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Interpapillary Lines—The Variable Part of the Human Fingerprint

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ABSTRACT: The dermatoglyphic pattern of human palms and soles is individually unique and unchanging. Their prints show the course of the papillary ridges as papillary lines. Case reports and a few older studies of repeatedly taken fingerprints could, however, show that so-called interpapillary lines can develop between the papillary lines. The questions of this study were: How often do interpapillary lines occur? Can the differences between papillary and interpapillary ridges be quantified?

Five-hundred and two ink prints of the palms and fingers from the archive of the Bochum Police Department were examined retrospectively. In 121 volunteers, the appearance of interpapillary lines was examined prospectively. From the later collective, the fingerprints of 13 people with interpapillary lines and nine people without were examined further by taking two silicon prints and measuring them with laser profilometry.

In 215 of the 502 ink prints (42.8%) interpapillary lines could be demonstrated. In those subjects younger than 20 years they were less frequently observed (34.1%) than in those above the age of 20 (51.8%). In all cases using laser profilometry the interpapillary lines could be related to a corresponding interpapillary ridge. The interpapillary ridge heights were $24.9 \pm 10.0 \mu\text{m}$, significantly lower than the papillary ridges, which measured $59.0 \pm 19.2 \mu\text{m}$. Interpapillary ridge widths were with $194.8 \pm 65.1 \mu\text{m}$ significantly narrower as compared to $435.5 \pm 57.4 \mu\text{m}$ in the papillary ridge. Those papillary ridges, between which interpapillary ridges were found, were significantly further apart from each other ($610.5 \pm 78.9 \mu\text{m}$) than those without interpapillary ridges ($484.9 \pm 70.6 \mu\text{m}$).

During the course of a lifetime new ridges between the regular papillary ridges can develop or manifest. The fact that interpapillary lines are more frequently found on the right hands in men and those with increasing age is consistent with the theory that they correspond to degenerative changes and with sensitivity of touch.

KEYWORDS: forensic science, fingerprint, papillar lines, interpapillary lines, skin, dermatoglyphic, palm, sole

The dermatoglyphic pattern of human palms and soles is individually unique and unchanging except in cases of damage or rare diseases (e.g., M. Darier). For this reason, prints of the palms and fingers have been used in the identification of criminals for a long time (1). In the prints, the papillary ridges appear as papillary lines. Between the papillary lines, prints of ridge fragments can be found

again and again; they distinguish themselves from papillary lines by their different width (2–4). These lines of the print stem from the so-called interpapillary or interstitial ridges (German “Schaumleisten”) (5). These interpapillary ridges have been known since the uniqueness and invariability of human dermatoglyphs has been used in forensic medicine. The appearance of interpapillary lines can be defined as follows (6): *a*) Interpapillary lines lie between the papillary lines and are smaller and frequently interrupted. *b*) Interpapillary lines do not show sweat gland openings. *c*) Isolated spots and short lines between the papillary lines do not account for interpapillary lines. *d*) All structures that fulfill the requirements above are classified as interpapillary lines when they occur in the space of at least three neighbored papillary ridges.

It is known that interpapillary ridges have a permanent structure (4), although further examination of this phenomenon has been neglected so far, interpapillary lines can be identified in the prints easily and do not interfere with the dactyloscopic identification. The aim of this study was to quantify the morphologic features of the interpapillary lines at the skin surface.

Materials and Methods

In order to guarantee that for the determination of the morphologic correlate the correct phenomena of the prints were taken, we examined the frequency of interpapillary lines of randomly selected fingerprints of the Bochum Police Department retrospectively. The interpapillary lines were graded according to their markedness and compared with literature. Apart from this we took the prints of volunteers of different age groups and examined them prospectively for the presence of interpapillary lines. From some of these volunteers, with and without interpapillary lines, three-dimensional prints were also taken and examined with a laser profilometer.

