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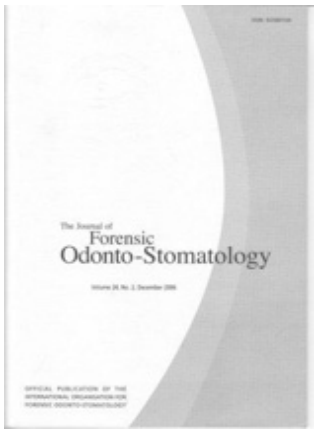

THE JOURNAL OF FORENSIC ODONTO-STOMATOLOGY

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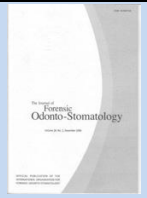

I-O-F-O-S

JOURNAL of FORENSIC ODONTO-STOMATOLOGY

VOLUME 35 Number 1 July 2017

CONTENTS

Sections: Abuse Neglect (AN), Anthropology Archeology (AA), Age Estimation (AE), Bite Marks (BM), Case Report (CR), Dental Damage (DD), Disaster Management (DM), Editorial (ED), Facial Reconstruction (FR), Identification (ID), Jurisprudence/Litigation (JL), Tools and Techniques (TT), Review (RE), Virtopsy (VI).

JOURNAL of FORENSIC ODONTO-STOMATOLOGY
VOLUME 35 Number 1 July 2017

JURISPRUDENCE AND LITIGATION

Awareness About Medico Legal Aspects And Consumer Protection Act Among Dentists

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The authors declare that they have no conflict of interest.

ABSTRACT

Background: *The practice of medicine in India has undergone considerable change affecting delivery of health in both positive and negative directions. As a result, there was a growing feeling that medical treatment should be made accountable and this led to doctors and dentists becoming subject to the process of law. Patients have become more aware of their right to compensation and as a consequence doctors and dentists should be knowledgeable about the laws that govern them. Aims and objectives: To assess the awareness about Medico legal aspects and Consumer Protection Act [CPA] among Dental professionals.* ***Materials and methods:*** *A self-structured validated questionnaire comprising of 20 questions related to medico legal aspects and CPA was designed. A total of 450 dental professionals were surveyed from 4 prime dental institutions in Chennai, India. Of the 450 professionals that were surveyed 150 were MDS faculty, 150 were BDS faculty and 150 were PG students. The data was subjected to SPSS, version 16 and statistically analysed using Chi square test and Fisher's exact test. A-p value less than 0.05 was considered to be statistically significant.* ***Results:*** *BDS faculty, MDS faculty and PG students were found to possess similar level of understanding and there was no significant difference between the groups. Knowledge was found to be equal between male and female dentists. The young practitioners were found to be more informed about CPA than the senior practitioners.* ***Conclusions:*** *It was found that most of the participants were aware of relevant Medico legal aspects, but were less aware of CPA. This study emphasises the need for education relevant to Medico legal aspects and CPA for dental professionals.*

KEYWORDS: consumer protection act, medico legal, awareness, dentist, questionnaire.

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INTRODUCTION

The medical profession is one of the most sacred and noble professions in the world. However, commercialisation and corporatisation has not left the medical profession untouched. As a result, the former relationship that was based on respect, trust and confidence between the doctor (dentist) and patient has deteriorated. There was an increasing societal feeling inc that the medical/dental profession should be made more accountable.

In India, the Consumer protection act [CPA] was enacted in 1986, to protect the interest of consumers. It was only on the 13th November 1995, that the medical/dental profession was brought within the ambit of CPA by the supreme court of India during the landmark case of Indian Medical Association vs VP Shantha [1]. While it would be difficult to define what amounts to medical negligence, The Supreme Court in A.S.Mittal vs State of U.P held that "a mistake by a medical practitioner which no reasonably competent and careful practitioner would have committed is a negligent one" [2].This again raises the question of who would decide if the proper standards have been met. Here, the court's follow "THE BOLAM RULE", which opined that a doctor is not guilty of negligence if he has acted in accordance with the practice accepted as proper by a responsible body of medical men [2].

A significant number of dentists are being summoned to court for grievance redressal by patients. Against this background it is essential that dentists should have an adequate knowledge of the law and for the implications on their profession. This study was performed to assess the level of knowledge and understanding relevant to CPA and Medico legal aspects that can affect Dentists.

MATERIALS AND METHODS

The aim of this study was to assess awareness of Medico legal aspects and of the Consumer Protection Act among Dental Professionals in Chennai, Tamil Nadu.

A cross-sectional questionnaire survey was carried out in 4 prime Dental Institutions providing post graduate [PG] courses in Chennai. A self-structured questionnaire comprising 20 questions was devised. The first fifteen questions were based on CPA- the location of the consumer forum, the provisions of CPA, the time period and method of filing a complaint, knowledge about compensation and appeal. Questions regarding record keeping, consent forms and medico legal aspects comprised the last five questions of the questionnaire. The questionnaire was validated following a Pilot study.

A total of 450 dental professionals were surveyed; 150 were MDS faculty, 150 were BDS faculty and 150 were PG students. The sample comprised 219 male and 231 female dentists. The sample was further refined based on experience of providing dentistry in private practice; 197 of the participants reported no experience of private practice, 241of the participants reported less than 20 years of experience of private practice and only 12 of the participants reported more than 20 years of experience of private practice.

The participants were informed about the nature of the study and were asked to respond to the set of 20 questions. Some who were unwilling to participate were excluded from the study.

Each correct answer was given a score of "1" and a score of "0" was given for a wrong answer. The data was subjected to SPSS, version 16 and statistically analysed using Chi square test and Fisher's exact

test. *P* value ≤ 0.05 was considered to be statistically significant.

RESULTS

The description of the participants in this study according to their gender, designation and experience is depicted in table1. A sample of 150 respondents was selected from each of the MDS, BDS and PG student groups. From the male participants 31% were from the BDS group, 39% from the MDS group and 30% from the PG group. The corresponding figures for the female participants was 36%, 28% and 36% respectively. From the sample of 450 participants 197 (43.8%) had no experience of private practice, 241 (53.6%) had less than 20 years of experience in private practice and only 12 (2.6%) had more than 20 years of experience in private practice. A comparison between those who had no experience of private practice and those with less than 20 years of experience in private practice was deemed worthy of consideration.

