

SIZE OF DESMOSOMES AND HEMIDESMOSOMES IN NORMAL HUMAN EPIDERMIS

Haruko Hino, Takasi Kobayasi and Gustav Asboe-Hansen

Department of Dermatology, University of Copenhagen, Rigshospital, Copenhagen, Denmark

Abstract. The dimensions of desmosomes and hemidesmosomes in normal human epidermis, i.e. their length and thickness, were studied in ordinary ultrathin sections. The length of desmosomes in the inner and middle squamous cell layer was 310 nm and 300 nm, while the thickness was 31 nm and 30 nm, respectively. In the outer squamous cell layer the values increased to 340 nm and 35 nm, respectively. The percentage total desmosomal length in relation to the perimeter of a cell showed the same tendency.

Key words: Desmosomes; Hemidesmosomes; Normal epidermis

A desmosome has a three-dimensional structure covering an area of a cell. Electron microscopy of ultrathin sections, however, reveals only the linear length, width or thickness at the section surface, while the exact area cannot be calculated.

Studies on the dimensions of epidermal desmosomes have been reported by many authors (3, 4, 9–13, 16, 18–20), whose findings range from 250 (19) to 700 nm (4, 9, 10) in length or diameter, and from 15 (16) to 80 nm (20) in thickness or intercellular distance, depending on the methods of fixation (8, 9, 16, 19) or staining (6, 7, 14), materials (1, 2, 9, 10, 16, 19), and the layer of epidermis investigated (1, 16, 19, 20). A few used the freeze-fracture technique (3, 4, 11, 12, 18).

Statistical analysis of the desmosomal sizes in normal human epidermis is necessary if pathological phenomena are to be evaluated. Using the ordinary ultrathin section method for electron microscopical observation, the authors studied the dimensions of desmosomes as well as hemidesmosomes in normal human epidermis, and their transformation from the inner to the outer parts of the epidermis.

MATERIAL AND METHODS

The material was normal skin of 5 middle-aged women obtained at mammoplasty surgery. 6.0% glutaraldehyde in a 0.15 M cacodylate buffer at pH 7.4 containing 7.5%

sucrose was used as the primary fixative. The specimens were postfixed with osmium tetroxide in the same buffer. After dehydration in serial steps of alcohol, the tissues were embedded in Epon 812. Ultrathin sections were cut with a Reichert ultramicrotome, ULTRACUT, and stained at room temperature with saturated uranyl acetate in 50.0% ethanol at pH 4.4 and lead citrate at pH 12.0 (15) for 20 and 15 min, respectively. The sections were examined with an electron microscope, JEOL 100CX.

Five strata of the epidermis were considered separately and compared, i.e. the stratum granulosum, the outer, middle and inner squamous cell layers, and the basal cell layer which has both desmosomes and hemidesmosomes. Three cells were chosen at random from each layer. The desmosomes and hemidesmosomes were studied for length and thickness on electron micrographs at final magnifications of 15 000 and 30 000 ×. The perimeter, viz. the length of the outline of each epidermal cell, was measured.

RESULTS

The numbers of intercellular junctions are shown in Table I.

There were a few gap junctions, whose sizes varied widely. Their lengths ranged between 165 and 475 nm, and their total thickness from 14 to 25 nm.

Fig. 1 and Table I show the lengths of the desmosomes. Three basal cells had 25, 31 and 28 desmosomes, respectively. The mean length of the 84 desmosomes was 336 nm. In three cells of the inner squamous cell layer, there were 89 desmosomes of 313 nm mean length. In the middle squamous cell layer, the desmosomes of three cells amounted to 120, whose mean length was 300 nm. In the outer squamous cell layer, 173 desmosomes were counted around three cells; their mean length was 342 nm. In the stratum granulosum, the corresponding counts around three cells were 145 desmosomes, with 344 nm for mean length. The hemidesmosomes, belonging to three basal cells, were distinct from the intercellular desmosomes. The number of hemidesmosomes counted was 185, mean length 171 nm.