Frequency and Markedness of Randomly Selected Fingerprints of the Bochum Police Department

Five-hundred and two randomly selected dermatoglyphic prints of 472 men (aged 21.2 ± 6.6 years) and 30 women (aged 22.7 ± 6.4 years) from the police headquarters of Bochum were examined by Siegfried Kyeck, the dactyloscopy-expert for the presence of interpapillary lines. In doubtful cases it was decided against the presence of interpapillary lines. Three different degrees of markedness were distinguished:

- weak: interpapillary lines scattered at the center of the fingertip or at the periphery only.

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- medium: many interpapillary lines at the center of the fingerprint.
- strong: many interpapillary lines, evenly distributed over the entire fingerprint.

Examination of Fingerprints of Volunteers of Different Age Groups

One-hundred and twenty-one fingerprints of 55 men and 66 women (aged 27.1 ± 16.5 years) were examined for the presence of interpapillary lines. Two independent examiners confirmed the presence of interpapillary lines according to the above mentioned definition.

Laserprofilometric Examination of Replica

Thirteen subjects with and nine subjects without interpapillary lines on examination of the dermatoglyphic prints' silica replicas (Silfo® Flexico Developments LTD, England) were taken and examined with laser profilometry.

In laser profilometry (UBM, Ettlingen, Germany) (7) a laser is moved above the surface to be examined. The photodiodes monitor each change of the focus of the laser, which results from the surface profile. The lens of the objective is electronically adjusted until the next change of focus. The position of the lens is continuously monitored. A computer translates the data into a two-dimensional profile. The system works without skin contact and measures with an accuracy better than $1 \mu\text{m}$. Through inverting the negative print, the relief of the ridges is apparent.

In the laserprofilometric examination the following parameters were examined:

- Height and width of the papillary ridges and interpapillary ridges.
- Distance between the papillary ridges.
- Distance between the papillary and interpapillary ridges.

From these data, the proportion between the height and the width of the papillary and the interpapillary ridge were calculated.

For each replica, three papillary ridges and three interpapillary ridges were examined and the mean value was calculated. In subjects with interpapillary lines, the papillary ridges in an area without interpapillary lines were also examined in order to detect possible differences in the structure of the papillary ridges in these areas and in the area of the interpapillary ridges. Differences between the different groups were assessed with the Student - T test (SPSS for Windows, SPSS, Germany). Significance was presumed at $p \leq 0.05$.

Results

Frequency of Interpapillary Lines in a Randomly Selected Collective of the Bochum Police Headquarters

Interpapillary lines were found in the prints of 215 (42.8%) of the 502 subjects examined. In those under the age of 20, interpapillary lines were found less frequently than in the average person (34.1%), in those above the age of 20, interpapillary lines were found exceptionally more often (51.8%). Subjects with interpapillary lines were on average 3.1 years older than those without interpapillary lines (Table 1).

When comparing the presence of interpapillary lines on the left and right hands, as well as for the individual fingers of the hand, a decrease of the interpapillary lines from the thumb to the fifth fin-

TABLE 1—*Frequency of interpapillary lines in a random collective of the police headquarters Bochum.*

Age	Persons Examined	Persons with Interpapillary Lines	Proportion of Persons with Interpapillary Lines in %
0 to 10 years	1	0	0
11 to 20 years	252	86	34.1
21 to 30 years	194	92	47.4
31 to 40 years	37	23	62.2
41 to 50 years	13	12	92.3
51 to 60 years	5	2	40.0
All ages	502	215	42.8

TABLE 2—*Relative frequency and markedness of interpapillary lines of the collective of Table 1 in % divided according to the different locations: left hand.*

Markedness	Thumb	Indicator	Middle Finger	Ring Finger	Little Finger	Palm
Weak	19.1	15.5	12.7	11	9.8	4.4
Medium	9.6	3.8	2.2	2	2.2	1.2
Strong	4.2	1.8	0.6	0.4	0.4	...
Total	32.9	21.1	15.5	13.4	12.4	5.6