Table 1 – characteristics of the sample

Category	BDS	MDS	PG	Total	% of BDS	% of MDS	% of PG
Male	68	85	66	219	31	39	30
Female	82	65	84	231	36	28	36
No practice	38	33	126	197	25	22	84
<20 Years	111	106	24	241	74	71	16
>20 Years	1	11	0	12	0.6	7.3	0.0

BDS – Bachelor of Dental Surgery
MDS – Master of Dental Surgery
PG – Post Graduate students

There was little difference in knowledge identified between the BDS, MDS and PG groups of students. 50.7% of the MDS group knew "how a complaint should be filed under CPA" (*P*<0.001) 47.1% were aware that "verdict is given within 90 days under CPA" [3] (*P*<0.001) and 46.5% had knowledge about "professional indemnity insurance" (*P*<0.001%). However, in the matter of "consent" ", 46.0% of students from the BDS group showed awareness compared to 28.1% from the MDS group of students (*P*<0.001). (Fig. 2)

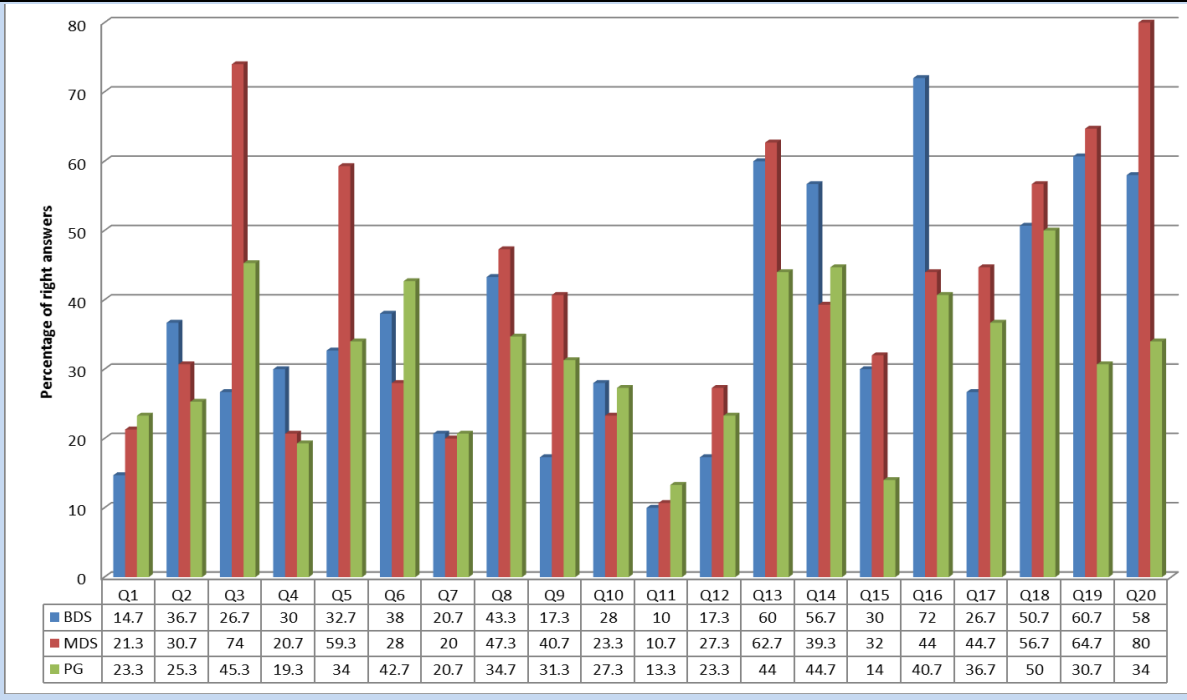
There was an almost equal spread of knowledge between male and female dentists. However the female group exhibited a marginally better understanding regarding medico legal aspects especially when it came to matters of consent (56.5%). (Fig.3)

The practitioners with experience of private practice were found to have a better understanding regarding medico legal aspects; for example record maintenance (59.3%), correct procedure to acquire consent and knowledge when consent is not a priority (58.9%). However, little difference in knowledge was demonstrated between practitioners and non-practitioners where CPA was the issue (Table 4). Accordingly, the practitioner's sample size was further classified as <10yrs, 10-20 yrs and >20 yrs experience of private practice. 91.1% of the senior practitioners knew about medical record maintenance and 75% were knowledgeable about consent forms (Fig. 5). In the matter of CPA, the 10-20 yrs experienced practitioners were knowledgeable, 31% knew that a complaint should be filed within 2 yrs,[3]31% were aware that the accused need not be present during the trial and 57.5% were knowledgeable about the defences available to a doctor. Those practitioners having <10yrs of experience showed an average understanding in the matter of

both CPA and Medico legal aspects involved in practice.

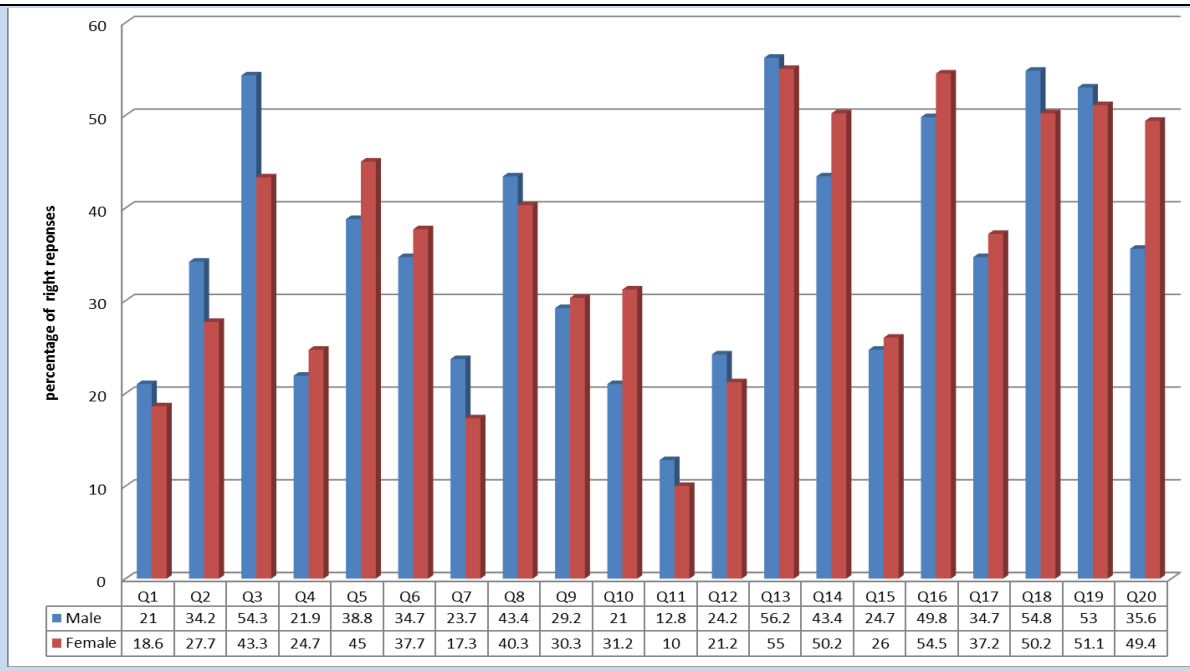
Only 30.9% ($P<0.005$) of the participants knew the location of the consumer forum.

