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BASIC STUDIES OF THE SKIN TRANSPLANT FOR TYMPANOPLASTY

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ABSTRACT

Histological and *in vivo* examinations of skins were made in order to offer one of the grounds of tympanic skin grafting in the following 14 regions: the external auditory canal (cartilagineous portion), the retroauricular region, the upper arm (medial and lateral parts), the forearm (anterior and posterior parts), the thorax, the back, the abdomen (lateral and hypogastric parts), the inguinal region, the gluteal region, and the thigh (medial and lateral parts). Although considerably different in relation to individuals, both the data show some common characteristic trends of skin in different regious of the body surface irrespective of age. The present data were summarized as follows: 1. Thick skin pieces can be usually removed from the gluteal region and the abdomen. 2. The distribution of sebaceous glands is relatively scarce in the upper and lower extremities. Accordingly, irrespective of the methods of transplantation, skin pieces removed from both the extremities are of more advantage in preventing them from infection and crust formation. 3. The distribution of sweat glands in skin pieces is almost uniform in the major regions of the body surface. Skin pieces removed by the split thickness graft method are evenly available for tympanic grafting, and those from the back and gluteal regions are of more advantage in preventing them from infection because of the deepest presence of sweat glands there. 4. The distribution and thickness of hairs have a relation with the success of tympanic skin grafting. Perforation of skin pieces, to be induced by the thin split thickness graft method, is prevented by using the thick split thickness graft method, due to regeneration from the remaining part of the hair roots in the deeper layer of skin pieces. The possibility of development of cholesteatoma from hair roots is, however, prevented by using the same skins in the full thickness graft method. 5. The extension and distribution of elastic fibers, especially of deep horizontal thick elastic fibers, has a relation with the success of tympanic skin grafting—skin pieces removed from the retroauricular region, the back and the gluteal region are of advantage, because the distribution and extension of deep horizontal thick elastic fibers are found far deeper in those regions than anywhere else. 6. Considering from the abovementioned data, it is probable that skin transplants removed from the thigh, the back, the gluteal and retroauricular regions are theoretically more avaiable as tympanoplastic material, although it is difficult to determine their superiority or inferiority in detail as tympanoplastic material in the skins of the whole body surface examined.

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The plastic operation of the tympanic membrane has been studied as one of the mest important problems of rehabilitative ear surgery. Until recently, skins, fascias, veins, periosea and cartilagineous membranes have been used as plastic materials. In this work, the basic problem of the skin pieces as one of materials for tympanoplasty was studied. This problem has been seldom studied in relation to the histological structures and minute functional activity of skin and of its accessory glands included to be taken from different regions of the body surface. Major previous studies have been mainly centered upon the problem of the thickness and areas of skin pieces, vascular relations and, further, amount of elastic fibers in them.

MATERIAL AND METHODS

Basic histological observations of skins were made in 12 human cadavers with the following ages and sexes—22 (male), 26 (female), 39 (male), 48 (male), 49 (male), 53 (male), 59 (female), 60 (male), 60 (male), 61 (male), 63 (male), and 65 (female) years old. Three skin pieces 1 cm^2 each were taken from the following 14 different regions of the body surface—1. the external auditory canal (cartilagineous portion), 2. the retroauricular region, 3 and 4. the upper arm (medial and lateral parts), 5 and 6. the forearm (anterior and posterior parts), 7. the thorax (mammary region), 8. the back (interscapular region), 9 and 10. the abdomen (lateral and hypogastric parts), 11. the inguinal region, 12. the gluteal region, and 13 and 14. the thigh (medial and lateral parts). Materials taken were fixed in 10% formalin, embedded in paraffin, and sectioned serially vertically and transversely in 20 μ. Sections were stained with Hansen's hematoxylin and eosin, and further with Weigert's resorcin-fuchsin. In vertical sections, the thickness of skin pieces without subcutaneous fat tissue, and topographic levels (depths from the skin surface) of sebaceous glands, sweat glands and hair roots, and further in transverse sections their frequencies of occurrence per cm^2 were quantitatively estimated.

Basic *in vivo* examinations of functional activity of sebaceous and sweat glands were made bilaterally in almost the same places, as examined in cadavers, in room temperature 20° to 26°C with humidity 50 to 60%, respectively by Endelin and Brun's method and by Kobori's method (1959) in 11 healthy persons ranging in age from 19 to 42 years.

The former histological examinations confirm histological characteristics of skins suitable for tympanic grafting in different regions of the body surfaces and the latter *in vivo* examinations confirm functional activity of the skin accessory glands, as one of the indices of function of the skin related, and further find a relation between the activity of the glands and prognosis of tympanoplasty.

In examining healing of wounds left in the medial part of the thigh or in

the gluteal region, from where skin transplants were taken, restoration of activity of sebaceous and sweat glands related was observed in patients—10 persons—7 men and 3 women ranging in age from 3 to 26 years. After removal of skin pieces from the medial part of the thigh or from the gluteal region and subsequent prevention of bleeding, wounds were directly covered with three or four folded Sofra-Tulle gauzes containing 1% fradiomycine sulphate, and further usually with ordinary gauzes. The ordinary gauzes alone were daily exchanged but not Sofra-Tulle gauzes. In 10 to 14 days after this treatment the direct Sofra-Tulle gauzes could be removed naturally without resistance and pain. Healing areas were daily examined for restoration of activity of sebaceous and sweat glands, respectively by Kobori's method (1959) and by 1% hydrochloric pilocarpin until these glands reach activity levels of controls.