TABLE 3—*Relative frequency and markedness of interpapillary lines of the collective of Table 1 in % divided according to the different locations: right hand.*

Markedness	Thumb	Indicator	Middle Finger	Ring Finger	Little Finger	Palm
Weak	20.3	18.1	14.7	14.1	10.6	4.4
Medium	12.7	4.6	2.2	1.6	2.2	1.2
Strong	4.6	1	0.6	0.4	0.2	...
Total	37.6	23.7	17.5	16.1	13	5.6

ger (Tables 2,3 was noted). On all fingers, the interpapillary lines were more frequently found on the right hand than on the left. In 12.6% of the subjects the interpapillary lines were found on one finger only, in 55.9% of the subjects they were present on at least four fingers.

Thirty of the 502 persons showed a strong expression of the interpapillary lines on at least one finger. Twenty-seven of these 30 persons possessed interpapillary lines on at least five other fingers. Those subjects who showed a strong expression of the interpapillary lines on at least one finger were older than those with a weak expression (28.1 ± 10.7 years as compared to 23.4 ± 7.3 years).

Frequency of Interpapillary Lines in a Randomly Selected Collective of Volunteers

Analogous to the random collective of the police department of Bochum, in this collective the interpapillary lines were more frequently found with increasing age in men as well as in women (Tables 4,5). Men exhibited this feature (43.6%) more often than women (33.3%). A typical fingerprint with interpapillary lines is shown in Fig. 1.

Laserprofilometric Examination of Replicas

With laser profilometry, the correlate of the papillary lines as well as of the interpapillary lines could be demonstrated (Figs. 2,3). The interpapillary lines represent the ridges that lie between two

TABLE 4—Frequency of interpapillary lines in male volunteers in a prospectively examined randomly selected collective in Bochum.

Age	Men Examined	Men with Interpapillary Lines	Proportion of Men with Interpapillary Lines in %
0 to 10 years	1	0	0
11 to 20 years	14	3	21.4
21 to 30 years	11	5	45.5
31 to 40 years	9	4	44.4
41 to 50 years	6	2	33.3
51 to 60 years	8	5	62.5
Over 61 years	6	5	83.3
All ages	55	24	43.6

TABLE 5—Frequency of interpapillary lines in female volunteers in a prospectively examined randomly selected collective in Bochum.

Age	Women Examined	Women with Interpapillary Lines	Proportion of Women with Interpapillary Lines in %
0 to 10 years	12	0	0
11 to 20 years	10	1	10.0
21 to 30 years	19	5	26.3
31 to 40 years	6	3	50.0
41 to 50 years	8	5	62.5
51 to 60 years	7	4	57.1
Over 61 years	4	2	50.0
All ages	66	20	33.3

papillary ridges (Figs. 4–7). They were smaller than the papillary ridges and were running to their top very steeply while the papillary ridges had a flattened plateau. At times in profilometry, smaller interpapillary ridges were found that could not be viewed with normal fingerprints.

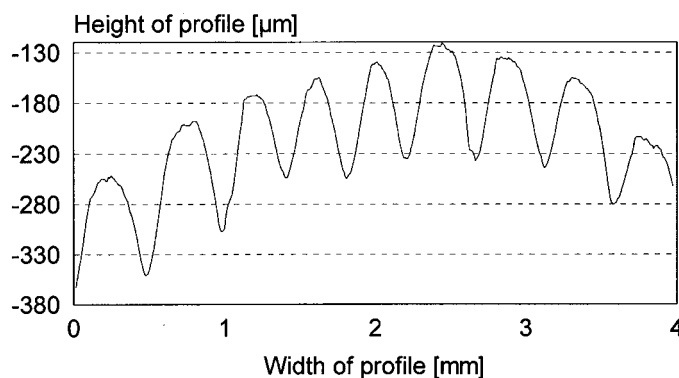


FIG. 2—Even distribution of papillary ridges without interpapillary ridges.

