J. Cosmet. Sci., **68,** 79–84 (January/February 2017)

Typology and atlases of human fingernails across ages and ethnicities

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INTRODUCTION

The intense expansion worldwide in the nail categories (care, maintenance, gel nail systems, and traditional nail polish) implies a need for cosmetic research to better understand the range of variations in the appearance of healthy, natural fingernails and to ascertain how age and ethnicity could drive nail dimensions. From a consumer perspective, addressing physiological and morphological changes of fingernails through the building of a data base is paramount and might, ultimately, affect consumers' habits or preferences. The work presented here aims to describe how ethnicity and/or age may affect some geometrical, structural, or physical properties of the fingernails.

SUBJECTS

The study comprised 280 women, aged 18–70 years, with a self-declared ethnicity of African–American, Asian/Southeast Asian, Caucasian, and Hispanic. The inclusion process required an equal number of subjects based on four ethnic groups and three age-classes range (18–30, 31–50, and 51–70 years). Hence, groups of 12–30 subjects per ethnicity and age class were formed. The fingernails of all subjects were carefully examined during the inclusion phase to make sure that they presented at least eight fingernails with a free edge of acceptable length. Brittle, peeling, and flaking nails were acceptable for the study. Any subjects who had known nail diseases were excluded from the study.

MATERIALS AND METHODS

The collection of typology data included four types of assessments:

A) *Imaging.* Imaging of the nail was done with two types of processes.

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1) Standardized photographs of the 10 individual fingernails of all subjects were acquired using a Nikon D90 DSLR camera with a 28–105 mm macro NIKKOR lens under standardized lightning. The recorded photographs, blind coded, were used for paired comparison and atlas creation.

2) The three-dimensional (3D) *in vivo* dimensions of the nail were analyzed through the PRIMOS (Phase Shift Rapid In-Vivo Measurement of Skin) imaging system using fringe projection measurement principles. It was utilized in conjunction with a custom stereotactic finger-positioning device from Canfield Scientific to measure certain parameters. Specifically, the nail profile was constructed from measures of width, arc width, length, arc length, and radius of curvature. Figure1 illustrates the visual reconstruction of a fingernail using the 3D measurements.

   Arcs of width or length reflect the curvatures in these two respective dimensions, where a theoretically, perfectly flat fingernail would present the same value as that of width or length. Accordingly, the ratios between arc/width and arc/length illustrate the extents of curvatures of fingernails in both axes, the higher the ratio, the more curved the fingernail along the respective axis. The curvature radius is the radius of a circle that is required to cover the entire circumference of the arc width of a fingernail. This measurement is possible because the shape of a fingernail is fairly symmetrical across its width (which is not the case along the length of a fingernail). The wide and flat fingernails would thus command larger curvature radii than narrow and curved fingernails. Another dimension measured is the distance between the center of the nail to the center of its base (namely, sagitta in geometry terms), which is referred here as the nail apex height. Taken together, these eight parameters describe the geometrical aspect of a fingernail.

B) *Thickness measurement of the nail plate.* This was carried out at the center, center left, and center right of all nail distal edges per subject, using a digital caliper offering a 0.05-mm precision. The thickness of a fingernail is the average value of the three measurements.

C) *Grading by trained experts.* Trained nail experts examined all 10 fingernails on every subject, one fingernail at a time, under controlled lighting with magnification. The grading was conducted in a blinded manner toward the age and ethnicity of the subjects. Various aspects of fingernails were assessed. Nail shape and presence/absence of

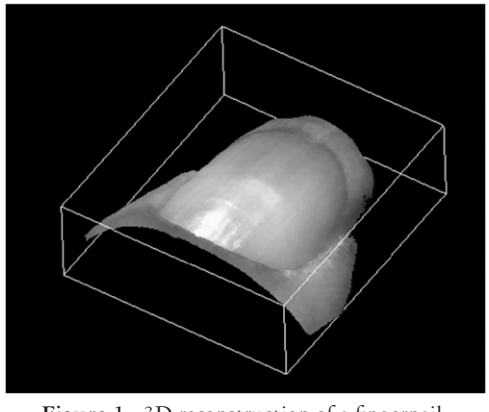

Figure 1. 3D reconstruction of a fingernail.

