured by Karahan et al. [11] and Abbasi et al. [1].

However, although there is a great deal of speculation on this subject, there is a lack of detailed morphologic data relating to the possible function of sheep interdigital glands.

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This report is intended to add further information regarding two points: The first being the fine structure of the sweat glands and the second being the fine structure of the hairs that protrude into the cavity of the sinus.

MATERIAL AND METHODS

The whole interdigital sinuses of both fore- and hind legs were removed from adult female ($n = 10$) sheep of the Karagouniko breed during slaughter. Pieces from the body and from the neck of the sinuses were fixed in a sodium cacodylate (0.1 M) buffered solution of 2% glutaraldehyde and 2% paraformaldehyde.

They were then washed 4 times, for 15 minutes each time, with sodium cacodylate buffer (pH 7.2), transferred for 1 hour to 1% OsO₄, and dehydrated in graded acetone. Tissues were critical point dried in carbon dioxide (72–75 Barr), mounted onto stubs, and sputter coated with platinum and gold in a Bal-Tec sputter coater. The specimens were observed in a JEOL, JSM 840 scanning electron microscope.

RESULTS

In agreement with known data, the basic sweat histological units of the interdigital sinus were glandular lobules and interlobular ducts, both of which were embedded in comparatively dense collagenous tissue. The sweat units were composed of tubuloalveolar glands, whose secretory portion consisted of a single layer of epithelial cells. The inner diameter of the acini ranged from 30 μm to 50 μm . The luminal surface of the epithelium exhibited two different cell types.

In the majority of tubuloalveoli, the glandular epithelium had a paved appearance. The cellular borders lay in the deep furrows among the bulging apical poles that were studded with short microvilli. The average cell diameter varied from 3 to 6 μm . On the luminal surface, evidence of an apocrine-like secretion was observed in the secretory cells, which had developed an apical cap. Apical caps (Fig. 1) were observed over the central area of the luminal side of cells and free in the lumen of the gland. Their diameter ranged from 1 to 2 μm . Subsequently, a round crater denoting the place of apocrine release was observed on the luminal plasma membrane.

The luminal surface of other glandular tubules provided a different picture. All cells were sharply demarcated by thick rows of microvilli at the cell perimeter. The polygonal, mainly quadrangular to heptagonal cells usually had a diameter of about

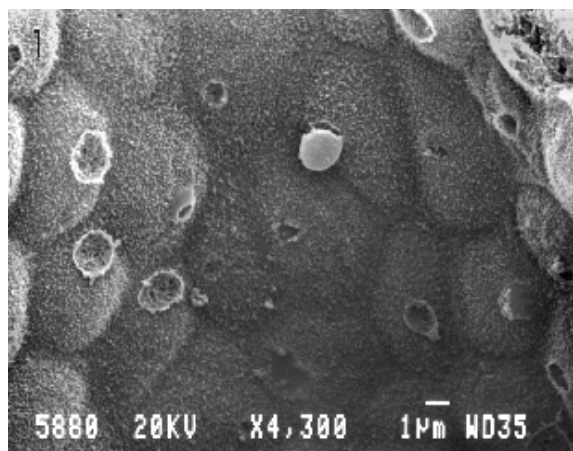


Figure 1. Scanning electron micrograph of the luminal surface of the tubuloalveolar gland exhibiting apocrine secretion. The epithelial cells present furrows in their borders.

6–7 μm . Their surface also was studded with short microvilli. In many epithelial cells, subjacent to the apical cell pole, a few globular structures, presumably representing secretory granules, were detected. A process of merocrine secretion (Fig. 2) released the contents of the apical secretory granules of a mean diameter of 0.7 μm . The apical caps of apocrine release ranged from 2–4 μm (Fig. 3).

The intralobular ducts were lined with a two-layered epithelium. The cells of the sweat ducts (Fig. 4) resembled the secretory cells except that they tended to be cuboidal rather than columnar, their apical microvilli were fewer in number, and they contained very few, if any, secretory granules. The diameter of the lining epithelial cells varied from 6 to 10 μm . The diameter of the ducts was 28 to 30 μm .

The numerous hairs that protruded into the waxy material had variable (28–56 μm) diameter. Two types were recognized which were identified and described according to Chernova's classification [6, 7]. The first type had circular to oval shape in cross section (Fig. 5). The cuticle was of the non-annular type, in which several scales fitted across the shaft directed towards the apex (Fig. 6). The height of the scales (along the shaft) was approximately the same as its width (across the shaft). The number of cells embracing the hair shaft diminished towards the apex. In the majority of hairs, the apical portion had a broad-leafed shape (Fig. 7).

The second hair type had a convex shape in cross section and a different cuticle pattern. The scales were numerous and tightly adhered and overlapped the shaft with a direction towards the apex. The height of the scales was low (Fig. 8).