42.7% ($P<0.001$) of the participants were unaware about "professional indemnity insurance".



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
BDS	14.7	36.7	26.7	30	32.7	38	20.7	43.3	17.3	28	10	17.3	60	56.7	30	72	26.7	50.7	60.7	58
MDS	21.3	30.7	74	20.7	59.3	28	20	47.3	40.7	23.3	10.7	27.3	62.7	39.3	32	44	44.7	56.7	64.7	80
PG	23.3	25.3	45.3	19.3	34	42.7	20.7	34.7	31.3	27.3	13.3	23.3	44	44.7	14	40.7	36.7	50	30.7	34

Fig.2: Percentage of right answers among BDS, MDS and Postgraduate student.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Male	21	34.2	54.3	21.9	38.8	34.7	23.7	43.4	29.2	21	12.8	24.2	56.2	43.4	24.7	49.8	34.7	54.8	53	35.6
Female	18.6	27.7	43.3	24.7	45	37.7	17.3	40.3	30.3	31.2	10	21.2	55	50.2	26	54.5	37.2	50.2	51.1	49.4

Fig. 3: Genderwise comparisons of right responses among subjects.

Table 4 - classification of correct answers on the basis of experience

Question	No practice	<20 years	>20years	Total
Q1	47	40	2	89
Q2	63	75	1	139
Q3	93	118	8	219
Q4	41	62	2	105
Q5	72	112	5	189
Q4	41	62	2	105
Q5	72	112	5	189
Q6	74	86	3	163
Q7	37	52	3	92
Q8	70	115	3	188
Q9	62	68	4	134
Q10	49	66	3	118
Q11	22	28	1	51
Q12	43	56	3	102
Q13	96	143	11	250
Q14	89	116	6	211
Q15	37	74	3	114
Q16	87	142	6	235
Q17	76	77	9	162
Q18	98	131	7	236
Q19	89	138	7	234
Q20	73	176	9	258

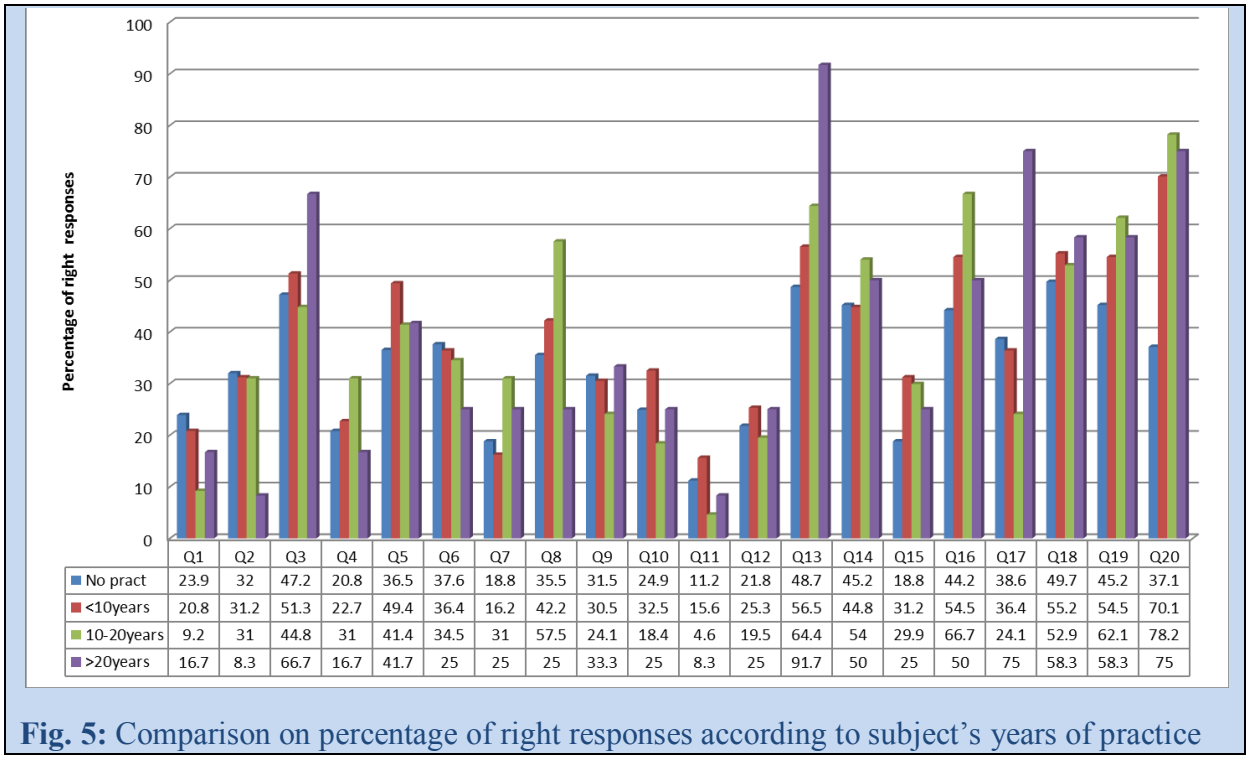


Fig. 5: Comparison on percentage of right responses according to subject's years of practice

DISCUSSION

Disputes were tried and settled through "Panchayath" systems headed by persons of higher status and character, before the formation of courts in India. The advent of "Lok Adalat" (people's court) followed this deep rooted system where a mediator was appointed whose principle task was to bring the parties together and facilitate an agreed solution. This system allows direct interaction with the judge and has no strict procedural laws. Alternate Dispute Redressal [ADR] provides parties with the opportunity to reduce hostility, regain a sense of control, gain acceptance of the outcome, resolve conflict in a peaceful manner, and achieve a greater sense of justice in individual cases. ADR has proved very efficient and most suited to the Indian financial and cultural interests. Before the advent of CPA, considered to be an expedient way to deliver justice, cases against dentists were tried before the Civil Courts under the Indian Contract Act. This proved both a lengthy and expensive process