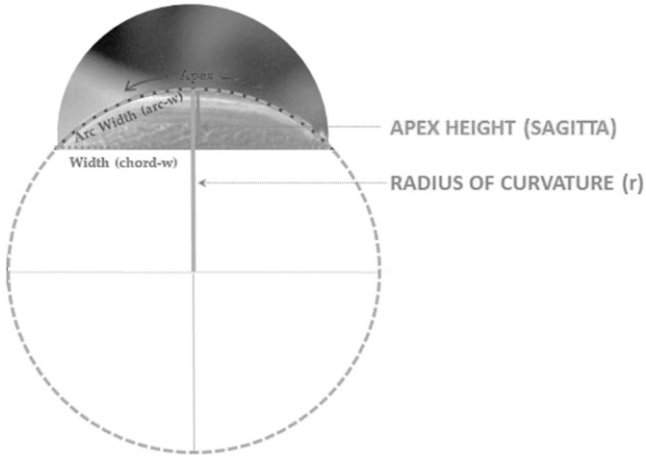

Figure 2. Illustrations of radius of curvature and nail apex height.

certain conditions (e.g., luluna, leukonychia, etc.) were assessed by categorical choices. The severity or level of vertical ridges, nail shine, peeling, and an overall "unhealthy" appearance were assessed by using an analog scale of 0–5 (0, none, 5, extremely).

D) *Self-assessments* of subjects about their agreements on the overall conditions and features of their fingernails as well as "like–dislike" feeling on some aspects of their fingernails. Subjects responded to a questionnaire of 25 items including aspects of fragility, hardness, thickness, and dullness.

The creation of the atlases, using the typology data acquired, was dependent on the type of attribute under assessment:

1) *Dimensional attribute atlases* were created from statistical analysis to determine the maximum and minimum values as well as the upper and lower quartile and median values for each attribute across the entire study population.

2) *Visual attribute atlases* were created from assessments by consumer perception of images on a computer using a paired comparison approach. Sixteen women of each ethnicity assessed the visual attributes for subjects of the same ethnicity. The sixteen women were equally divided across two age groups: 18–30 and 31–55 years of age. Images for the paired comparison study were selected to represent values across the full range of expert assessments.

RESULTS

OVERALL MEASUREMENT RANGES

Table I summarizes the ranges of variations of some dimensional characteristics of all observed fingernails (10 nails × 280 subjects), according to age and ethnicity. All values are expressed in millimeter.

Data from Table I indicate that age or ethnicity are of a rather low impact on most morphological criteria with regard to the respective low ranges of averaged values. The rather large

Table I
Ranges of Values (in mm) of Some Recorded Dimensions of the 10 Fingernails of All People (2800 Nails) According to Age and Ethnicity

Parameter	Global range	Range of average values/age	Range of average values/ethnicity
Thickness	0.074–0.967	0.341–0.381	0.341(HI)–0.381(AS)
Length	9.8–20.3	13.06–13.76	13.15 (CA)–14.05 (AA)
width	8.4–12.4	9.84–10.3	9.93 (AS)–10.46 (AA)
Depth/height	2–4.5	3.19–3.34	3.06 (AS)–3.44 (AA)
Curvature radius	4.4–8.5	5.46–5.91	5.6 (HI)–5.82 (CA)

AA: African–American; AS: Asian; CA: Caucasian; HI = Hispanic.

global range observed simply illustrates the differently sized fingernails (e.g., pinky or index vs. thumb). However, in spite of their low impacts, statistical differences were observed between ages and ethnicities. For example, interage or interethnicity comparisons on same fingers show that the thickness of the youngest age group is significantly ($p < 0.05$) lower than that of the oldest age group and is slightly but significantly higher ($p < 0.05$) in Asian and African–American subjects than that of Caucasian and Hispanic subjects.

THICKNESS OF THE NAIL

Since thickness is an important factor that may impact hardness, resistance, or fragility of fingernails, a statistical analysis (principal component analysis, PCA) integrates all factors associated to thickness (age, ethnicity, dimensions of morphologic criteria, expert scorings, and self-assessments). It allows to define four large clusters: Cluster 1: strong and healthy nails, Cluster 2: medium, Cluster 3: dull and aging nails, and Cluster 4: weak and soft nails. This PCA analysis is illustrated in Figure 3.

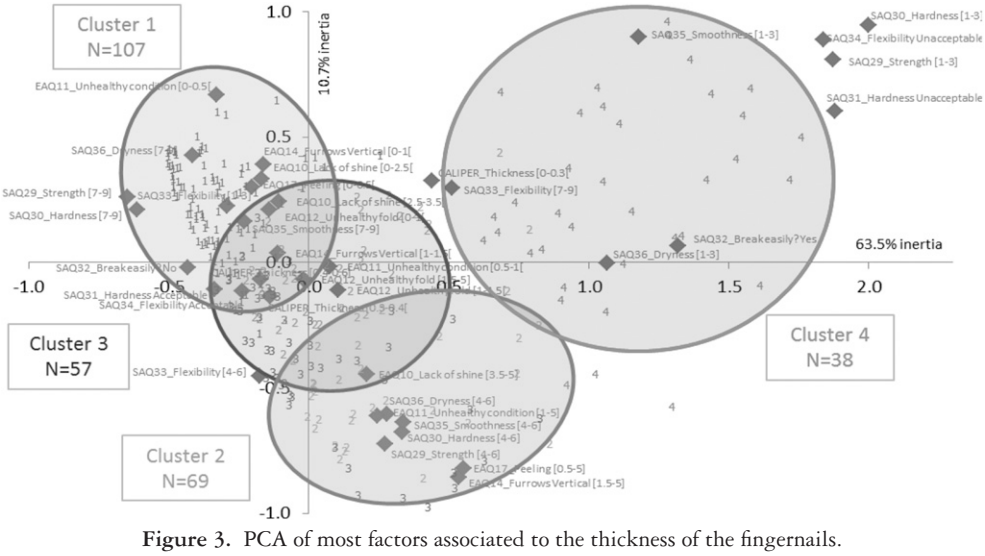

Figure 3. PCA of most factors associated to the thickness of the fingernails.