OBSERVATIONS

Histological

Thickness of skins (Table 1). Measurements were restricted to skins (epidermis and corium) without subcutaneous fat tissue. As shown in Table 1, the thickness was maximum 2.27 mm in the gluteal region, and minimum 1.66 mm in the posterior part of the forearm, decreasing between in order in the lateral part of the abdomen, the inguinal region, the cartilagineous portion of the external auditory canal, the thorax, hypogastric part of the abdomen, the back, the lateral part of the thigh, the medial part of the thigh, the retroauricular region, the medial part of the upper arm, the lateral part of the upper arm, and the anterior part of the forearm.

Distribution of sebaceous glands (Tables 1 and 2). Frequencies of occurrence per cm^2 of sebaceous glands were estimated. The frequencies were maximum 66.2 in the retroauricular region and minimum 4.5 in the medial part of the thigh—decreasing between in order in the back, the cartilagineous portion of the external auditory canal, the thorax, the lateral part of the upper arm, the hypogastric part of the abdomen, the gluteal region and further the inguinal region, the medial part of the upper arm, the anterior and posterior parts of the forearm, the lateral part of the abdomen and the lateral part of the thigh.

Topographic levels (depths from the skin surface) of sebaceous glands in vertical section were expressed by measuring the distance between the skin surface and the middle point of the main body of the gland. The levels were maximum 0.81 mm in the back, and minimum 0.33 mm in the medial part of the thigh, decreasing in order in the gluteal region, the thorax, the retroauricular region, the lateral part of the abdomen, the cartilagineous portion of the external auditory canal, the hypogastric part of the abdomen, the inguinal region, the lateral part of the upper arm, the anterior and posterior parts of the forearm, the medial part of the upper arm and the lateral part of the thigh.

TABLE 1. The thickness* of skins in different regions of the body surface and topographic levels (depths from the skin surface in mm) of skin components (sebaceoust** and swea*** glands, hair roots# and elastic fibers##)

Age in years→ / Sex→ / No. of cases→ / Regions ↓		22 m 1	26 f 1	39 m 1	48 m 1	49 m 1	53 m 1	59 f 1	60 m 1	60 m 1	61 m 1	63 m 1	65 f 1	Averaged values	Standard deviations
external auditory canal	*	1.9	2.0	1.8	1.7	1.8	2.2	2.1	2.2	1.9	2.3	1.9	2.1	1.99	0.235
	**	0.6	0.6	0.7	0.6	0.7	0.5	0.7	0.7	0.6	0.5	0.5	0.4	0.59	0.092
	***	0.6~2.0	0.7~2.1	0.8~1.8	0.6~1.7	0.5~1.7	0.5~2.2	0.6~2.1	0.8~2.2	0.4~2.0	0.6~2.2	0.7~1.8	0.7~2.1	0.62~1.99	0.130, 0.992
	#	1.9	1.5	1.0	1.2	1.4	1.8	1.8	2.0	1.8	1.4	1.8	1.8	1.60	0.345
	##	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.18	0.032
retro-auricular	*	2.0	1.9	1.7	1.4	1.5	1.7	1.6	1.7	1.9	1.8	2.2	1.7	1.76	0.263
	**	0.7	0.6	0.6	0.8	0.7	0.7	0.6	0.8	0.5	0.8	0.7	0.6	0.68	0.119
	***	0.7~1.7	0.6~1.4	0.9~1.6	0.9~1.2	0.8~1.3	0.8~1.8	0.7~1.6	0.6~1.8	0.5~1.9	0.5~1.8	0.4~2.1	0.4~1.6	0.65~1.65	0.181, 0.272
	#	1.3	1.5	1.5	1.0	1.1	1.4	1.4	1.2	1.3	1.6	1.5	1.3	1.34	0.225
	##	0.5	0.4	0.4	0.6	0.5	0.5	0.4	0.3	0.5	0.7	0.4	0.3	0.42	0.090
upper arm lateral	*	1.9	1.6	1.7	1.4	1.8	1.7	1.8	1.8	1.9	1.7	1.9	1.6	1.73	0.163
	**	0.4	0.5	0.4	0.6	0.5	0.7	0.5	0.6	0.5	0.5	0.6	0.7	0.54	0.112
	***	0.6~1.8	0.4~1.6	0.5~1.8	0.4~1.4	0.6~1.8	0.6~1.7	0.6~1.7	0.5~1.8	0.7~1.8	0.6~1.7	0.6~1.8	0.9~1.6	0.58~1.71	0.172, 0.125
	#	1.7	1.5	1.3	1.0	1.4	1.5	1.6	1.4	1.3	1.6	1.4	1.3	1.41	0.224
	##	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.19	0.032
medial	*	1.8	1.7	1.7	1.5	1.8	1.8	1.7	1.7	2.1	1.7	1.8	1.5	1.80	0.197
	**	0.5	0.4	0.4	0.5	0.6	0.6	0.7	0.5	0.5	0.4	0.4	0.6	0.51	0.072
	***	0.7~1.8	0.8~1.7	1.0~1.7	0.7~1.4	0.8~1.8	0.6~1.9	0.8~1.8	0.6~1.9	0.6~1.6	0.5~1.6	0.7~1.7	0.6~1.5	0.70~1.70	0.161, 0.153
	#	1.6	1.4	1.3	1.0	1.3	1.5	1.7	1.4	1.3	1.5	1.4	1.0	1.36	0.292
	##	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.14	0.033
forearm anterior	*	1.7	1.7	1.6	1.5	1.6	1.7	1.5	1.7	2.0	1.8	1.7	1.7	1.68	0.186
	**	0.5	0.4	0.3	0.4	0.4	0.4	0.4	0.5	0.6	0.5	0.8	0.6	0.52	0.112
	***	0.7~1.4	0.6~1.3	0.8~1.6	0.9~1.4	0.9~1.6	0.7~1.7	0.9~1.5	0.7~1.8	0.8~1.5	0.7~1.8	0.9~1.6	1.0~1.5	0.80~1.56	0.092, 0.121
	#	1.4	1.2	1.2	1.1	1.3	1.4	1.1	1.2	1.5	1.4	1.3	1.4	1.28	0.185
	##	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.16	0.021
posterior	*	1.8	1.7	1.6	1.6	1.6	1.5	1.4	1.8	1.7	1.5	1.9	1.8	1.67	0.163
	**	0.6	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.53	0.080
	***	0.9~1.8	0.8~1.7	0.7~1.5	1.8~1.6	0.7~1.6	0.7~1.4	0.8~1.4	0.9~1.7	0.8~1.7	0.8~1.5	0.8~1.7	0.8~1.7	0.79~1.60	0.110, 0.110
	#	1.4	1.0	1.2	1.5	1.5	1.4	0.9	1.4	1.4	1.1	1.2	1.4	1.28	0.222
	##	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.19	0.034