Dental negligence falls under section 2 (0) of CPA because the Indian Dentist Act did not make provisions to: [4]

- Entertain any complaint from the patient
- Take action against dentist in case of negligence
- Award compensation

CPA has provisions that protect the dentist from unwarranted mental turmoil and defamation of character. These provisions were set out by the Supreme Court as part of the landmark Jacob Matthew vs. State of Punjab judgment. When a complaint has been filed against a dentist, the dentist is given a copy of the complaint with instruction to respond with a version of their recollection of events leading up to the complaint within a time frame of 45 days. It would appear that the Court places greater value on the written report of the dentist more than that of he patient's recollection of events.The Supreme Court in Suresh Gupta vs. Government of National Capital Territory of Delhi, stated that a dentist who has acted in accordance with a practice deemed proper by a reasonable body of practitioners cannot be considered negligent merely because there is an opinion that takes a contrary view.[5] It follows that dentists must stay abreast of current knowledge of the laws that govern the profession of dentistry particularly against the background of an increasingly litigious society. Dentists should also be aware of Professional Indemnity Insurance that provides both financial and legal protection when liability is proven as a result of errors and omissions committed whilst rendering professional services. The policy covers only civil liability claims and expenses incurred in defence of the case, subject to the sum assured in the policy, Any amount over and above this amount would be borne by the dentist. The policy also provides retrospective cover in some circumstances where claims reported on renewal but pertaining to an earlier period also become payable. Professional indemnity insurance is presently under-utilized in India.[6]

This study was conducted to assess awareness of CPA and medico legal aspects of dental practice among professionals at Dental Institutions in Chennai, India. More than half of the study population had no knowledge regarding the location of the consumer forum in Chennai. 71.6% of the study participants were under the impression that there was no time limit for a complaint to be filed by a patient, while only 23.3% of the study participants were aware that a complaint

has to be filed within 2 yrs from the cause of action. [7]

The main advantage of CPA over the Civil Courts in India is expediency in resolution. Just 42.0% of the participating dentists were aware of the fact that a verdict is usually given within 90 days of the first hearing and only 26.2% were aware of the fact that an appeal is considered within 30days from the date of court order. Caveats include a consideration for cases submitted outwith the 30 day time frame for appeal still to be subject to consideration . [3]

72.9% of the participants thought that no appeal was to be possible beyond the three levels of the consumer forum, the three levels being: [8]

- District Forum – where cases up to Rs.20/- Lakhs are tried
- State Commission – where cases above Rs.20/- Lakhs but less than Rs.1/- Crore are tried. Appeal cases, decided by the District forum are also tried.
- National Commission – where cases above Rs.1/- Crore are tried and redressel from the State commission lie here.

The appeal after the Consumer Forum's decision lies directly with The Supreme Court of India and only 11.3% were knowledgeable about this fact.

Of the 450 participants, only 211 (46.9%) knew that a Charitable Hospital that provides free treatment to all patients does not fall within the ambit of CPA. This is less when compared to the study by Anil et al in Bilaspur, which showed 70% awareness among medical practitioners.[9]

Our study revealed that knowledge regarding the aims and objectives of CPA and it application in regard to our field of practice is limited, similar to studies conducted by Anil et al[8] and Jasuma et al.[10]

The study indicated little difference in knowledge relating to this study between MDS participants, BDS paqrticipants and PG participants. This is contrary to the study conducted in Ghaziabad by Sumanth Prasad et al,[11] in which the MDS faculty was found more knowledgeable as compared to BDS participants and PG participants.

There was an equal distribution of awareness seen among male and female dentists in our study, which is not in agreement with the study conducted by Singh et al in Udaipur city,[12] which showed higher awareness among male dentists.

Our study showed that senior dentists had a better level of understanding regarding medico-legal aspects, which is in accordance with the findings of the study conducted in Vadodra by Jasuma et al.[10]

Our study revealed that the young practitioners are knowledgeable about CPA in comparison with Senior Practitioners. This is not in accord with the study conducted by Anil et al in Bilaspur.[9] This may be attributed to the lack of streamlined continuing dental education.

The observations of the present study are at variance with the findings reported by Gurminder et al in his systematic review of five Indian cross-sectional studies. Their review did not include a comparison between senior and junior practitioners.[13]

The overall assessment of correct responses reveals that the knowledge about CPA is below average and awareness is average when it comes to medico legal aspects in regular practice.

CONCLUSION

Against a climate of increases societal litigation, the dentist is no longer considered to be the expert. Dental treatment is never straightforward and things can go wrong, but contemporaneous knowledge of the laws governing the dental profession are paramount. This study emphasises the need for dental professionals to be "up to speed" in this discipline.

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JOURNAL of FORENSIC ODONTO-STOMATOLOGY
VOLUME 35 Number 1 July 2017

SECTION ANTHROPOLOGY

Sex Prediction From Morphometric Palatal Rugae Measures

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ABSTRACT

Background: While abundant research has been conducted on palatal rugae (PR), the literature pertaining to the sex dimorphism of the palatal rugae and their use for sex prediction is inconclusive. Moreover, palatal rugae have been classified into categories based on length, shape, direction and unification but accurate rugal morphometric linear and angular measurements have not yet been reported. Objective: The aims of this study were to -1- assess the dimensions and bilateral symmetry of the first three palatal rugae in an adult population and -2- explore sex dimorphism and the ability to predict sex from palatal rugae measurements. Materials and methods: The maxillary dental casts of 252 non-growing subjects (119 males, 130 females, mean age 25.6 ± 7.7 years) were scanned using a laser system (Perceptron ScanWorks® V5). Angular and linear transverse and anteroposteior measures of the first three palatal rugae were recorded. Independent samples t-tests and paired samples t-tests were used to test for side related differences and sex dimorphism. Multiple logistic regression was employed to model sex using associated palatal rugae measures. Results: Palatal rugae exhibited lateral asymmetry in the majority of bilateral measures. Males presented with larger values for 9 out of 28 parameters. Four linear rugae measurements and one angular measurement together correctly classified 71.4% of the subjects in their true gender. Conclusions: Morphometric palatal rugae measurements demonstrated promising usefulness in sex prediction. Recording morphometric linear and angular measures is recommended as an adjunct to the commonly used classification based on the shapes of rugae.

