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POPULATION DATA

Palatal rugae patterning in a modern Indonesian population

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Abstract
Background Palatal rugae patterning has been suggested as useful complementary information for forensic purposes, when there are limitations in using the primary identifiers and when the individual patterning from e.g. a dental cast can be traced or the pattern can differentiate between alternative populations of origin.
Objectives The aim of this study was to identify the rugae patterns in a sample modern Indonesian population, to compare the patterns to previously reported observations, and to consider the requirements for possible forensic applications.
Material and methods Archival dental casts were randomly selected to include 47 male and 53 female Indonesian patients of the Dental Hospital of the Faculty of Dentistry, University of Indonesia. The age and ethnic/geographic origin of the subjects were also recorded. The Trobo classification was applied to analyze the rugae shape patterns.
Results The results showed the line, sinuous, and curve types of rugae as predominant shapes, representing together about 83 % of the rugae of the study sample that for its size was considered reasonably representative of the Indonesian population. All recorded individual rugae patterns were unique, i.e. no similar patterns were found for any two individuals. The results are consistent with slow rugae loss at an average rate of one ruga in about 15 (±2) years after early adulthood.
Conclusions The palatal rugae patterns provide potentially useful supplementary information to establish the identity of an individual, but only when appropriate antemortem data are available. For this purpose, it is suggested that optical 3D oral/dental scanning is used to retain the data on the rugal and oropalatal patterns. Suitable pattern recognition methods may also reduce the potential effects of rugae modification in time.

Keywords Forensic odontology · Palatal rugae · Trobo classification · Rugoscopy

Introduction

Human forensic identification relies on distinctive characteristics of individuals and systematic procedures to identify them. One of the applied disciplines is forensic odontology, predominantly by the comparison of antemortem and postmortem dental records to determine the identifying features and ideally the exact identity of the individual. Teeth have high resistance to damage and decomposition by time and environmental challenges, and with all their variations, dental characteristics provide an established primary approach to human identification, together with fingerprints and DNA.

Beyond teeth, the oral cavity is well known to exhibit other individual features such as the palatal rugae [1]. The examination of the rugae, or rugoscopy, has been suggested to be used in forensic odontology, based on the claimed individually unique morphology of the rugae patterns, and on their resistance to trauma due to protection by lips, tongue, cheeks, and bone [2–4].

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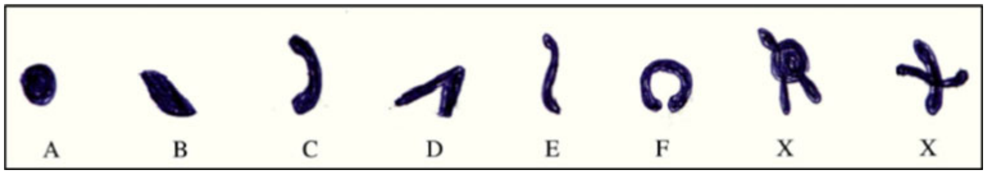

Fig. 1 Trobo classification of the palatal rugae [5]: **a** Point; **b** Line; **c** Curve; **d** Angled; **e** Sinuous; **f** Circular; (X) Compound shapes

Palatal rugae (rugae palatinae or plicae palatinae transversae) are asymmetrical and irregular elevations of the mucosa located in the anterior third of the palate, made from the lateral membrane of the incisive papilla and arranged in a transverse direction from the palatine raphe located in the mid-sagittal plane [3]. Human rugae are formed during the third month or about 12 to 14 weeks of intrauterine life from connective tissue that covers the palatine ridge on the maxillary bone, with development and growth mutually controlled by epithelial-mesenchymal interaction by specific extracellular matrix molecules that are spatiotemporally expressed during development [1, 4, 5]. The rugae will grow during the palatal development, but change less in shape and pattern and are rather well maintained after adolescence [3, 4]. Physiologically the palatal rugae contribute to oral swallowing, food crushing and preventing loss of food from the mouth, perception of taste and tongue position, and to speech and suction in children [6, 7].