thorax (mammary)	*	2.2	2.0	2.1	1.8	1.8	1.9	1.7	1.9	1.7	1.7	2.2	1.7	1.81	0.182
	**	0.6	0.7	0.7	0.6	0.8	0.6	0.6	0.7	0.8	0.8	0.6	0.8	0.69	0.075
	***	0.9～1.9	0.7～2.0	0.7～2.1	0.8～1.8	0.7～1.7	0.6～1.9	0.4～1.7	0.6～1.8	0.5～1.7	0.5～1.6	0.6～2.0	0.7～1.7	0.64～1.79	0.116, 0.175
	#	1.7	1.5	1.9	1.4	1.4	1.4	1.5	1.4	1.5	1.8	1.4	1.4	1.50	0.172
	##	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.23	0.034
back (inter-scapular)	*	2.0	1.8	2.1	1.8	1.8	1.9	1.7	1.9	1.7	1.7	2.2	1.7	1.87	0.173
	**	0.7	0.6	0.8	0.9	0.7	0.8	0.9	0.7	0.7	0.6	0.7	0.8	0.81	0.129
	***	1.2～1.9	1.2～1.8	1.4～2.1	1.0～1.9	1.2～1.9	1.3～2.0	1.5～1.9	1.5～1.7	1.3～1.7	1.2～1.7	1.2～1.8	0.7～1.7	1.23～1.84	0.231, 0.138
	#	1.9	1.6	1.5	1.4	1.5	2.0	1.5	2.0	1.9	2.2	2.0	1.4	1.74	0.282
	##	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.4	0.4	0.4	0.3	0.4	0.36	0.079
abdomen lateral	*	2.2	1.9	2.0	1.9	2.0	2.5	2.4	2.5	2.3	2.0	2.1	1.8	2.13	0.236
	**	0.7	0.5	0.6	0.5	0.5	0.6	0.6	0.7	0.6	0.6	0.7	0.6	0.60	0.078
	***	0.7～2.1	0.9～1.8	1.0～2.0	1.2～1.8	1.1～1.9	0.9～2.5	0.8～2.4	0.7～2.5	0.9～2.3	0.7～2.0	0.7～1.9	0.8～1.9	0.87～2.10	0.153, 0.242
	#	1.9	1.8	1.7	1.3	1.5	1.9	1.8	1.8	1.9	1.4	1.4	1.6	1.67	0.221
	##	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.21	0.032
hypogastric	*	2.2	1.9	1.7	1.6	1.8	1.9	1.8	2.4	1.8	1.9	2.0	1.8	1.90	0.276
	**	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.7	0.7	0.6	0.4	0.57	0.071
	***	0.8～2.1	0.7～1.9	1.0～1.7	0.9～1.6	1.1～1.8	1.0～1.8	1.0～1.8	0.9～2.2	0.8～1.7	1.0～1.9	1.0～2.0	1.1～1.8	1.03～1.86	0.303, 0.189
	#	1.5	1.3	1.0	1.0	1.4	1.6	1.6	1.9	1.7	1.6	1.5	1.5	1.45	0.223
	##	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.22	0.031
inguinal	*	2.1	2.0	1.8	1.7	2.0	2.3	2.2	2.3	1.9	2.0	2.2	2.1	2.05	0.219
	**	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.6	0.7	0.6	0.5	0.56	0.195
	***	0.8～1.5	0.6～1.4	0.9～1.8	0.7～1.6	0.7～2.0	0.8～2.1	0.9～2.3	0.8～2.3	0.8～1.9	0.9～2.0	0.9～2.2	1.0～1.9	0.82～1.91	0.127, 0.205
	#	1.8	1.6	1.5	1.4	1.4	2.0	1.9	2.0	1.4	1.6	2.0	1.8	1.70	0.228
	##	0.2	0.2	0.1	0.1	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.20	0.062
gluteal	*	2.3	2.1	2.1	2.0	2.0	2.5	2.3	2.4	2.4	2.3	2.6	2.3	2.27	0.212
	**	0.7	0.8	0.6	0.9	0.9	0.9	0.7	0.8	0.8	0.8	0.9	0.8	0.81	0.073
	***	1.0～2.0	1.0～1.8	1.2～2.1	1.1～2.0	1.1～2.0	1.2～2.4	1.2～2.2	1.1～2.2	1.2～2.3	1.2～2.2	1.3～2.2	1.0～2.1	1.13～2.12	0.136, 0.147
	#	1.9	1.5	1.8	1.5	1.6	1.9	2.0	2.2	2.0	1.8	1.9	1.6	1.81	0.232
	##	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.21	0.039
thigh lateral	*	1.9	1.8	1.7	1.7	1.7	2.2	1.8	1.9	1.9	1.8	1.7	1.9	1.83	0.171
	**	0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.3	0.3	0.4	0.4	0.3	0.37	0.072
	***	1.0～1.7	0.9～1.8	0.7～1.6	0.8～1.6	0.6～1.7	0.7～2.2	0.8～1.7	0.9～1.8	1.2～1.8	1.3～1.7	1.2～1.7	1.3～1.9	0.95～1.76	0.333, 0.193
	#	1.6	1.4	1.5	1.2	1.3	1.6	1.4	1.5	1.6	1.4	1.4	0.9	1.40	0.222
	##	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.18	0.039
medial	*	1.8	1.6	1.5	1.7	1.8	2.1	1.9	2.1	1.7	1.8	2.0	1.8	1.82	0.205
	**	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.33	0.035
	***	0.9～1.7	0.9～1.5	1.0～1.5	1.0～1.6	1.1～1.7	1.1～2.2	0.8～1.9	0.9～2.0	1.0～1.9	1.1～1.8	0.9～1.9	0.9～1.8	0.97～1.80	0.121, 0.212
	#	1.7	1.5	1.6	1.3	1.4	1.8	1.7	1.5	1.6	1.8	1.5	1.3	1.56	0.182
	##	0.2	0.1	0.2	0.2	0.2	0.2	0 2	0.2	0.2	0.1	0.1	0.1	0.18	0.039