KEYWORDS: Palatal rugae, forensic odontology, sex prediction, human identification

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INTRODUCTION

A specific part of the palate, the area containing the palatal rugae, has been shown to be of significant value to forensic odontology and medicolegal identification processes.[1,2] Also known as plicae palatinae transversae, these structures are a series of transverse folds of palatal mucosa that are located in the anterior region of the palate on either side of the median palatal raphe and behind the incisive papilla.[3] Although prevalent conventional forensic methods to rely on fingerprints, DNA and dental records, the uniqueness and immutability of the palatal rugae,[1-6] their reported sex dimorphism[7,8] and their apparent ethnic specificity[9,10] promote their use in instances where fingerprints are not available (fires, decomposition and massive trauma) and when conventional dental records are of limited value (because of edentulism or significant changes in dental work since last record).

To date, the vast majority of studies assessing the palatal rugae have been based on various classification systems based on characteristics such as length, shape, direction and/or other specific features such as the presence of unification or divergence.[11-13] Such classifications bestow simplicity characterization and summation, but the diversity of criteria used across different methods represents an obstacle to meaningful comparisons. For example, Lysell classifies rugae $\geq$ 5 mm in length into primary rugae, whereas Thomas and Kotze[14] (1983) define 5mm-long rugae as secondary and only longer rugae as primary. While Thomas and Kotze[14] identify four major rugae shapes (curved, wavy, straight and circular), the classification by Trobo comprises six patterns, Basauri lists seven patterns, and dos Santos describes ten.[11,14]

Accordingly, using the actual morphometric dimensions of the palatal rugae yields accurate data comparable across different studies and different populations. The aim of this study is to assess the dimensions and bilateral symmetry of the first three palatal rugae in an adult population and to explore sex dimorphism and the ability to predict sex from morphometric palatal rugae measurements. While presumably similar to other Caucasian populations, this is the first study of palatal rugae in the Lebanese population, thus amenable to comparisons with Mediterranean, Near Eastern and other populations.

MATERIAL AND METHODS

The study sample consisted of the pre-treatment orthodontic records of 252 non-growing subjects (119 males, 130 females, mean age 25.6 ± 7.7 years) recruited from the database of patients treated in the orthodontic division at the American University of Beirut Medical Center. Inclusion criteria were: age > 16 years for females and age > 18 years for males; complete set of fully erupted permanent dentition (excluding third molars); presence of high quality pre-treatment dental cast; absence of posterior cross-bite as evaluated on dental casts. Subjects with systemic disease, craniofacial anomalies, history of orthodontic treatment and/or surgical treatment involving the head and neck were excluded. This retrospective investigation was approved by the Institutional Review Board.

Maxillary and mandibular dental casts were de-identified by research support personnel not directly involved in the research. All remaining procedures were carried out by the principal investigator (M.S.). Dental casts were scanned using the laser scanning system Perceptron (ScanWorks® V5), which consists of a scanning probe attached to the Cimcore Infinite 2.0 (Seven axis) CMM Arm and is complemented by a point cloud handling software, IMInspect from PolyWorks® (InnovMetric Software, Quebec, Canada).

Each resultant three-dimensional image was carefully scrutinized to assess the acquisition of sufficient surface profile for all relevant anatomical structures before saving for subsequent analysis.

Saved data files were processed using IMInspect software from PolyWorks® to generate the polygonal model derived from the point cloud for all anatomical structures present in the model, at point-to-point resolutions up to 12µm. The same software was used to measure and record all palatal rugae measurements.

The first three palatal rugae, anterior, middle and posterior rugae were numbered 1, 2, and 3, respectively, and the right and left sides identified as R and L. The most medial (m: mR1/mL1, mR2/mL2, mR3/mL3) and most lateral (l: lR1/lL1, lR2/LL2, lR3/lL3) points were digitized (Fig. 1). The median palatal plane (MPP) was constructed through the median palatal raphe and the following measurements were then computed (Fig. 2):

- length of the rugae on right and left sides (R1, R2, R3, L1, L2, L3), from most medial to most lateral points.
- transverse distances between bilateral rugae points: transverse perpendicular distances between medial (Tm1, Tm2, Tm3) and lateral (Tl1, Tl2, Tl3) points.
- anteroposterior (AP) distances between opposing medial (m) and lateral (l) right (R) and left (L) rugae points: APmR-1/2 and APmR-2/3 between the medial right points and APlR-1/2 and APlR-2/3 between the lateral right rugae points. The same was measured on the left side (APmL-1/2, APmL-2/3, APlL-1/2 and APlL-2/3).
- rugae divergence angles: outer lR3-IP-lL3 (RDA-out), and inner mR3-IP-mL3 (RDA-in).
- rugae angles: formed by the MPP and a line joining the medial and lateral points of each rugae on the right (AngR1/MPP, AngR2/MPP, AngR3/MPP) and left (AngL1/MPP, AngL2/MPP, AngL3/MPP) sides.

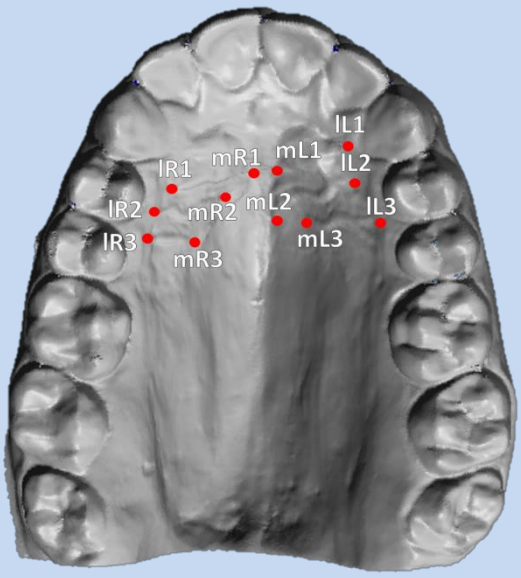

Fig. 1: The anterior, middle and posterior rugae are numbered 1, 2, and 3, respectively. The right and left sides are identified as R and L. Medial (m) and lateral (l) points are digitized. Definitions are detailed in text