Many population-specific studies have been carried out on the rugae patterns in various parts of the world, and is apparently particularly popular in India [5–31]. Such studies have demonstrated that palatal rugae show unique characteristics even between family members [8, 13]. The potential population-specific differences have led us to undertake a study on the Indonesian characteristics of the palatal rugae patterning.

Objectives

The research aimed to study the palatal rugae patterns in an Indonesian sample population, to compare them with patterns previously reported from elsewhere, and to discuss the requirements for their potential forensic application.

Materials and methods

The study sample of archival dental casts of 100 Indonesian subjects (47 males, 53 females), 13 to 75 years old (mean/median 37.4/34.5 years for all, mean 35.0/40.0 years for females/males), included no cases of palatal defects, but was otherwise randomly selected from archival dental casts of the Dental Hospital of the Faculty of Dentistry, University of Indonesia, with recorded age and local ethnic/geographic origin. The study sample included Indonesians of mostly native Austronesian speakers by mother tongue and local ethnic/geographic origin of the parents. In these terms, the five largest groups were Javanese (N=45), Sundanese (N=15), Indonesian Chinese (N=14), Bataks (N=9), and Malays (N=8) and covered 91 % of the subjects of the sample population. The remaining six groups of Madura, Betawi, Minahasa, Gorontalo, Ambon, and Ternate origin were represented by one to three subjects each, all of them Austronesian native speakers. As the linguistic groups of the island of Java (mainly Javanese and Sundanese, with immigrants from the outer islands) make about half of the total Indonesian population, for its size the sample is taken to be reasonably representative of the whole population, with the possible exceptions of slight overrepresentation of Indonesian Chinese.

The collected dental cast samples were used to determine the patterns and number of rugae. The casts were made of high-strength dental plaster using maxillary alginate impressions. The rugae patterns were delineated for better contrast

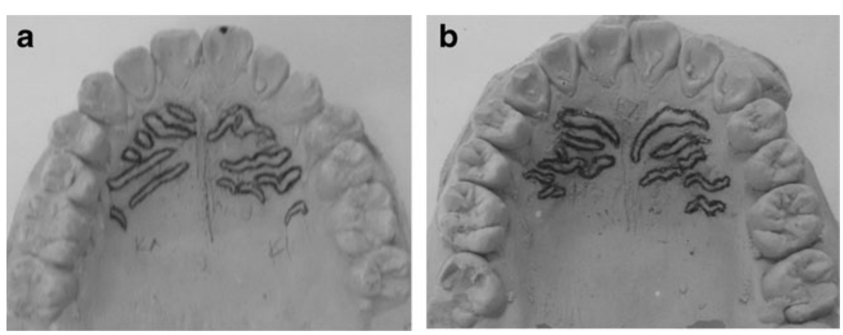

Fig. 2 Delineated rugae in two dental casts of right(ka)/left(ki) sides: a) n=7/6; b) n=7/6

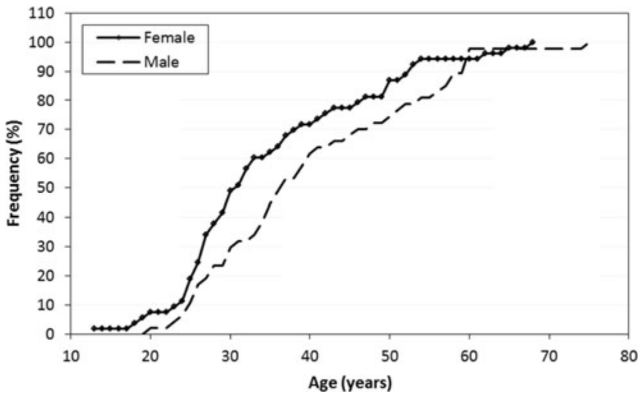

Fig 3 Cumulative age distribution of the subjects

using a sharp graphite pencil under adequate light and magnification and subjected to macroscopic visual analysis.