The values indicated in 14 different regions of the body in Tables 1 to 3 mean averaged values which are based upon measurements of three skin pieces (3 cm^2 in all) in each region.

TABLE 2. Frequencies per cm² of occurrence of skin accessories (sebaceous glands *, sweat glands ** and hair roots ***)

Age in years→ / Sex→ / No. of cases→ / Regions ↓		22 m 1	26 f 1	39 m 1	48 m 1	49 m 1	53 m 1	59 f 1	60 m 1	60 m 1	61 m 1	63 m 1	65 f 1	Averaged values and Standard deviations	
external auditory canal	*	36	34	32	40	32	36	35	28	32	28	31	28	32.7	4.12
	**	126	120	153	108	105	99	116	98	89	102	120	104	111.7	21.15
	***	105	80	88	98	92	102	77	91	78	79	88	80	88.2	8.47
retro-auricular	*	66	52	48	52	60	68	72	80	60	76	80	80	66.2	9.01
	**	158	142	136	152	148	135	163	152	131	168	140	126	147.5	12.11
	***	66	52	59	48	63	59	60	49	56	80	60	52	57.7	9.92
upper arm lateral	*	32	22	28	48	22	22	18	20	12	15	25	21	23.8	9.85
	**	151	155	168	159	148	145	162	132	160	115	153	128	148.0	17.57
	***	58	62	47	44	52	62	58	59	61	72	68	51	57.8	5.70
medial	*	12	8	16	12	10	9	9	8	9	8	8	12	10.1	2.60
	**	122	132	152	123	115	136	103	98	112	103	111	116	118.6	17.91
	***	47	50	52	60	51	44	50	55	48	59	53	51	51.1	5.27
forearm anterior	*	10	8	8	9	6	6	8	12	6	6	9	7	7.9	1.96
	**	132	144	155	169	132	120	115	111	128	148	145	116	134.5	19.24
	***	31	36	40	29	28	39	32	29	23	20	19	24	29.2	6.93
posterior	*	8	9	10	10	12	9	11	11	5	5	5	4	8.3	2.62
	**	136	142	140	155	164	158	140	147	116	131	120	147	141.3	15.90
	***	30	25	28	27	31	19	23	19	17	25	25	23	24.3	4.12
thorax (mammary)	*	30	18	28	16	40	16	20	24	25	32	23	24	24.5	8.01
	**	180	172	172	175	152	123	128	132	120	128	135	147	147.0	19.26
	***	50	52	55	76	72	49	57	53	63	51	44	43	63.8	10.57
back (inter-scapular)	*	42	35	40	32	40	32	30	32	38	35	45	16	34.8	9.19
	**	185	170	205	176	168	178	149	143	148	161	140	171	165.4	21.02
	***	92	78	88	80	64	75	64	80	71	79	67	56	74.5	15.30
abdomen lateral	*	10	7	8	12	10	9	9	8	5	6	5	5	7.8	2.28
	**	176	160	172	157	152	132	123	140	125	148	140	138	147.0	17.57
	***	45	40	43	39	29	45	37	31	44	33	31	56	39.4	8.74
hypogastric	*	21	16	20	20	15	12	10	12	16	14	14	16	15.5	3.62
	**	152	140	145	163	160	165	151	139	132	122	128	120	129.8	15.13
	***	66	51	61	41	29	30	36	39	47	42	39	43	43.7	12.37
inguinal	*	13	10	7	12	13	10	10	15	9	10	9	7	10.4	2.71
	**	174	160	168	159	160	139	156	119	132	144	156	133	150.0	18.33
	***	50	41	47	37	33	45	37	31	36	33	28	31	37.3	7.30
gluteal	*	13	15	16	15	13	15	16	15	13	16	20	14	15.1	2.32
	**	180	172	197	192	171	168	160	157	124	139	133	119	159.3	25.77
	***	65	57	61	41	29	30	36	39	47	42	39	43	44.1	11.69
thigh lateral	*	8	6	4	8	5	5	6	8	6	6	4	4	5.8	1.32
	**	198	182	196	176	164	163	160	158	140	144	132	124	161.4	25.54
	***	46	45	46	39	47	40	44	49	44	39	36	48	44.4	4.24
medial	*	7	5	6	5	3	3	4	4	3	4	5	5	4.5	1.22
	**	182	160	168	172	176	159	148	133	117	123	144	104	148.9	26.38
	***	62	50	51	63	44	47	51	49	52	53	36	55	51.1	8.91

Distribution of sweat glands (Tables 1 and 2). The same method was used, as described in the section of sebaceous glands. Frequencies of sweat glands were maximum 165.4 in the back and minimum 111.7 in the cartilagineous portion of the external auditory canal, decreasing in order in the lateral part of the thigh, the gluteal region, the inguinal region, the medial part of the thigh, the lateral part of the upper arm, the retroauricular region, the thorax, and the anterior and posterior parts of the forearm. It was found, however, as shown in Table 2, that the frequency difference is averagely not so great, and the frequency ranges around 120 in different regions.