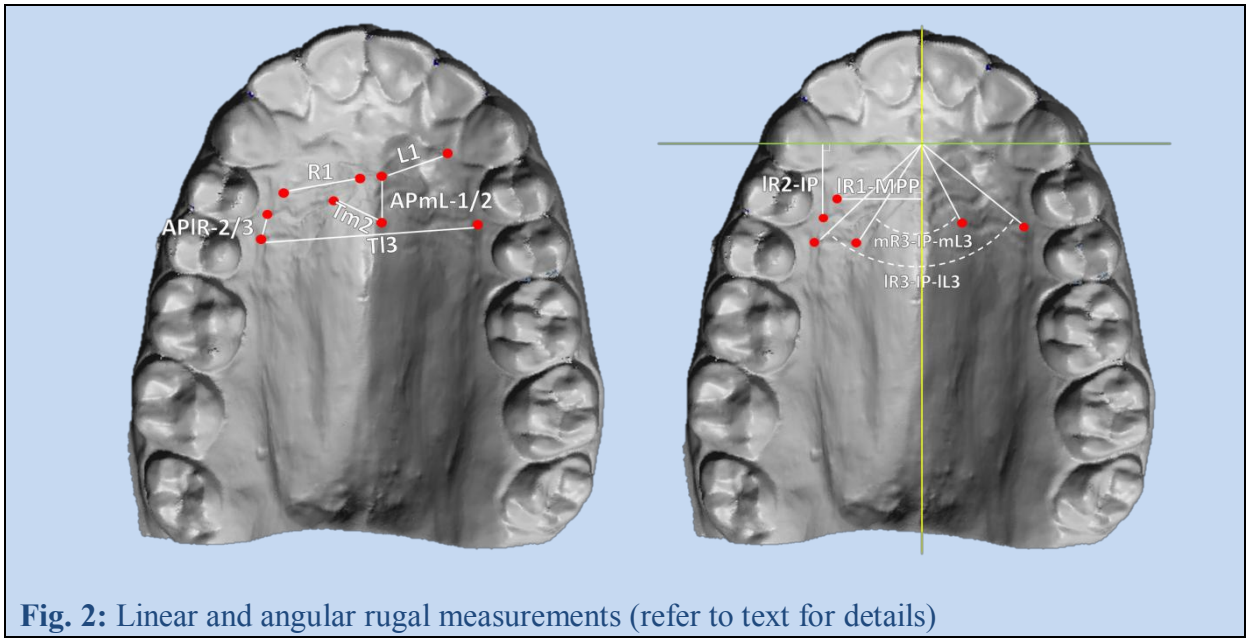

Fig. 2: Linear and angular rugal measurements (refer to text for details)

Independent samples t-tests were used to evaluate differences among palatal rugae dimensions between males and females and paired samples t-tests were used to compare right and left measures in the overall sample and in males and females separately. Rugae dimensions associated with sex at $p < 0.20$ were explored as predictors of sex in the multivariate analysis which was conducted using multiple logistic regressions.

To assess intra-observer reliability, all measurements were repeated on 50 randomly selected casts at least 14 days after the initial assessment. The repeated measures were evaluated with the two-way mixed effects intra-class correlations for absolute agreement on single measures. In addition, measurements on 50 randomly selected models were repeated by another investigator (R.H.) to evaluate inter-rater reliability.

Data were processed using the Statistical Package for Social Sciences (IBM SPSS®, version 20.0, Armonk, NY) and Stata Statistical Software (version 11.1, College Station, TX). Statistical significance was set at 0.05.

RESULTS

The intraclass correlations ranged between 0.897 and 0.991 for intra and inter-rater reliability, demonstrating high correspondence.

The third rugae were on average the longest on either side of the palate (10.37 ± 2.91 on the right, 11.25 ± 2.96 on the left; **Table 1**) and also the farthest away from each other (Tm3 = 8.06 ± 3.41 mm compared to 6.41 ± 2.63 and 3.56 ± 1.70 for the second and first rugae, respectively). Medial separation between opposing rugae exhibited wide variability, ranging between 0.71 and 10.19 mm for the first rugae; 1.71 - 12.81 mm for the second rugae and 1.68 - 17.35 mm for the third. Anteroposteriorly, the mean distance between any two opposing rugae points ranged between 4.1 ± 1.89 mm and 5.61 ± 2.32, the separation between the 2nd and 3rd rugae points generally being greater than that between the 1st and 2nd, except for the lateral rugae points on the right side of the palate (APlR-1/2= 5.8 ± 2.72 mm and APlR-2/3= 5.61 ± 2.66 mm). Anteroposterior distances between rugae points were similarly widespread, minimum values ranging between 0.56 and

1.1 mm and maximum values ranging between 8.82 and 16.49 mm.

Angular measurements of the palatal rugae were even more widespread and displayed large standard deviations. Mean outer and inner rugae divergence angles were 99.11 ± 16.32 and 39.91 ± 19.91 degrees, respectively. Average angular measurements to the MMP ranged between 61.13 ± 15.74 and 93.86 ± 26.79 degrees, but individual measures were as low 18.65 degrees for AngR1 and as high as 171.23 degrees for AngR3.

The majority of bilateral measures displayed right/left asymmetry in the overall sample (**Table 2**) and in the male (**Table 3**) and female (**Table 4**) subsamples separately. In the overall sample, only second rugae length and the anteroposterior distance between 2nd and 3rd medial and lateral rugae points showed no significant side-related differences. The first and third rugae were on average 0.78 ± 2.09 and 0.88 ± 3.61 mm longer on the left side ($p < 0.001$); the anteroposterior distance between the first and second rugae points was 0.51 ± 2.26 mm greater on the left medially, but it was larger on the right laterally (1.4 ± 3.34 mm, $p < 0.001$). The angles formed by all three rugae and the MPP were statistically significantly larger on the right side, the difference ranging between 9.51 ± 10.93 degrees for the first rugae and 25.41 ± 28.91 degrees for the third rugae ($p < 0.001$).
A similar situation was present in the male subset (Table 3) with the exception that third rugae length and the antero-posterior distance between the medial points of the first and second rugae did not display any right-left differences ($p > 0.05$). A larger number of variable exhibited asymmetry in females compared to males. The same differences observed in the overall sample were also displayed by the female subset (Table 4), with an additional statistically significant right-left difference in the anteroposterior distance between the second and third lateral rugae points ($p = 0.004$).