The ratio of the desmosomes or hemidesmo-

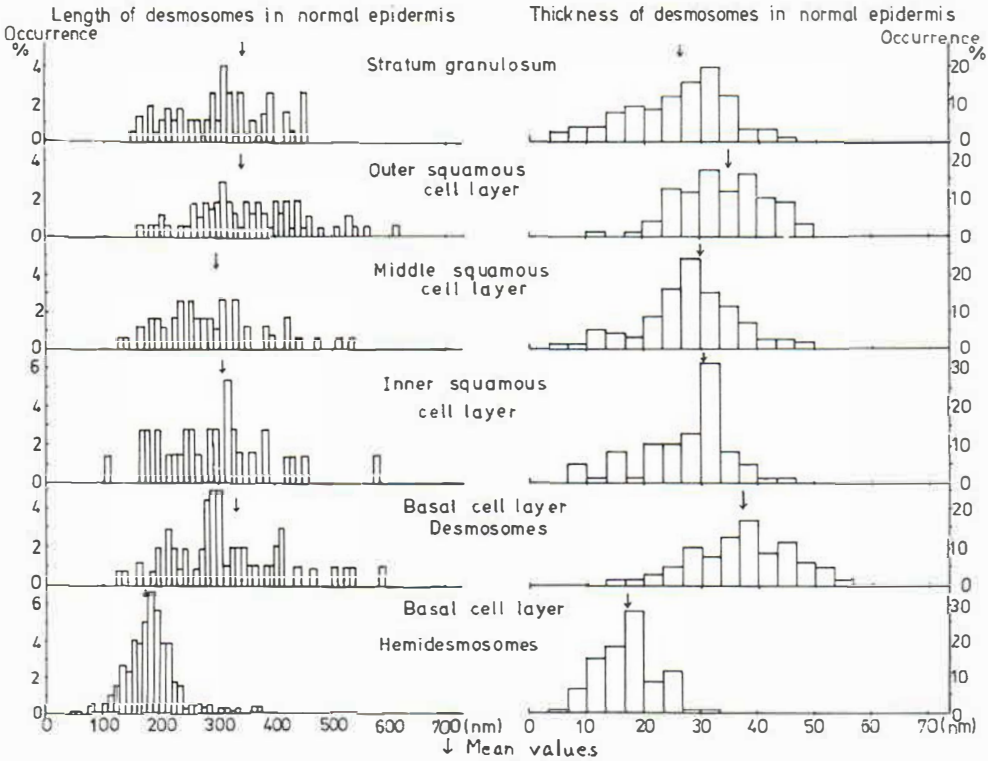


Fig. 1. Length and thickness of desmosomes in normal epidermis.

somes to the perimeter of the same cell in different epidermal layers was

$$\frac{\text{Total length of desmosomes}}{\text{Total length of cell outlines}} \times 100 (\%)$$

as shown in Table II. In the inner squamous cell layer, the total length of desmosomes of three cells was 27860 nm, while the total length of the cell perimeters was 129170 nm and the ratio 21.57%. In the middle squamous cell layer the ratio was 25.36%, in the outer squamous cell layer 33.69%, and in the stratum granulosum 33.49%. The percentage of desmosomes occupying the cell perimeter showed a slight increase outwards from 19.60% over 21.57% to 25.36%. In the outer squamous cell layer, both the mean length of desmosomes and the percentage desmosomal length of the cell perimeter increased up to 342 nm, or 33.69%, respectively. In the case of basal cells, the ratio of hemidesmosomes to the basal cell line facing the dermo-epidermal junction was 43.12%, while 19.60% of the remaining cell outlines was occupied by desmosomes.

However, the total length of desmosomes plus hemidesmosomes was 59990 nm, the total perimeter of three basal cells 217670 nm, and the percentage length of desmosomes plus hemidesmosomes to the cell perimeter was 27.56%. This value showed no evident difference between basal cell layer and squamous cell layers.

The thickness of desmosomes or hemidesmosomes varied depending on how they were measured. Table III and Fig. 2 show three values, viz. 1) total thickness including the attachment plaques of both sides, 2) thickness exclusive of the attachment plaques, which means the distance between the two inner leaflets of the plasma membranes, and 3) the intercellular space, which means the distance between the two outer leaflets of the plasma membranes. The difference between the former two indicates the thickness of the attachment plaques of both sides, which is about 17–20 nm for each. The difference between the latter two denotes the thickness of the two plasma membranes, which is about 3–10 nm for each. The distance between the outer leaflet of the plasma membrane of a basal cell and

Table I. Length and thickness of desmosomes and hemidesmosomes

	Individual cell						Epidermal layer				
	No. of desmosomes	Length (nm)		Thickness (nm) ^a		Total no. of desmosomes	Length (nm)		Thickness (nm) ^a		
		Mean length	S.D.	Mean thickness	S.D.		Mean length	S.D.	Mean thickness	S.D.	
Stratum granulosum	1	33	364.0	163.3	28.7	7.3	145	344.0	129.0	26.0	10.0
	2	47	350.0	116.6	24.7	8.7					
	3	65	316.7	113.3	29.2	11.3					
Outer squamous cell layer	1	64	338.0	113.3	33.3	7.3	173	342.2	103.3	34.7	8.7
	2	63	370.0	96.6	38.7	6.7					
	3	46	308.7	89.3	30.7	10.0					
Middle squamous cell layer	1	37	321.0	104.6	31.3	5.3	120	299.9	97.5	29.0	7.2
	2	46	284.0	92.0	28.0	7.3					
	3	37	297.3	93.3	28.7	8.0					
Inner squamous cell layer	1	38	296.0	103.3	27.3	9.3	89	312.9	119.3	31.1	9.4
	2	20	323.9	119.3	30.0	8.7					
	3	31	326.7	134.7	36.0	7.3					
Basal cell layer Desmosomes	1	25	363.3	165.3	30.3	4.6	84	336.0	137.6	37.1	9.2
	2	31	364.4	133.4	35.2	8.4					
	3	28	280.0	98.0	34.9	8.0					
Hemidesmosomes	1	64	163.4	58.6	18.6	2.7	185	170.9	71.0	17.3	2.9
	2	55	206.4	67.8	16.9	2.9					
	3	66	150.8	71.0	15.2	2.7					