Topographic levels (depths) of sweat glands in vertical sections were expressed by measuring two distances, 1. between the skin surface and upper margin of the sweat gland body and 2. between the skin surface and lower margin of the sweat gland body. The former distance was maximum 1.23 mm in the back and minimum 0.58 mm in the lateral part of the upper arm, decreasing in order in the gluteal region, the lateral and medial parts of the thigh, the hypogastric and lateral parts of the abdomen, the inguinal region, the anterior and posterior parts of the forearm, the retroauricular region, the thorax, the medial part of the upper arm and the cartilagineous portion of the external auditory canal. The latter distance was maximum 2.12 mm in the gluteal region and minimum 1.56 mm in the posterior part of the forearm, decreasing in order in the anterior part of the abdomen, the inguinal region, cartilagineous portion of the external auditory canal, the hypogastric part of the abdomen, the back, medial part of the thigh, the thorax, the lateral part of the thigh, the retroauricular region, the medial and lateral parts of the upper arm and the posterior part of the forearm.

Frequencies of occurrence per cm^2 of hair roots. The frequencies were maximum 88.2 in the cartilagineous portion of the external auditory canal and minimum 24.3 in the posterior part of the forearm, decreasing in order in the back, the thorax, the lateral part of the thigh, the retroauricular region, the medial part of the upper arm, the medial part of the thigh, the lateral part of the upper arm, the gluteal region, the lateral and hypogastric parts of the abdomen, the inguinal region and the anterior part of the forearm.

Topographic levels (depths from the skin surface) of hair roots. The levels were expressed by measuring the distance between the skin surface and the lower end of the hair root. The distance was maximum 1.81 mm in the gluteal region and minimum 1.28 mm in the anterior and posterior parts of the forearm, decreasing in order in the back, the inguinal region, the lateral part of the abdomen, the cartilagineous portion of the external auditory canal, the medial part of the thigh, the lateral part of the upper arm, the retroauricular region and the medial part of the upper arm.

Elastic fibers in skins were divided into two groups, 1. horizontal thick

elastic fibers in the deeper layer of the skin and 2. vertical thin elastic fibers in the superficial layer originating from the former group. The extension of the horizontal deep thick elastic fibers was expressed by measuring the distance between the skin surface and the upper margin of this group and was maximum 0.42 mm in the retroauricular region and minimum 0.14 mm in the medial part of the upper arm, decreasing in order in the back, the thorax, the hypogastric part of the abdomen, the lateral part of the abdomen, the gluteal region, the lateral part of the upper arm, the inguinal region, the posterior part of the forearm, cartilagineous portion of the external auditory canal, the medial and lateral parts of the thigh, and the anterior part of the forearm (Table 1). The lower margin of this group corresponds in length to lower margin of the corium but sometimes extends to subcutaneous fat tissue.

The extension of vertical, superficial thin elastic fibers was estimated by measuring two distances, 1. the distance between the skin surface and the upper margin of the extension, and 2. the distance between the skin surface and the lower margin. The former distance was maximum 0.24 mm in the back and minimum 0.06 mm in the anterior part of the forearm, decreasing in order in the thorax, the inguinal region, the cartilagineous portion of the external auditory canal, the retroauricular region, the lateral and hypogastric parts of the abdomen and the medial part of the thigh. The latter distance was maximum 0.39 mm in the retroauricular region and minimum 0.11 mm in the anterior part of the forearm, decreasing in order in the back, the gluteal region, the lateral part of the thigh, the thorax, the hypogastric part of the abdomen, the medial part of the thigh, the posterior part of the forearm, the medial part of the upper arm, the inguinal region and the lateral part of the abdomen.

In vivo

Functional activity of skin accessory glands (Table 3). Frequencies of occurrence per cm^2 of active sebaceous glands were shown in Table 3 and were maximum 24.3 in the right side and 23.2 in the left side in the retroauricular region and minimum 0.6 in the both sides in the anterior part of the forearm, decreasing in order in the back, the thorax, the cartilagineous portion of the external auditory canal, the gluteal region and the lateral part of the abdomen and further sharply decreasing in the lateral part of the upper arm, the medial and lateral parts of the thigh, the posterior part of the forearm, and the medial part of the upper arm. There was some sign of sex difference in the frequencies—the active sebaceous glands were somewhat more abundant in men than in women, especially marked in the cartilagineous portion of the external auditory canal, the back and the retroauricular region. No marked sex difference was found in the upper and lower extremities. Further, no difference was found in relation to the sides.