Nine out of the 28 assessed palatal rugae measures exhibited male-female differences, measurements being larger in males (**Table 5**). The second and third rugae were on average 0.73 ± 0.32 and 1.11 ± 0.36 mm longer in males than in females, respectively ($p = 0.024$ and $p = 0.002$, respectively) but there were no statistically significant differences in the lengths of any of the remaining rugae. TLL3 was the only additional transverse measure that differed between genders, the separation being on average 1.53 ± 0.44 mm larger in males. All medial anteroposterior distances between opposing rugae were similarly greater in males, the mean difference ranging between 0.6 ± 0.21 and 0.86 ± 0.26 mm ($p \leq 0.005$). Laterally, only the distance between the 2nd and 3rd left rugae was larger in males ($p = 0.011$). As for the angular measures, only AngR1/MPP was statistically significantly larger in males (mean difference = 5.98 ± 2.50; $p = 0.018$).

In multivariate analysis, 5 variables significantly predicted sex and correctly classified subjects in 71.4% of instances (X^2 (3) = 44.18; $p < 0.001$; Tjur's R^2 = 0.169; **Table 6**). The four linear measurements (R3, APmR-1/2, APmR-2/3 and APlL-2/3) were negatively associated with being female (regression coefficients ranging between -0.13 and -0.24). With every 1 mm increase in any of these four measurements, the odds of being female is multiplied by a value ranging between 0.785 (CI: 0.667-0.991) and 0.880 (CI: 0.802-0.967). Conversely, the only angular measurement predicting sex (AngL3/MPP, $p = 0.013$) was positively associated with being female, the odds multiplied by 1.022 (CI: 1.005-1.040) with every degree increase in AngL3/MPP.

A simpler method of sex prediction was explored, employing multivariate models

by using right side variables or left side variables separately (*data not shown*). These explorations produced models with inferior characteristics (lower percent correctly predicted and lower R^2 values) and were therefore rejected.

Table 1. Descriptive statistics for palatal rugae dimensions (n = 252)

	Mean	SD	Min.	Max.
R1	9.60	1.80	4.44	14.85
R2	10.12	2.55	4.39	17.10
R3	10.37	2.91	4.18	18.25
L1	10.38	1.85	4.46	16.53
L2	10.21	2.75	3.53	17.25
L3	11.25	2.96	4.33	20.51
Tm1	3.56	1.70	0.71	10.19
Tm2	6.41	2.63	1.71	12.81
Tm3	8.06	3.41	1.68	17.35
TI1	19.09	2.75	9.44	28.43
TI2	21.07	3.05	9.61	30.88
TI3	22.64	3.59	9.32	34.15
APmR-1/2	4.10	1.89	0.64	8.82
APmR-2/3	5.12	2.09	0.56	10.50
APmL-1/2	4.62	1.70	0.82	10.28
APmL-2/3	5.08	1.94	0.68	11.02
APIR-1/2	5.80	2.72	0.28	15.19
APIR-2/3	5.61	2.66	1.10	16.49
APIL-1/2	4.40	2.20	0.67	12.68
APIL-2/3	5.29	2.32	0.68	13.01
RDA-out	99.11	16.32	54.13	150.41
RDA-in	39.91	19.91	2.98	107.49
AngR1/MMP	70.64	19.71	18.65	142.23
AngR2/MMP	84.18	23.28	34.44	148.91
AngR3/MMP	93.86	26.79	40.06	171.23
AngL1/MMP	61.13	15.74	14.62	108.61
AngL2/MMP	63.48	18.60	25.45	123.68
AngL3/MMP	68.46	18.55	28.41	158.08

Notes. Linear measures recorded in millimeters; angular measures recorded in degrees; SD: standard deviation; Min.: minimum; Max.: maximum.

DISCUSSION

Using features that are unique to an individual is key in post-mortem identification. The present study focuses on the uniqueness and immutability of the palatal rugae,[2,4-6] their apparent ethnic specificity,[9,10,15] and particularly on their reported gender dimorphism.[7,8,16] These characteristics are valuable in instances where fingerprints are not available (fires, decomposition and massive trauma)[17] and when conventional dental records are of limited value (because of edentulism or significant changes in dental work since last record.[18] Moreover, with the common usage of mouth scanners providing instant imaging, their use would be facilitated.

Table 2. Differences in palatal rugae dimensions between right and left sides (n = 252)

	Right	Left	Paired difference		
	Mean (SD)	Mean (SD)	Mean (SD)	t	*p* value[Ŧ]
(R/L)1	9.60 (1.80)	10.38 (1.85)	-0.78 (2.09)	-5.93	<0.001**
(R/L)2	10.12 (2.55)	10.21 (2.75)	-0.09 (3.19)	-0.43	0.667
(R/L)3	10.37 (2.91)	11.25 (2.96)	-0.88 (3.61)	-3.89	<0.001**
APm(R/L)-1/2	4.10 (1.89)	4.62 (1.70)	-0.51 (2.26)	-3.62	<0.001**
APm(R/L)-2/3	5.12 (2.09)	5.08 (1.94)	0.04 (2.58)	0.25	0.807
APl(R/L)-1/2	5.80 (2.72)	4.40 (2.20)	1.40 (3.34)	6.64	<0.001**
APl(R/L)-2/3	5.61 (2.68)	5.29 (2.32)	0.32 (3.51)	1.44	0.152
Ang(R/L)1/MPP	70.64 (19.71)	61.13 (15.74)	9.51 (19.93)	7.58	<0.001**
Ang(R/L)2/MPP	84.18 (23.28)	63.48 (18.60)	20.69 (22.99)	14.29	<0.001**
Ang(R/L)3/MPP	93.86 (26.79)	68.46 (18.55)	25.41 (28.91)	13.95	<0.001**

Notes. Linear measures recorded in millimeters; angular measures recorded in degrees; SD: standard deviation; Ŧ*p* values from paired t-test at 251 degrees of freedom; *statistically significant at $p < 0.05$; **statistically significant at $p < 0.01$.