The number and patterns of palatal rugae on left and right sides of the median palatine raphe were recorded. The rugae shapes were analyzed according to the Trobo classification [5]. This classification divides rugae into simple and compound rugae as shown in Fig. 1, with the compound shapes implying polymorphic union of two or more simple shapes. Examples of observed rugae patterns are shown in Fig. 2.

All palatal rugae types were recorded in the data chart, and unpaired t-test, ANOVA, and Chi-square testing were used to statistical comparison of the sample groups. SPSS 20.0 software was used in statistical analysis, assuming $p<0.05$ as statistically significant. To assess intra-observer variation in interpretation, double determinations were performed for 20 subjects. Concordance between repeat observations exceeded 84 %.

Results

The age distribution of the subjects according to gender is shown in Fig. 3. The subjects were initially divided into four age groups: I, max 20 years (N=5); II, 21 to 40 years (N=62); III, 41 to 60 years (N=30); IV, and more than 60 years old (N=3). As the groups I and IV were small, simpler grouping I+II and III+IV was also used.

The observed numbers of palatal rugae according to gender and palatal side are shown in Table 1. The mean number of rugae was slightly higher in females than in males on both sides of the palate. The mean number of rugae was also slightly higher on the right than on the left side of the palate in both females and males. However, neither of these differences were statistically significant. No two subjects showed a similar rugae pattern, so that for the sample of subjects the rugae patterns were individually unique.

The distribution of the numbers of rugae according to the shape class is shown in Table 2. The most common shape classes were the line type (B), sinuous type (E), and curve type (C), all at rather similar frequencies between 25 and 30 %, and representing together 83.3 % of all rugae. All other types appeared at a lower than 10 % frequency for any given type, and the circle type (F, 0.7 %) was least common. No significant differences were observed in the numbers of rugae in a given shape class between genders (p=0.538), although there was a tendency of the relatively infrequent angled (D) rugae to appear about twice as often in females as in males.

The total number of rugae is compared according to the age group in Table 2. With the exception of the first (small) age group, the mean number of rugae appears to be gradually decreasing with age group so that the difference between groups was statistically significant.

Discussion

The palatal rugae are widely considered to be unique to an individual in terms of combined patterns of shape, length, width, prominence, number, and orientation [3, 4, 10]. Uniqueness of the palatal rugae patterns is also commonly reported in the rugae studies [5–30]. This was true also in the sample of a modern Indonesian population of the present study, where no two individuals exhibited similar rugae patterns. The sample was relatively small (N=100), but comparable in size with many previous studies (Table 4).

The uniqueness and protected position from trauma in the oral cavity are thought to give rugae patterns potential for forensic applications [4, 8, 13, 14]. However, for such purposes it is necessary that the rugae features do not change to an unmanageable extent between the initial characterisation and later comparison, as in ante- and postmortem assessments. Slow reduction in the mean number of palatal rugae with

Table 1 Numbers and mean numbers of rugae by gender and palatal side (R=right, L=left, T=total)

Gender	N	No. of rugae (R/L/T)	No. of rugae, mean±SD (R/L/T)	p*
Male	47	220 / 213 / 433	4.68±1.73 / 4.53±1.65 / 9.21±2.60	0.303
Female	53	266 / 254 / 520	5.02±1.70 / 4.79±1.68 / 9.81±3.11	
Total	100	486 / 467 / 953	4.86±1.72 / 4.67±1.67 / 9.53±2.89	-