Figure 4. Examples of the various severity in the vertical ridges of fingernails.

PRESENCE OF VERTICAL RIDGES

Experts graded these longitudinal striations according to their densities and visual depth (see Figure 4). The expert assessed scores indicated that the grades of ridges significantly increase with age, irrespective of ethnicity and where, overall, 67% of all subjects declared presence of vertical ridges.

EXPERT AND SUBJECT PERCEPTION OF "UNHEALTHY" FINGERNAILS

Although the very term "unhealthy" is of a complex definition, it likely integrates aspects linked to surface irregularities (bumps, irregular growth of the terminal edge, lack of shine, vertical and horizontal striations, yellowing/discoloration, etc.). Figure 5 shows examples of the various severity of unhealthy appearance according to expert assessment.

Increased grades were found clearly associated to age (see Figure 6). These age-related trends were found in the four ethnic groups studied. This parameter, together with the presence or severity of ridges, again suggests that aging has a much larger impact on aspects of fingernails than ethnic origin.

DISCUSSION

The work presented here attempts to draw some major characteristics of the fingernails of adult women of different age groups and ethnicities. With regard to the rather low number of studied women vis à vis the world population, it cannot obviously represent a definitive data base. It nevertheless allows observation of low amplitudes of variations in morphometric features of the fingernails and impacts of age or ethnicity. The 10 fingernails of women, for the most part, have larger dimensional differences interdigit (e.g., thumbs vs. pinky) than interindividual, interage, or interethnicity. The respective narrow ranges of geometric figures (width, arc width, thickness, etc.) by fingers are similar on both hands (e.g. same data obtained in left/right indexes or thumbs). In some epidemiological studies for skin and hair, large interindividual variations among a same ethnic group are observed (1, 2). In contrast to some highly variable skin or hair criteria with age or ethnicity (thickness, color, microrelief, shape, etc.) fingernails appear a rather constant skin appendage in dimensional aspects (3).

However, apart from low affected geometric dimensions, aging induces noticeable changes in the structure/relief and thickness properties of fingernails in all ethnic groups

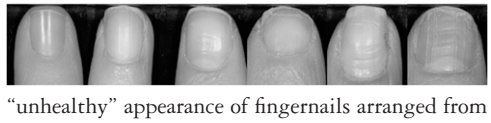

Figure 5. Examples of the "unhealthy" appearance of fingernails arranged from left to right in the order of severity based on expert assessment.

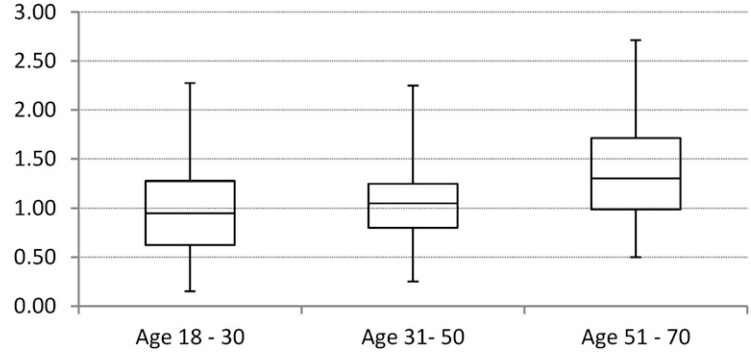

Figure 6. Box chart showing expert grading of vertical ridges according to age groups. The number of data points for ages 18–30 is 75, for ages 31–50 is 105, and for ages 51–70 is 88. The severity of vertical ridges is significantly higher in the age group 51–70 than the two younger groups (Tukey, $p < 0.001$).

studied here. More numerous and more profound longitudinal ridges, increased fragility and brittleness appear closely associated with aging, irrespective of ethnicity, in agreement with previous works (4–8) and methodologies (9).

The findings from the present study (as demonstrated by the clusters defined via PCA analysis with regard thickness) suggest that differences between fingernails are more driven by physical properties or their "healthy" perception. Apart from individual (or culturally/ethnically driven) desires in changing the color or shapes of fingernails, the development of new nail care products should then primarily aim at camouflaging the progressive structural and physical changes of fingernails that are brought by an ineluctable aging process that concerns all ethnicities.

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