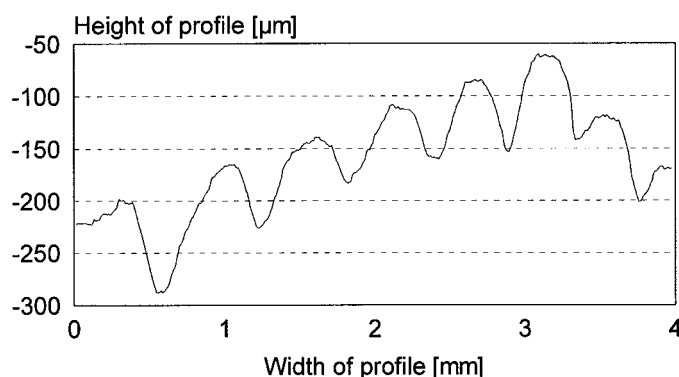


FIG. 3—Ridge profile with obvious flattening of the papillary ridges at the top and steep decline to the valley between the ridges.

The papillary ridges were $59.0 \pm 19.2 \mu\text{m}$, significantly taller than the interpapillary ridges at $24.9 \pm 10.0 \mu\text{m}$ ($p \leq 0.001$). This equals a proportion of 2.4 to 1. Likewise the papillary ridges were $435.5 \pm 57.4 \mu\text{m}$, 2.2 times wider than the interpapillary ridges with $194.8 \pm 65.1 \mu\text{m}$ ($p \leq 0.001$). This proportion remained rel-



FIG. 1—Ink print with interpapillary lines (arrow).

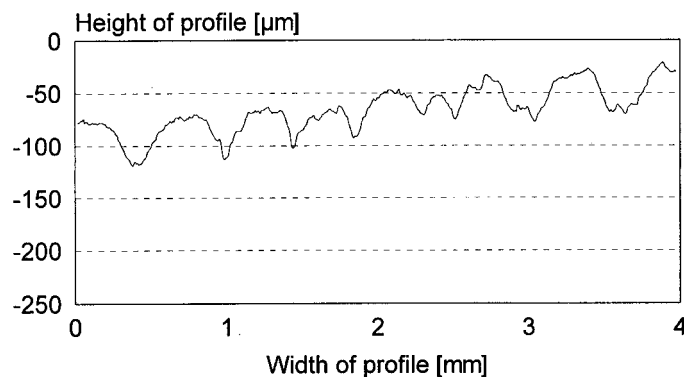


FIG. 4—Ridge profile with obviously lower papillary ridges than in Figs. 2 and 3. The top is even more flattened. At a higher magnification (Fig. 5) interpapillary ridges are seen.

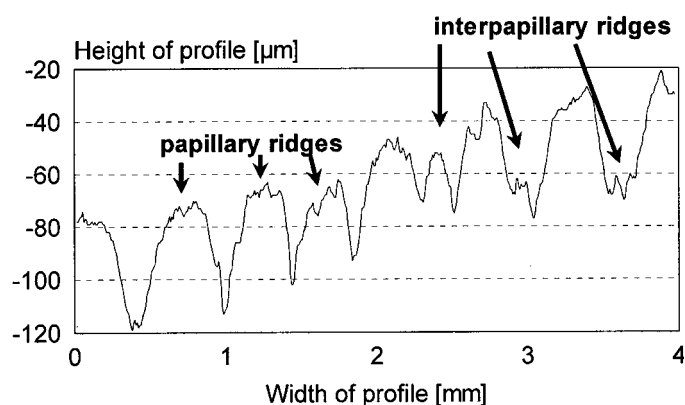


FIG. 5—Higher magnification of the profile from Fig. 4 with interpapillary ridges between the more widely spaced papillary.