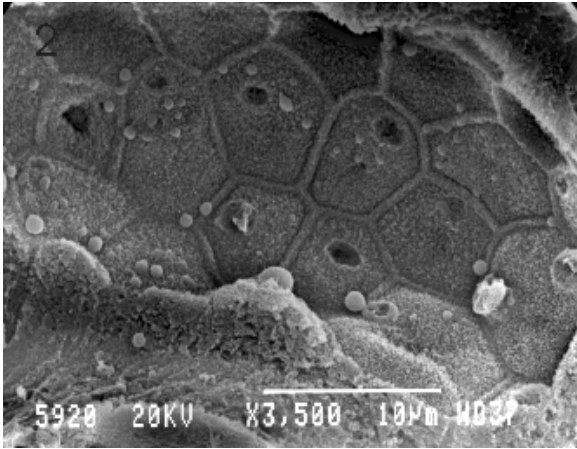


Figure 2. Scanning electron micrograph of the luminal surface of the tubuloalveolar gland exhibiting simultaneous apocrine and merocrine secretion. Note that on the same cell's surface, craters and granules are observed.

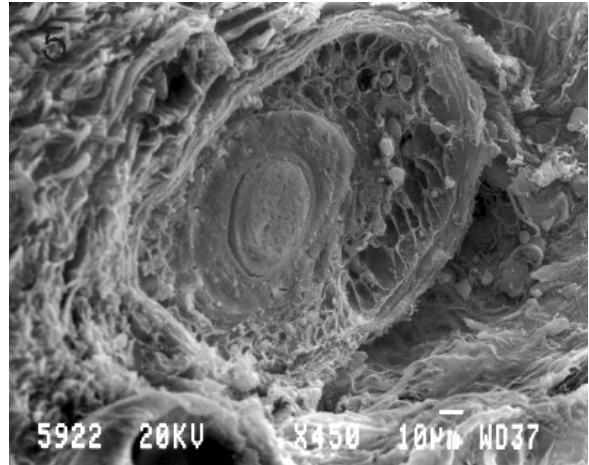


Figure 5. Scanning electron micrograph of a transverse section of a hair follicle with prominent sebaceous gland.

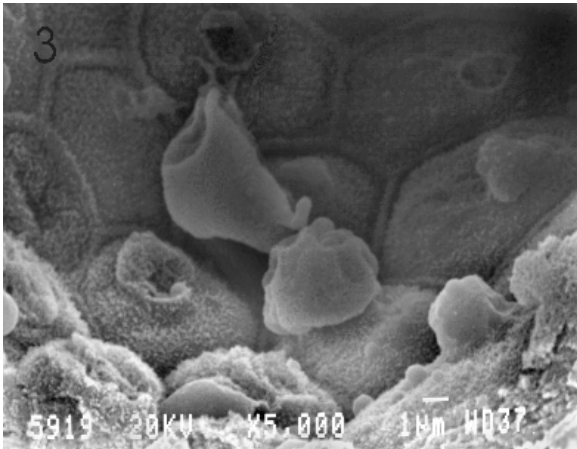


Figure 3. Scanning electron micrograph of apical caps of apocrine release. The epithelial cells of the tubuloalveolar glands possess rows of microvilli on their borders.

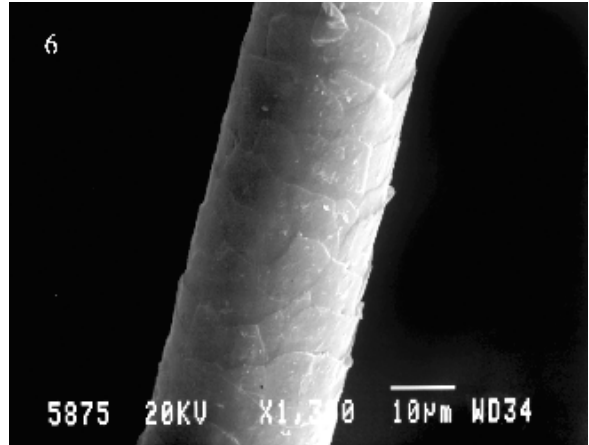


Figure 6. Scanning electron micrograph of a portion of a hair.

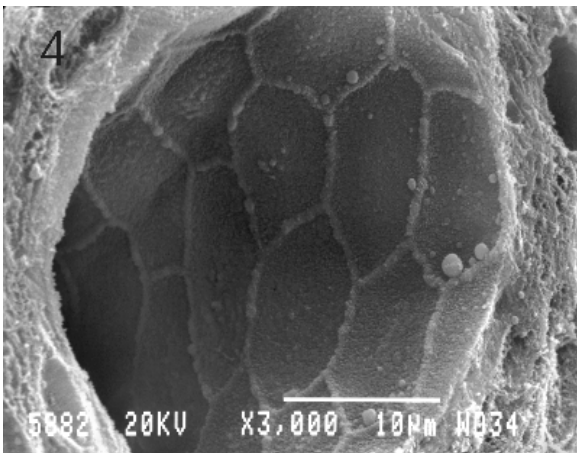


Figure 4. Scanning electron micrograph of the luminal surface of an interlobular duct.