Frequencies per cm^2 of occurrence of active sweat glands were maximum

TABLE 3. Frequencies per cm² of occurrence of active sebaceous * and sweat ** glands *in vivo*

Age in years→ Sex→ Regions ↓		19 m	19 m	20 f	21 m	26 f	27 m	27 f	33 m	37 m	42 m	42 f	Averaged values	Standard deviations
external auditory canal	*	18(19)	15(13)	11(10)	13(11)	13(13)	11(15)	18(15)	17(17)	16(20)	18(19)	16(20)	15.0(16.1)	2.33(3.35)
	**	44(44)	40(44)	36(36)	40(36)	28(32)	32(36)	32(32)	36(40)	32(32)	32(36)		35.1(37.0)	5.29(4.01)
retro-auricular	*	25(22)	26(27)	20(19)	22(26)	19(20)	21(22)	29(31)	23(31)	23(21)	19(18)	18(20)	24.3(23.2)	3.33(4.29)
	**	50(48)	51(47)	39(43)	36(40)	39(36)	43(48)	42(46)	39(43)	48(52)	48(48)		44.5(45.6)	5.02(5.27)
upper arm lateral	*	2(1)	2(2)	1(1)	1(0)	1(0)	1(0)	1(1)	2(1)	1(2)	1(1)	1(1)	1.3(0.9)	0.34(0.69)
	**	48(44)	40(42)	31(32)	41(37)	27(35)	41(38)	23(24)	39(42)	35(35)	38(35)		35.8(36.1)	8.30(6.40)
medial	*	1(0)	0(0)	1(1)	1(0)	1(1)	1(0)	0(0)	1(2)	2(2)	0(1)	0(0)	0.7(0.6)	0.67(0.66)
	**	40(38)	44(41)	35(37)	45(48)	36(32)	45(4)	25(23)	29(32)	36(40)	36(35)		37.4(38.0)	6.40(8.25)
forearm anterior	*	0(0)	1(1)	0(0)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	0.6(0.6)	0.33(0.33)
	**	36(33)	32(29)	38(36)	33(29)	22(23)	28(30)	26(28)	31(28)	28(26)	27(33)		30.1(30.4)	5.71(5.31)
posterior	*	1(2)	1(1)	2(1)	1 (0)	1(1)	1(0)	1(1)	0(0)	0(1)	0(0)	1(1)	0.8(0.7)	0.32(0.64)
	**	42(40)	40(37)	33(35)	36(39)	38(38)	37(38)	29(31)	30(26)	29(30)	30(32)		33.9(34.7)	4.29(4.71)
thorax (mammary)	*	20	22	14	13	14	13	18	16	16	16	18	15.3	3.01
	**	38	36	24	33	25	28	29	36	41	33		31.9	5.69
back (inter-scapular)	*	25	28	17	19	18	19	13	18	18	20	18	18.0	5.02
	**	47	49	29	45	36	44	33	38	42	44		40.5	6.67
abdomen (lateral)	*	6	4	2	3	3	3	2	3	5	4	3	3.5	1.32
	**	33	33	18	28	21	26	25	26	30	30		26.9	4.98
gluteal	*	5	6	3	3	4	3	2	4	4	5	5	4.0	1.34
	**	40	36	29	40	26	24	29	36	36	39		35.3	5.35
thigh lateral	*	1(1)	1(1)	2(1)	0(1)	0(1)	0(1)	0(1)	1(2)	0(1)	1(1)	1(1)	0.7(1.2)	0.71(0.34)
	**	49(48)	51(48)	32(33)	48(47)	38(35)	44(41)	32(37)	39(42)	43(45)	43(44)		41.7(43.0)	6.35(5.98)
medial	*	1(2)	1(1)	0(1)	1(2)	1(1)	1(1)	1(1)	0(1)	1(1)	1(2)	0(1)	0.7(1.3)	0.32(0.33)
	**	51(48)	50(47)	26(29)	44(43)	31(31)	47(43)	30(35)	43(44)	36(40)	40(41)		40.3(41.3)	7.11(6.35)

Figures without and within parentheses: mean values of right and left sides.

44.5 in the right side and 45.6 in the left side in the retroauricular region and minimum 26.9 in the lateral part of the abdomen, decreasing in order in the medial and lateral parts of the thigh, the back, the medial part of the upper arm, the cartilagineous portion of the external auditory canal, the lateral part of the upper arm, the gluteal region, the posterior part of the forearm, the thorax and the anterior part of the forearm. It was found, as shown in Table 3, that the frequencies range from 40 to 30 with small differences. There was some sign of sex difference—active sweat glands were somewhat less abundant in women than in men. No marked differences were found in relation to age and sides.

Healing of wound surfaces which were left by removing skin pieces for tympanoplasty was expressed by restoration of functional activity of sebaceous and sweat glands. As shown in Table 4, the restoration of them appeared to be dependent upon the thickness of skin pieces removed. The restoration was almost in proportion to the thickness of skin pieces.

TABLE 4. Restoration of activity of sebaceous and sweat gland rests in wounds left by removing skin pieces in the medial part of the thigh * and in the gluteal region **

Case No.	Age in years	Sex	Side of tympanoplasty	Side of removal of skin pieces	Thickness of skin pieces	Frequency per cm^2 active skin glands	Days for removal of covering gauze	Restoration of activity of skin glands: Weeks after removal of skin pieces 2	3	4	6	8
1 M.A.	3	f	r	r**	0.5	9	14	2	9	10		
2 H.T.	10	m	r	r*	0.4	3(49)	14	0	2(39)	3(46)		
3 K.K.	10	m	l	l*	0.5	3(39)	13	2	2(22)	3(35)	(43)	
4 T.S.	10	m	l	l*	0.5	5(48)	13	3	3(30)	5(42)	(48)	
5 S.T.	19	m	r	r*	0.2	2(48)	12	1	2(40)	(50)		
6 A.H.	22	f	l	l*	0.4	2(32)	13	2	(15)	(21)	(33)	
6' A.H.	22	f	l	l*	0.9	2(28)	21	2	(9)	(12)	(20)	(23)
7 F.S.	24	m	r	r*	0.3	3(29)	13	0(13)	1(25)	3(31)		
8 S.K.	24	f	r	r*	0.2	2(29)	12	2(20)	2(24)	(24)	(29)	
9 K.N.	26	m	r	r*	0.2	1(32)	11	1(25)	1(28)	(35)		
10 S.K.	26	m	l	l*	0.4	2(39)	14	0(0)	2(25)	(31)	(37)	

Figures within parentheses: mean values of sweat glands.