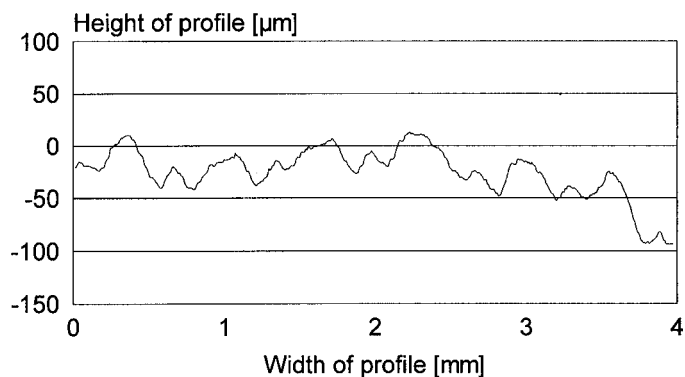


FIG. 6—Markedly lower papillary ridges than in Figs. 2 and 3.

actively constant, so that between relatively tall and wide papillary ridges, relatively tall and wide interpapillary ridges were found.

The papillary ridges of volunteers without interpapillary ridges were with a distance of $484.9 \pm 70.6 \mu\text{m}$, significantly closer together than those papillary ridges between which interpapillary ridges were found. They were on average $610.5 \pm 78.9 \mu\text{m}$ apart ($p \leq 0.01$). The papillary ridges of the volunteers with interpapillary ridges tended to be less tall and were significantly narrower than the papillary ridges of volunteers without interpapillary ridges in the valley of the ridges (height: $60.6 \pm 19.2 \mu\text{m}$ as compared to $71.2 \pm 22.7 \mu\text{m}$ $p = 0.061$; width $435.5 \pm 57.4 \mu\text{m}$ as compared to $488.3 \pm 71.2 \mu\text{m}$, $p = 0.01$).

The distance between the papillary ridges and the interpapillary ridges was $316.9 \pm 48.5 \mu\text{m}$, half the size of the distance between the papillary ridges themselves ($610.5 \pm 78.9 \mu\text{m}$) as the interpapillary ridges were situated in the middle of two papillary ridges.

In men, the ridges were higher and wider than in women. The papillary ridges of men without interpapillary ridges were $85.5 \pm 21.5 \mu\text{m}$, significantly higher ($p = 0.015$) and, with a width of $513.0 \pm 89.3 \mu\text{m}$, tendentially ($p = 0.235$) wider than in females who had a height of $59.7 \pm 16.9 \mu\text{m}$ and a width of $468.6 \pm 49.1 \mu\text{m}$. Similarly, the distance between the papillary ridges in men without interpapillary ridges tended to be wider ($506.9 \pm 88.7 \mu\text{m}$ ($p = 0.286$) in men compared to $467.4 \pm 50.2 \mu\text{m}$ in women). Parallel to the larger distances and taller papillary ridges, the interpapillary lines occurred more frequently in men than in women (see above).

When, however, interpapillary ridges were present, their distances did not differ between the sexes. The papillary ridges with interpapillary ridges between them were, for example, separated by $612.4 \pm 80.4 \mu\text{m}$ in men, and by $608.4 \pm 80.8 \mu\text{m}$ in women. The same holds true for the distances between the interpapillary ridges and the papillary ridges: in this case men even tended to have a smaller distance ($310.9 \pm 42.6 \mu\text{m}$) than women ($322.8 \pm 55.0 \mu\text{m}$) ($p = 0.559$). This phenomenon points towards the possible importance of the distance between papillary ridges for the development of interpapillary ridges.

Discussion

The so-called interpapillary or interstitial lines of the ink prints could be related to a well-defined morphologic structure of human skin. The so-called interpapillary ridges are present whenever the prints show interpapillary lines. They are by definition smaller and narrower than the surrounding papillary ridges. In no case could we find more than one interpapillary ridge between two papillary ridges.