* Thickness: Desmosomes: intercellular space=distance between two outer leaflets of plasma membranes. Hemidesmosomes: distance between outer leaflet of plasma membrane and junction plate.

Table II. Percentage length of desmosomes of cell outline

Σd =total length of desmosomes of each cell (nm). N =length of each cell outline (nm). ΣD =total length of desmosomes (nm). ΣN =total length of each cell outline (nm)

	Individual cell			Total of each layer of epidermis			
		Σd (nm)	N (nm)	$\Sigma d/N$ (%)	ΣD (nm)	ΣN (nm)	$\Sigma D/\Sigma N$ (%)
Stratum granulosum	1	12020	28170	42.66	49060	146500	33.49
	2	16450	46170	35.62			
	3	20590	72170	28.54			
Outer squamous cell layer	1	21650	59000	36.69	59190	175670	33.69
	2	23330	67670	34.48			
	3	14210	49000	29.01			
Middle squamous cell layer	1	11890	47000	25.29	35970	141830	25.36
	2	13080	57330	22.81			
	3	11000	37500	29.33			
Inner squamous cell layer	1	11250	60670	18.54	27860	129170	21.57
	2	6480	39170	16.54			
	3	10130	29330	34.52			
Basal cell layer Desmosomes	1	9080	38670	23.48	28230	144010	19.60
	2	11310	42670	26.50			
	3	7840	62670	12.51			
Hemidesmosomes	1	10460	24000	43.58	31760	73660	43.12
	2	11350	24330	46.64			
	3	9950	25330	32.29			

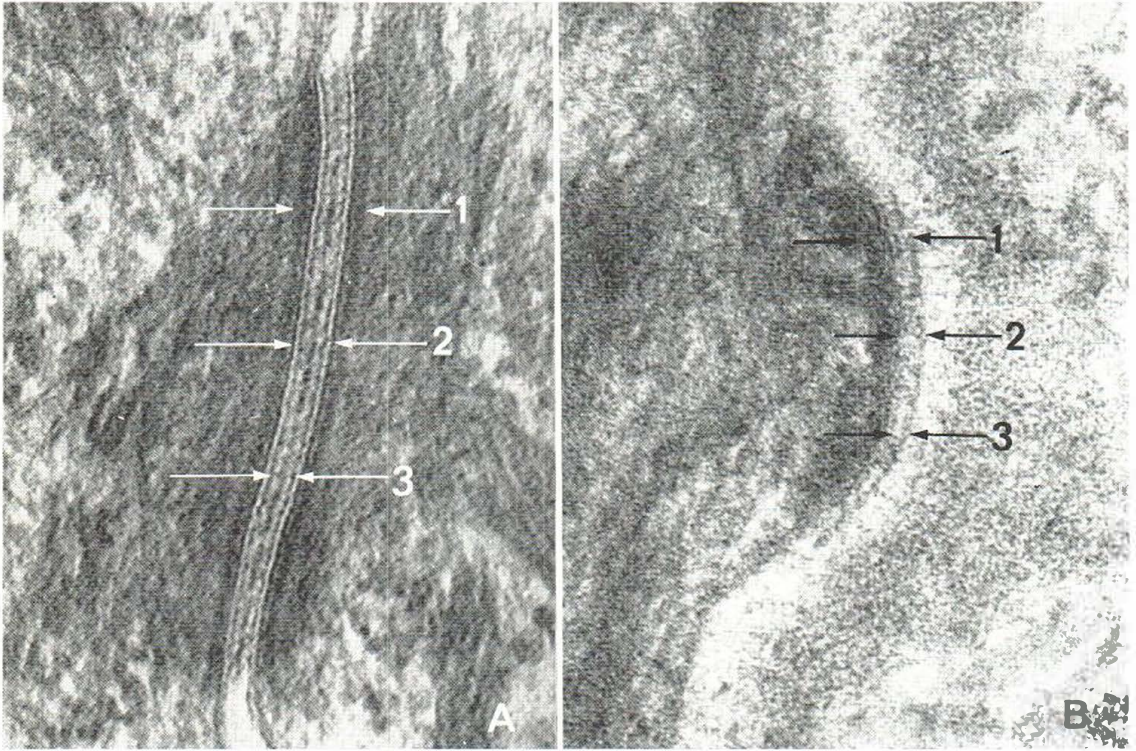


Fig. 2. (A) Desmosome. (B) Hemidesmosome. Thicknesses 1, 2, and 3 are shown in Table III. $\times 150\ 000$.