*Independent t-test between all males and females

Table 2 Numbers of observed rugae by shape class and gender

Gender	Number (%) of observed rugae by shape class							Total no. (%) of rugae
	A (point)	B (line)	C (curve)	D (angled)	E (sinuous)	F (circular)	X (comp.)	
Male	39 (9.0)	120 (27.7)	121 (27.9)	8 (1.8)	122 (28.2)	4 (0.9)	19 (4.4)	433 (45.4)
Female	43 (8.3)	158 (30.4)	122 (23.5)	17 (3.3)	151 (29.0)	3 (0.6)	26 (5.0)	520 (54.6)
Total	82 (8.6)	278 (29.2)	243 (25.5)	25 (2.6)	273 (28.6)	7 (0.7)	45 (4.7)	953 (100)

increasing age has been previously reported [13]. For comparison, fitting the ungrouped total number of observed rugae of all subjects in the present study as a function of age t (in years) by linear regression gives the predicted mean total number of rugae as

$$n(t) = -0.058t + 11.68 \quad (1)$$

This expression suggests an average loss rate of about one ruga in 17 years. The correlation is relatively poor ($r^2=0.067$) with large scatter as the range of the number of rugae is from 6 to 14/18 rugae in the two first age groups and from 3 to 10/16 rugae in the two last age groups of Table 2. Taking the groups I and IV as small and lumping the groups I+II and III+IV together, a new comparison was made between the two combined age groups, showing a significantly lower mean number of rugae for the older combined age group (Fig. 3). The line connecting the mean ages and mean number of rugae of the combined age groups would predict the number of rugae as

$$n(t) = -0.075t + 12.34 \quad (2)$$

This expression would imply loss of rugae at a rate of about one in 13 years. The uncertainty (scatter) remains considerable, but the standard deviation of the mean number of rugae is similar for both combined age groups (Fig. 4).

Using the mean rate of Eqs. 1 and 2, the modelled rugae loss in time can explain about half of the observed difference in the mean number of rugae between female and male subjects (Table 1) from the 5 years lower mean age of females. Also, other change than number of rugae may take place, for example in the general geometry of the palate and exposed rugae of edentulous cases or after oral surgery [4, 23]. Such changes may still be small enough to allow for correct identification with sufficient pattern recognition tools.

It has been suggested that some rugae characteristics such as their mean number, numbers at the right and left sides of the palate, or frequencies of the shapes of rugae can differ between certain human populations, or between women and men in given populations [2, 5, 9, 10]. While in the present study the mean number of rugae was slightly higher in females than in males on both sides of the palate, and the mean number of rugae was also slightly higher on the right than on the left side of the palate in both females and males, neither of these differences were statistically significant. Although this may be partly because of the small size of the sample population, the large range in the number of rugae between individuals means that relatively small differences in mean numbers of rugae would not reliably differentiate between individuals or even sizable groups of them. In the population sample of the present study, thought to be reasonably representative of the Indonesian population in general, the three most common rugae shapes (line, sinuous, and curve types) each appeared at rather similar frequencies (about 25 to 30 %) and together covered about 83 % of the subjects.

For a simple comparison of results from a number of previous rugae studies, the relative frequencies of the common rugae shapes of line (also called straight), sinuous (wavy), and curved types are compared in Table 3, as the same rugae

Table 3 Number of rugae according to age group

Age group	N	Total rugae	Number of rugae per individual				p*
			Mean±SD	Min	Median	Max	
I (13–20 years)	5	46	9.20±3.11	6	9	14	0.019
II (21–40 years)	62	645	10.2±2.62	6	10	18	
III (41–60 years)	30	241	8.39±3.02	3	8.5	16	
IV (61–75 years)	3	21	7.75±3.30	3	9	10	
Total	100	953	9.53±2.88	3	10	18	-