Interpapillary ridges are not a rare phenomenon. In fact, they are obviously present in a large proportion of the middle European population. Our data are in keeping with those described in the literature (42.8% in our study, 40.7% in Ref (6)). Our finding that the presence of interpapillary lines increases with increasing age is met by the fact that interpapillary lines are present in only 14% of children under the age of eleven years and in only 34% of adolescents between the age of 11 and 20 years. In adults, the frequency of interpapillary lines increases with age and reaches 52.8% in those over the age of 60. Judging by this increase with age, one can surmise that the interpapillary ridges manifest or even develop with age. As those persons with at least one finger with strong interpapillary ridges were on average 4.7 years older than those with weak interpapillary ridges, one can conclude that the interpapillary ridges start out as a few ridges and multiply with time. The de novo development of interpapillary ridges is also documented through follow-up studies of single individuals in Ref (2) unpublished material of the police headquarters of Bochum, Germany).

In the study presented, the frequency of interpapillary lines decreased from the thumb to the little finger. Further, on the right hand, interpapillary lines were more frequently found than on the left. Similar results were described in Ref (6): 32.9%, respectively, and 37.6% of all thumb prints examined showed interpapillary lines, with the right thumb frequently more positive than the left. Then, the frequency of interpapillary lines decreased respectively from the second finger to 23.7%, 21.1%, 12.4%, to 13% on the little finger.

The distribution of frequency of interpapillary lines follows the width of the fingers. Only the third finger does not obey this rule,

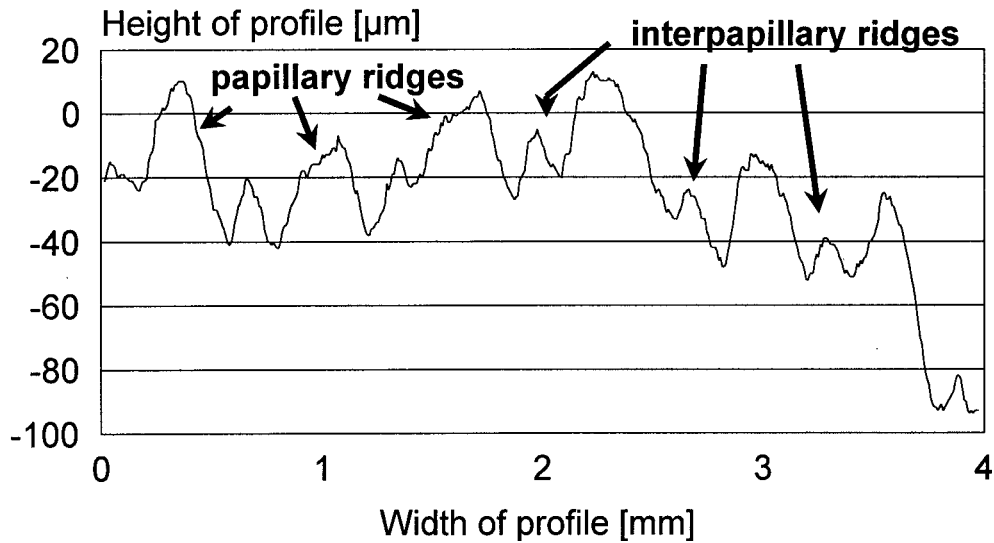


FIG. 7—Higher magnification of Fig. 6. Many interpapillary ridges.

as it is usually wider than the second finger (8). An explanation for the higher prevalence on the right hand and in men points towards the same direction: the fingers tend to be wider on the right hand and men usually have larger and wider fingers (8). Our profilometric data confirm that interpapillary ridges are primarily found between widely spaced papillary ridges: papillary ridges on fingers without interpapillary ridges were $488.3 \pm 71.2 \mu\text{m}$ closer together than those on fingers with interpapillary lines that were separated by $610.5 \pm 78.9 \mu\text{m}$. In agreement is the fact that in males, in whom the interpapillary ridges are more frequently found, the papillary ridges are usually further apart than in females. The distance between those papillary ridges that are separated by interpapillary ridges is, however, roughly the same in men and women.