DISCUSSION

The quantitative measurement of different skins of human cadavers is to be one of the grounds to determine which should be better skin pieces available for autotransplantation in tympanoplasty in the whole surface of the human body. The present quantitative measurements show two general trends: 1. skins and their accessories are inversely decreased respectively in thickness and frequency with age and 2. some common characteristics of skin in different regions of the body surface are seen irrespective of age, although considerably different in those of an individual (Tables 1 and 2). It may be probable that, in autotransplantation of skins for tympanoplasty, the skin piece, if only better

available, will not bring any disadvantage in any age and in any individual.

The following data, given by previous quantitative measurements, show that the thickness of skins is maximum 4.5 mm to minimum 0.6 mm with average intermediate values 2 to 2.2 mm (Leider and Buncke, 1954) and 4 to 1 mm (Kopsch, 1955)[8]. According to Yazawa (1933)[20], who examined skins of children and adults, the skin is thickest 2.6 mm in the back, decreasing to 2.2 mm in the thorax, 2.0 mm in the abdomen, 1.8 mm in the gluteal region and 1.4 to 1.5 mm in the upper arm. The present measurements show that the thickness is maximum 2.27 mm in the gluteal region and minimum 1.66 mm in the posterior part of the forearm—with intermediate values 2.13 mm in the lateral part of the abdomen and more decreased values 2.05 mm in the inguinal region and cartilagineous portion of the external auditory canal.

Our recent transplantation of skins has been performed by 4 methods—1. epidermic graft method (Thiersch's method and Ollier-Thiersch's method), 2. split thickness graft method (Leveton, 1946)[11], 3. full thickness graft method (Krause and Wolff-Krause) and 4. three-quarters thickness graft (Peer, 1959;[16] Guilford and Wright, 1959)[3]. Padgett *et al.* (1948)[15] suggested some standard indices of the skin thickness for general plastic operation of skins as follows: 1. 0.2 to 0.25 mm in the Thiersch's method, 2. 0.3 to 0.45 mm and 0.55 to 0.65 mm in the split thickness graft (thin and thick types) and 3. 0.8 to 1.0 mm in the full thickness graft. As shown in Table 4, the thicknesses of transplanted skin pieces for tympanoplasty, ranging from 0.2 to 0.5 mm are included within the range of Padgett *et al.* (1948)[15] and most of them are within the thickness of the split thickness graft. Table 4 suggests that the thicknesses themselves, included within this range, do not show any disadvantage in transplantation for tympanoplasty but indicate something in healing of wounds left by removing skin pieces. The thicker the skin piece is within this range, the more rapid healing of the wound left is. From this point of view, we can expect that the removal of skins from the gluteal region, the lateral part of the abdomen, the cartilagineous portion of the external auditory canal, the inguinal region and the hypogastric part of the abdomen is of more advantage.

Distribution of sebaceous glands in the skins is variable in different regions of the whole body. The present measurements show that the sebaceous glands are most abundant in the retroauricular region, the back and the cartilagineous portion of the external auditory canal while less abundant in the lateral and medial parts of the thigh and in the lateral part of the abdomen and further in the forearm. This fact accords with the data of Ito *et al.* (1949)[4]. Topographic levels (depths from the skin surface) of sebaceous glands are also variable in different regions of the body. According to Miyake (1959)[12], sebaceous glands are generally found about 0.5 mm deep from the skin surface. The present measurements show that they are present 0.33 mm deep in the medial part of the thigh and deep enough to be about 0.81 mm in the back,

the gluteal region, the retroauricular region, the thorax and the lateral part of the abdomen. From the standard indication of Padgett *et al.* (1948)[15] it may be supposed that skin pieces removed by Thiersch's method do not contain sebaceous glands in any region of the whole body surface, and split thickness grafts do not contain them in the back, the gluteal region, the retroauricular region and the thorax. Sebaceous glands and their collecting ducts contained in skin pieces have been reported to be of disadvantage, *i.e.*, to increase crusts and infections through their collecting ducts. On the other hand, the present data show that, in the thigh and the gluteal region where sebaceous glands are contained in the deep layer, wounds left by removing skin pieces are rapidly healed (Table 4).

On the distribution of sweat glands, Krause (1874)[10] described that sweat glands in the upper extremity are twice as abundant as those in the lower extremity and sweat glands of the anterior surface of the trunk twice as many as those of the back, and he found further that they are more abundant in the flexor than in the extensor surface. Kōyama (1937)[9], in estimating their distribution per cm^2, found that they are more abundant in the anterior surface of the trunk than in the posterior surface and he further found no significant difference of distribution between upper and lower extremities. The present data show that the distribution of sweat glands is most abundant in the back, the gluteal region, the lateral part of the thigh and the inguinal region and is least in the cartilagineous portion of the external auditory canal and the medial part of the upper arm. According to Miyake (1959)[12], topographic levels (depths from the skin surface) of sweat glands depend upon the thicknesses of skins and 2.0 mm in the gluteal region and 0.5 mm in the forearm. The present data show that the levels are deepest 2.12 mm in the skin of the gluteal region, and slightly less deep 0.58 mm in the lateral part of the upper arm. From these data, it may be supposed that the skin pieces removed by the split thickness graft method (thick type) do not contain sweat glands, and that those removed by the full thickness method include a number of sweat glands. It may be of more advantage, in the viewpoint of possibility for infection through their collecting ducts, that skins of the medial part of the upper arm and of the anterior part of the forearm are most suitable for transplantation because of scarcity of sweat glands in these regions (Table 2). Other parts show no marked difference of frequencies of the sweat glands. Therefore, so far as their frequencies are concerned, the skins in the major parts of the body surface appear to be evenly available for transplantation in tympanoplasty, showing neither advantage nor disadvantage.