*ANOVA

Table 4 Comparison of recent rugae studies on various world populations

Study	N	% line/sinuous/curve [1)]	Population origin	Classification	References
Ebos	84	27.2/21.1/6.2	Nigeria	Trobo	[5]
Goyal & Goyal	114	22.1/47.8/15.6	Rwanda	Thomas & Kotze (modified)	[25]
Azab et al.	108	25.3/36.8/22.7	Egypt	Thomas & Kotze (from [12])	[26]
Abdellatif et al.	80 72	20.7/29.4/35.4 19.7/44.4/28.3	Egypt (children only) Saudi Arabia (–"-)	Thomas & Kotze	[28]
Kapali et al.	110 220	3.6/55.8/23.2 15.2/40.6/25.8	Australia (Aboriginal) Australia (Caucasian)	Lysell/Thomas & Kotze	[12]
Nayak et al.	30 30	16.0/34.5/44.7 26.5/38.3/26.8	India (Gujarat) India (Karnataka)	Thomas&Kotze (modified)	[17]
Gondivkar et al.	108	0 / 71+19 / 6.7 [2)]	India (Gujarat)	Trobo (modified) [2)]	[18]
Kotrashetti et al.	50 50	27.5/37.9/22.7 21.5/47.6/20.0	India (Maharashtra) India (Karnataka)	Thomas & Kotze (modified)	[19]
Indira et al.	100	22/24/30 [3)]	India (Bangalore)	dos Santos	[21]
Dawasaz & Dinkar	120	3.0/46+20.5/12.6 [4)]	India (Goa)	Thomas & Kotze (modified)	[22]
Shetty & Premalatha	100	16.4/59.6/20.8	India (Mangalore)	Thomas & Kotze	[29]
Rath & Reginald	100 100	37.3/28.9/15.3 6.7/45.9/24.4	India (Andhra Pradesh) India (Odisha)	Thomas & Kotze (modified as in [17])	[30]
Santos & Caldas	50 50 50	1st rugae: 54 / 7 /30 3rd rugae: 23 /72 / 5 mean: 38.5/39.5/17.5	Portugal	Basauri	[24]
Hermosilla et al.	120	14.9/43.0/27.0	Chile	Thomas&Kotze	[10]
Present study	100	29.2/28.6/25.5	Indonesia	Trobo	-

1) also called straight/wavy/curved depending on classification

2) no "line" recorded, includes both "sinuous" and "wavy"

3) estimated from Figure 2 of [21]

4) includes "wavy"+"papillary"; see [22]

shapes are the most frequent reported ones in almost all studies regardless of the origin of the population. In spite of some differences in terminology, these particular shapes are also rather similarly defined both in verbal descriptions and in the supporting type drawings of the classifications by Trobo, Basauri, Lysell, and Thomas & Kotze [3, 10, 20, 27]. The observations have been used to claim that the frequencies can be used to differentiate between populations of e.g. northern and southern India to a probability exceeding 70 % [19, 30]. However, the regional frequencies are not consistent in different studies for example in Karnataka or Gujarat in India [17–19, 29]. Partly this could be because of sampling, but reported frequencies may also vary according to the interpretation of a given shape type because of ambiguous definitions of the rugae shapes, or other deviations in classification. For example, one of the common supporting example drawings of the line/straight shape does not unambiguously differ from the simple sinuous/wavy types in the Trobo, Basauri, or Thomas & Kotze classification [10, 20, 27]. Also, the difference between curve(d) and angled types may not have been clear when the rugae exhibit relatively sharp bending to an opening angle that does not correspond to the classification model drawings of an angled type. Furthermore, any major shapes may have been occasionally misinterpreted as continuous longer rugae when the impression or casting fails to fully reproduce narrow discontinuities in them. This would result in an incorrect number of rugae and/or type of rugae, also possibly