Even though the interpapillary ridges obviously manifest during the course of life, their heredity seems certain. In 112 identical twins only one pair showed discrepancy regarding their interpapillary lines. In 141 nonidentical twins of the same sex in only one pair both twins expressed interpapillary lines (9). The late manifestation of interpapillary ridges does not contradict their heredity.

Papillary ridges are influenced by aging as well as by wear and tear (10). Massive signs of wear and tear could be found on the hands of housewives and builders (11). Possibly there is a connection between the higher mechanic stress of the right hand and the consecutive wear and tear of skin ridges on the one side and the more frequent development of interpapillary ridges on the other side.

The papillary ridges promote the function of picking up and holding things by increasing friction (12). They are optimally suited to take up a force that is acting vertically as the fibrocytes, respectively, the collagen fibers run perpendicular to the ridges (13,14). As in cases where the distance between the skin ridges are large and their width is small, the relative number of skin ridges per unit area is decreased, and the interpapillary ridges could improve a poor ability to hold and feel objects. A similar occurrence is the "Bartossche Phenomenon" which states that in stumps of fingers dermatoglyphs can develop through vibration (15).

In the field of forensic dactyloscopy, it is of great interest whether the interpapillary ridges belong to the unchangeable characteristics, the so-called minutiae. After analyzing the present data, we believe that interpapillary lines should be considered in the evaluation of fingerprints because, according to epidemiological

data and case reports, interpapillaries develop throughout life but they never disappear.

References

- Galton F. Finger prints. London: Macmillan & Co, 1892.
- Wilder H, Wentworth B. Personal identification. Boston: Badger, 1918.
- Cummins H, Mildo C. Finger prints, palms and soles. An introduction to dermatoglyphics. Philadelphia: Blakiston & Co, 1943.
- Penrose LS, Plomley NJB. Structure of interstitial epidermal ridges. *Z Morph Anthropol* 1969;61:81-4.
- Penrose LS. Memorandum on dermatoglyphic nomenclature. *Birth Defects* 1968;4:1-13.
- Cohausz E, Linde HJ, Wendt G. Die Zwischenlinie im Fingerabdruck. *Z Morph Anthropol* 1955;47:71-82.
- Saur R, Schramm U, Steinhoff R, Wolff H. Strukturanalyse der Hautoberfläche durch computergestützte Laser-Profilometrie, neues Verfahren zur quantitativen Bestimmung der Rauheitsstruktur der Haut. *Hautarzt* 1991;42:499-506.
- Abel W. Kritische Untersuchungen über die Entwicklung der Papillarmuster auf den Fingerbeeren. *Zeitschrift für menschliche Vererbungs- und Konstitutionslehre* 1938;21:497-529.
- Wendt G. Zwillingsuntersuchungen über Zwischenlinien und weiße Linien im Abdruck der menschlichen Fingerbeere. *Acta Genet* 1956;6: 143-55.
- Heindl K. System und Praxis der Daktyloskopie. Berlin, Leipzig: De Gruyter und Co, 1927.
- Steffens C. Vergleichende Untersuchungen der Minutien der Fingerbeerenmuster bei Familien und eineiigen Zwillingspaaren. *Anthrop Anz* 1965;42:234-9.
- Buck C. Untersuchungen zur biomechanischen Bedeutung der Hautleisten. Thesis, Ruhr-Universität Bochum, 1990.
- Niemitz C. Zur funktionellen Anatomie der Papillarleisten und ihrer Muster bei *Tarsius bancanus bornecanus* Horsfield. *Z Säugetierkunde* 1977;42:321-46.
- Misumi Y, Akioshi T. Scanning electron mikroskopische structure of the fingerprint as related to the dermal surface. *Anat Rec* 1984;208:49-55.
- Valsik JA. Das Bartossche Phänomen in der Dermatoglyphik. *Morph Antrop* 1964;56:112-7.

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