Concerning the distribution of hairs, Taniguchi (1933)[18] described that hairs are most abundant in the scalp, abundant uniformly in the thorax, the back and the gluteal region, and slightly less abundant in the abdomen and in the upper and lower extremities. The present data show that the distribution

is most abundant in the cartilagineous portion of the external auditory canal, the back and the thorax while it is least in the anterior and posterior parts of the forearm. Topographic levels of hair roots are found deepest in the gluteal region, the back, the inguinal region and the lateral part of the abdomen and slightly less deep in the anterior and posterior parts of the forearm and in the retroauricural region.

Transplantation of skin pieces taken by Thiesch's method appears to have a disadvantageous relation with the thickness of hairs, *i.g.*, perforation of the tympanic membrane by hairs, but transplantation of skin pieces by the split thickness graft method appears to have practically no relation with this failure because of regeneration from hair roots left in the deeper layer. However, Kley (1959)[5] found that sections of remaining hair roots induce the occurrence of pearl tumor (Cholesteatoma). Table 1 suggests, from the viewpoint of the regeneration, that skins of the gluteal region, the back, the inguinal region, and the lateral part of the abdomen are more available.

Distribution of elastic fibers has an important relation with success of skin transplantation in tympanoplasty. Abundance of elastic fibers in transplanted skin pieces has been reported to induce perforation herein, due to their contraction and bending (Wullstein, 1954)[19]. The present data show that they are divisible into two groups, superficial vertical thin and deep horizontal thick. Therefore, skin pieces to be transplanted must be those in which horizontal thick elastic fibers remain as deep as possible in level—thick skins are satisfied for this condition. Table 1 suggests, from the viewpoint of the level of the horizontal thick elastic fibers, that skin in the retroauricular region, the back and the thorax are more available for transplantation by the split thickness graft method. Superficial vertical thin elastic fibers, practically, have no direct relation with the failure in tympanoplasty.

Distribution of active sebaceous glands—The *in vivo* data are almost in accordance in trend with the histological data (Tables 2 and 3). The *in vivo* data, however, show that the distribution of active sebaceous glands in different regions of the body surface to be transplanted for tympanoplasty is far less frequent and its regional difference is almost negligible. This may also neglect the possibility of forming crusts and infections through their collecting ducts.

Distribution of active sweat glands—Ogata (1935)[14] found that the sweat glands are divisible into two types, active and inactive. According to him, the active sweat glands are far less abundant than those found histologically. The present data show that sweat glands range histologically from maximum 165.4 to minimum 111.7 per cm^2, while the active sweat glands are from 45.1 to 26.9 per cm^2. Although slightly different, active sweat glands and those found histologically, respectively, are almost uniform in frequency per cm^2 in the major regions of the body surface. From the viewpoint of depths of sweat

glands but not from the viewpoint of frequencies, it seem better to use skins such as those of the back, the gluteal region and the thigh for transplantation in tympanoplasty. In these regions, sweat glands remain in the deepest level (Table 1). This prevents transplanted skin pieces, taken by the split thickness graft method, from pyosis.

Healing of wounds which are left by removing skin pieces for tympanoplasty —the wounds and subsequent granulations have been reported to be reformed and healed by regeneration of surrounding epidermis, epidermic hair follicles and sebaceous glands. The surface of the granulations has been found to be covered by regenerated epidermis in 6 to 10 days (Gillman, 1947)[2]. Further, Gillman (1947)[2] suggested that sweat glands take a minor part in the epidermis regeneration. Strauss (1956)[17] insisted that sebaceous glands contribute in forming immature epidermis cells which are produced explosively from their basal cells, and the sebaceous glands in the related area are restored in activity in 2 to 3 weeks. In agreement with the data of Gillman (1947)[2] and Strauss (1956)[17], the present *in vivo* data confirm that some difference of healing exists between the wounds left by different methods, depending upon how abundant sebaceous glands remain in the wounds. In the Thiersch's method and the split thickness graft method (thin type), it takes about 2 weeks while in the thick split thickness graft method it requires about 3 weeks (Table 4).

Cicatrices in wounds which are left by removal of skin pieces for tympanoplasty are discussed here. Brown *et al.* (1958)[1] found that rests of sweat and sebaceous glands remaining in the deep layer if the skin prevent cicatrization in wounds. Padgett *et al.* (1948)[15] recommended X-ray radiation to prevent the cicatrization and keloid in wounds. It is probable that the occurrence of cicatrix is due to delayed epidermization in wounds. This delay may be brought about by removal of too thick skin pieces, by some secondary infection or other mechanic pressure. The removal of the too thick skin pieces induces delay of epidermization by losing rests of sweat and sebaceous glands and hair epidermic follicles. Kodama (1956)[7] suggested to apply the Thiersch's skin transplantation in such cases. Najarian (1957)[13] reported to apply suspensions of skin homogenated by the mixer upon granulated or fresh wounds. Further, Kodama (1956)[7] suggested 3 indications, 1. oil and subsequent compression bandage for wounds in the less than 1/2 thickness skin removal, 2. usual surgical treatment for two weeks and subsequent skin transplantation by Thiersch's method in the 1/2 to 2/3 thickness skin removal and 3. the Thiersch's skin transplantation in the more than 2/3 thickness or full thickness skin removal. The present author would like to recommend the Thiersch's skin transplantation or the split thickness graft method in the more than 2/3 thickness or full thickness skin removal for tympanoplasty.

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