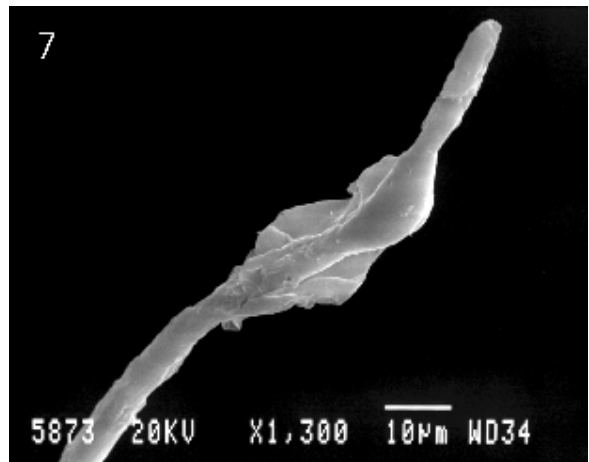


Figure 7. Scanning electron micrograph of the broad tip of a hair.

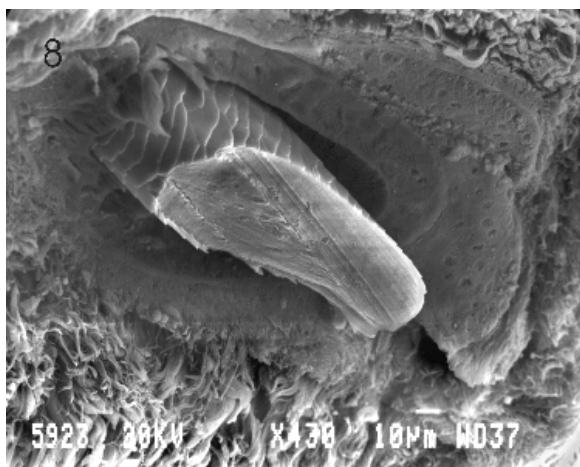


Figure 8. Scanning electron micrograph of a transverse section of a convex hair.

DISCUSSION

The sweat glands of the interdigital sinus of various artiodactyla have often been characterized as being of the apocrine category, based on a variety of structural characteristics and in contrast with eccrine sweat glands. The particular cytological features which characterize this category of sweat glands as apocrine appears, from an electron microscopic view, to be based on a misconception concerning the way secretion is passed out of these cells. For this reason, the term apocrine is no longer favoured, and a suitable replacement in the terminology or classification of types of sweat glands has to be considered. Few papers regarding the histology of interdigital glands allude to the double (apocrine-merocrine) mode of secretion [3, 5, 18, 19]. As far as it is known, however, the present paper refers, for the first time, to simultaneous apocrine and merocrine secretion. Scanty reports exist on the simultaneous functioning of two different secretion models in a single secretory cell type. Such a secretory pattern was observed in the anal gland of the woodchuck [23], in the rat Harderian gland [8], in the rat coagulating gland [9], and in the non-lactating human mammary gland [24].

In the present study, the simultaneous functioning of two different secretion modes (apocrine and merocrine) in a single secretory cell type was recorded. This means that apocrine and merocrine secretion are spatially, temporally, and mechanically separated processes [9].

Müller-Schwartz et al. [17] introduced the term "osmetrichia", in order to describe a special morpho-

logical feature of tarsal hairs in black-tailed deer (*Odocoileus hemionus columbianus*). These hairs claimed to be specialized for holding the materials which provide chemical signals in social communication. Osmetrichia in the interdigital gland of the brocket deer (*Mazama gouazoubira*) was reported by Ajmat et al. [2]. In the present study, no such micromorphological characteristics of hairs were observed. However, the curved shape of the stem of many hairs could lead to an analogous deduction. In addition, the appearance of the broad hair tip corroborates the idea that the interdigital sheep hairs could be modified to retain and dispense secretory material.

The function of the interdigital glands has been suggested to be that of scent marking in trails [18, 19, 22]. Conversely, Chapman [5] and Janicki et al. [10] suggested that the interdigital sinus might not act as a scent gland. The location of the opening of the interdigital sinus on the dorsal limb surface puts in doubt the generally accepted role of the sinus. Janicki et al. [10] proposed that the glands might have a role in lubricating the movable parts of the claw of roebuck.

In sheep, no biochemical data exist about the composition of the interdigital sinus secretions. A combination of scent marking and lubrication of the claw seems reasonable. Additionally, the simultaneous apocrine and merocrine release in various glands has been correlated with the secretion of protective and defensive substances [9, 24]. In sheep, the interdigital sinus is involved in the pathological conditions which cause lameness in the ovine extremities [25].

Therefore, the suggestion that the interdigital sinus has a unique function needs careful consideration. The ovine interdigital sinus should be functionally assessed on the basis of individual glands rather than being generalised.

A detailed histochemical and immunohistochemical investigation would be of great value.

CONCLUSIONS

The ovine interdigital sinus possesses a sweat glandular component which exhibits double secretory activity. Knowledge of the morphological features of sweat glands, as well as of hairs, could be useful to understand the function and the pathology of the interdigital sinus in the sheep.

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