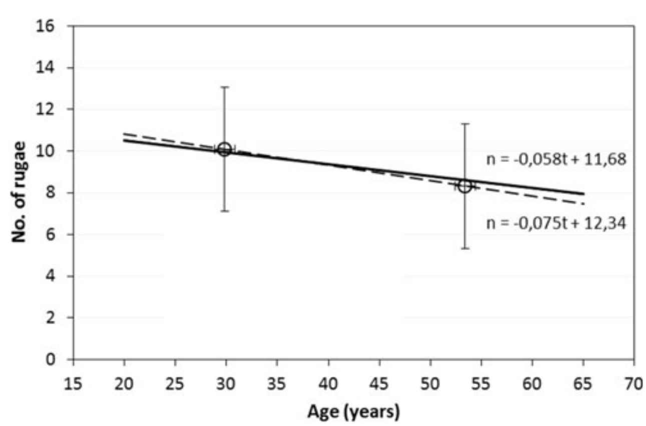

Fig 4 Number of rugae (n) as a function of age (t) from linear regression to all data (*solid line*) and to the combined age groups of 13–40 years and 41–75 years old subjects (*dashed line* through the mean points)

mislabeling them as primary/principal rugae (e.g. length≥ 5 mm). Unusual interpretation can be suspected for example in [18], where—unlike in any other study—no line type rugae are reported, but both "sinuous" and "wavy" types appear, representing 90 % of all rugae types. Therefore, the claimed ability to discern between populations is not well established purely on the basis of statistical comparison of such data. Successful differentiation between populations seems to require more reliable characterisation of the rugae patterns.

Another requirement for forensic applications is that the initial (antemortem) data are available in some applicable format for later (postmortem) comparison. This is currently not the case, as dental casts that were used in this work are inconvenient to store, not centrally registered, and generally inaccessible for later forensic analysis. To overcome the limitation, digital photography, image analysis, and/or 3D laser scanning of the rugae have been suggested to reduce or avoid manual measurements and to facilitate easy data storage and transfer [15, 16, 22]. For modern dental practices, a step forward could be applying suitable optical 3D oral/dental scans used for design and fabrication of dental/oral fixtures, restorations and implants. In this way, only digital data need to be prepared, stored, and updated to define the dental/oral geometry, and obtaining the data could be a part of normal dental service. With full use of the rugae patterns and other oral/dental geometry, the pattern recognition would not need to be hampered by the lacking standardisation of the rugae shapes. Current limitations can be seen in the availability of suitable 3D scanners, related design/fabrication tools, and personnel trained to use them. Furthermore, for forensic purposes, the scanned data should be accessible later, and therefore, need to be stored in a suitable media, format, and access site.

The concordance of the identified rugae was rather modest 84 % between two evaluators of the same 20 dental casts. The disagreement of 16 % does not accurately reflect the actual error rate, but clearly suggests need for improvement or clarity in interpretation.

The palatal rugae patterns may be unique to an individual, but this alone does not guarantee correct identification. For example, comparison can be difficult without extant and unbiased antemortem data or palatal cast. Even with good quality antemortem palatal cast or comparable information, the expected rate of identification may be closer 90-95 % in edentulous cases [20]. The antemortem images may be biased if not carefully prepared, and interpretation in terms of rugae classification may follow unequal standards and practices. Considering the results of the present work and those reported elsewhere, the differences in rugae patterns between genders or populations are not necessarily sufficient to support definite identification of an individual, even when there are significant differences in specific averaged features of palatal rugae. Therefore, the most reliable approach to definite identification from the rugae patterns remains with comparison to an extant good quality antemortem palatal cast or an equivalent image of the palatal topology of rugae.

In conclusion, the uniqueness of palatal rugae patterns would be insufficient for identifying an individual, when pre-existing (antemortem) data are unavailable or inconsistently interpreted in a later evaluation. Also, the claimed significant differences in the rugae patterns between populations appear to critically depend on the applied indicators and their interpretation that are not standardised. Data on antemortem rugae patterns could become better available from optical 3D oral/dental scans of modern dental services, but would nevertheless need to be combined with suitable pattern recognition techniques to cope with the possible geometric modifications between the initial (antemortem) and later (postmortem) rugae patterns. An example of such modification is the observed gradual reduction with age in the mean number of rugae, corresponding to a loss rate of about one ruga in 15±2 years after early adulthood.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was not required for the retrospective study on archival data on dental casts, with approval of the faculty's Ethics Committee.

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