the junction plate was measured as the thickness of hemidesmosomes (5), shown in Tables I and III and Figs. 1 and 2.

The mean thickness of hemidesmosomes was 17 nm. The desmosomes of the basal cells had 37 nm of mean thickness, while those of the inner and middle squamous cell layers were 31 nm and 29 nm, respectively. In the outer squamous cell layer, the

desmosomes became as thick as 35 nm. The desmosomes in the stratum granulosum, however, were 26 nm.

DISCUSSION

When the thickness of desmosomes is discussed, it is necessary to define which part of the desmosomes is measured. This is why, in the present

Table III. Thickness of desmosomes and hemidesmosomes

Desmosomes: thickness 1: total, incl. attachment plaques. Thickness 2: excl. attachment plaques = distance between two inner leaflets of plasma membranes. Thickness 3: intercellular space = distance between two outer leaflets of plasma membranes. Hemidesmosomes: Thickness 1: total, incl. attachment plaque and junction plate. Thickness 2: excl. attachment plaque = distance between inner leaflet of plasma membrane and junction plate. Thickness 3: distance between outer leaflet of plasma membrane and junction plate

	Thickness 1 (nm)	Thickness 2 (nm)	Thickness 3 (nm)
Stratum granulosum	82.9	44.1	26.0
Outer squamous cell layer	74.9	40.0	34.7
Middle squamous cell layer	83.2	41.8	29.0
Inner squamous cell layer	81.3	45.0	31.1
Basal cell layer			
Desmosomes	85.8	46.9	37.1
Hemidesmosomes	58.1	26.0	17.3

study, the intercellular space was measured as the thickness of desmosomes. Moreover, the thickness of the attachment plaques did not show any evident change between the epidermal layers or during transformation of the epidermal cells. The intercellular space, on the other hand, may be influenced and easily changed by several factors, e.g. under pathological conditions and in response to mechanical or chemical effects.

Snell (19, 20) used guinea-pig skin, and found that the total thickness of a desmosome was about 70–80 nm in the basal layer and the squamous cell layer, while the diameter was about 250–700 nm. These figures are quite similar to ours. Raknerud (13), who studied the desmosomal transformation during keratinization of the interfollicular epidermis of the hairless mouse, found the thickness of the desmosomes to vary between 25 and 35.5 nm. When we assumed the intercellular space to be the thickness of desmosomes, our results were 26–37 nm and thus almost the same.

Rupec (16) classified desmosomes into the well-known desmosomes, simple desmosomes, and nexus or gap junction. He found the intermediate dense layer to correspond to the outer leaflet of the plasma membrane, and believed that it did not belong to the intercellular space. The attachment plaque was 15 nm, and the intercellular part of a desmosome 15 nm. Rupec found the width of a gap junction to be 20 nm, which is similar to our finding.

In hemidesmosomes, Rupec et al. (17) found the attachment plaque to be 20–30 nm, the plasma membrane 10 nm, and the distance between the junction plate and the plasma membrane of basal cell, 25–30 nm. In our study, the distance between the plasma membrane and the junction plate turned out to be lower than Rupec's value.

Using the freeze-fracture technique, Orwin et al. (11, 12) related the desmosomal length to the cell perimeter. In sheep wool follicle, they reported the desmosome length to be 2% in the mitotic zone and 5% in the more differentiated layers. The number of desmosomes increased during differentiation of the matrix cells. These results are at considerable variance with ours.

Snell (19), Raknerud (13), and Caputo et al. (3) reported the desmosomes of the stratum granulosum to be modified along with the round keratinocytes being transformed to flat shapes. Parallel with the changes in cell shape, the desmosomes belonging to them became narrower. In our

study, however, the major change in desmosomes occurred between the middle and the outer squamous cell layers; they became longer and wider, but between the outer squamous cell layer and stratum granulosum the thickness was slightly decreased, suggesting that the desmosome shape changes according to the shape of their mother cell. The percentage desmosomal occupancy of the perimeter of the cell showed the same tendency.

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H. Hino, M.D.
Department of Dermatology
Rigshospital
Blegdamsvej 9
DK-2100 Copenhagen Ø
Denmark