Table 3. Differences in palatal rugae dimensions between right and left sides in male subjects (n = 119)

	Right	Left	Paired difference		
	Mean (SD)	Mean (SD)	Mean (SD)	t	*p* value[Ŧ]
(R/L)1	9.58 (1.80)	10.61 (1.80)	-1.03 (2.19)	-5.14	<0.001**
(R/L)2	10.50 (2.69)	10.22 (2.66)	0.28 (3.13)	0.98	0.331
(R/L)3	10.95 (2.88)	11.44 (2.98)	-0.49 (3.57)	-1.50	0.137
APm(R/L)-1/2	4.53 (2.02)	4.93 (1.76)	-0.40 (2.28)	-1.94	0.055
APm(R/L)-2/3	5.57 (2.17)	5.44 (1.84)	0.12 (2.42)	0.54	0.593
APl(R/L)-1/2	5.65 (2.46)	4.39 (2.14)	1.26 (2.99)	4.49	<0.001**
APl(R/L)-2/3	5.36 (2.43)	5.68 (2.34)	-0.32 (3.40)	-1.04	0.303
Ang(R/L)1/MPP	73.80 (22.11)	61.88 (15.54)	11.92 (19.45)	6.69	<0.001**
Ang(R/L)2/MPP	84.75 (25.29)	62.23 (19.70)	22.52 (20.61)	11.92	<0.001**
Ang(R/L)3/MPP	91.62 (27.13)	66.73 (18.77)	24.89 (29.10)	9.33	<0.001**

Notes. Linear measures recorded in millimeters; angular measures recorded in degrees; SD: standard deviation; Ŧp values from paired t-test at 118 degrees of freedom; *statistically significant at $p < 0.05$; **statistically significant at $p < 0.01$.

Specifically on sex identification, the gold-standard method remains DNA analysis. Rugoscopy figures among the morphological methods that evaluate structures that may vary within their environment over time. While odontometric evaluations have been used for sex differentiation (mesiodistal[19,20] and buccolingual[21] dimensions of teeth, tooth morphology,[22] mean canine index,[23,24] earlier studies on palatal rugae focused on their number (greater in males)[15] and patterns.[25]

Table 4. Differences in palatal rugae dimensions between right and left sides in female subjects (n = 133)

	Right	Left	Paired difference		
	Mean (SD)	Mean (SD)	Mean (SD)	t	*p* value[Ŧ]
(R/L)1	9.62 (1.81)	10.18 (1.87)	-0.56 (1.98)	-3.25	0.001**
(R/L)2	9.78 (2.37)	10.19 (2.83)	-0.41 (3.21)	-1.49	0.139
(R/L)3	9.84 (2.86)	11.07 (2.94)	-1.23 (3.62)	-3.94	<0.001**
APm(R/L)-1/2	3.72 (1.67)	4.33 (1.59)	-0.61 (2.24)	-3.16	0.002**
APm(R/L)-2/3	4.71 (1.93)	4.74 (1.98)	-0.03 (2.72)	-0.13	0.896
APl(R/L)-1/2	5.93 (2.93)	4.41 (2.26)	1.52 (3.62)	4.83	<0.001**
APl(R/L)-2/3	5.83 (2.83)	4.94 (2.26)	0.89 (3.51)	2.92	0.004**
Ang(R/L)1/MPP	67.81 (16.86)	60.46 (15.95)	7.36 (20.17)	4.21	<0.001**
Ang(R/L)2/MPP	83.66 (21.52)	64.60 (17.55)	19.05 (24.89)	8.83	<0.001**
Ang(R/L)3/MPP	95.86 (26.42)	70.00 (18.29)	25.87 (28.83)	10.35	<0.001**

Notes. Linear measures recorded in millimeters; angular measures recorded in degrees; SD: standard deviation; [Ŧ]p values from paired t-test at 132 degrees of freedom; *statistically significant at $p < 0.05$; **statistically significant at $p < 0.01$.

This study contributes components of palatal rugae related to gender differences that have not been reported earlier. Although only the lengths of the tight second and third palatal rugae differed significantly between males and females, the lengths of all remaining rugae were consistently greater in males to varying extents (but were not statistically significant). Medial separation between rugae on opposite sides of the palate did not differ between genders for any of the assessed rugae, suggesting a close transverse association between the MPP and rugae origin points irrespective of gender. Sex differences were also predominant in anteroposterior distances between opposing rugae, especially at the medial end where all comparisons were statistically significant.

While it is difficult to compare our numeric data with the predominantly descriptive data from previous studies, signs of larger palatal rugae measurements in males seem to also be present in previous studies. Jain and Jain[26] reported a statistically significant lower number of fragmented rugae (< 3 mm) and larger number of primary rugae (5-10 mm) in males compared to females; Fawzi et al.[27] obtained similar results in a study conducted in Saudi Arabia. In a different assessment, Babu et al.[28] also reported gender disparity: a larger (though not statistically significant) mean number of primary rugae in males and larger mean numbers of secondary and tertiary rugae in females.

Our data indicated that females had less of the longer and more of the shorter rugae, and an average rugae length smaller than in males. Other authors have found no differences in mean numbers of primary and/or other rugae categorized on length,[11,29,30] but the divergence in results probably relates to the classification in other studies into three broad categories compared to our direct measurements. In a recent study, Alani et al. measured the length of the 3rd rugae on 82 dental casts and also found no statistically significant differences between males and females although mean length was 0.93 mm greater in males.[31]

Table 5. Distribution of palatal rugae dimensions by sex (n = 252)

	Males (n = 119)	Females (n = 133)	Difference		
	Mean (SD)	Mean (SD)	Mean (SE)	t	*p* value[Ŧ]
R1	9.58 (1.80)	9.62 (1.81)	-0.04 (0.23)	-0.16	0.871
R2	10.50 (2.69)	9.78 (2.37)	0.73 (0.32)	2.28	0.024*
R3	10.95 (2.88)	9.84 (2.86)	1.11 (0.36)	3.08	0.002**
L1	10.61 (1.80)	10.18 (1.87)	0.43 (0.23)	1.87	0.062
L2	10.22 (2.66)	10.19 (2.83)	0.03 (0.35)	0.09	0.929
L3	11.44 (2.98)	11.08 (2.94)	0.37 (0.37)	0.99	0.324
Tm1	3.56 (1.77)	3.56 (1.65)	0.00 (0.22)	0.02	0.983
Tm2	6.52 (2.78)	6.32 (2.49)	0.20 (0.33)	0.60	0.551
Tm3	8.42 (3.76)	7.73 (3.05)	0.69 (0.43)	1.62	0.107
Tl1	19.43 (2.82)	18.78 (2.66)	0.65 (0.35)	1.89	0.060
Tl2	21.37 (3.16)	20.79 (2.94)	0.59 (0.38)	1.53	0.128
Tl3	23.44 (3.47)	21.91 (3.56)	1.53 (0.44)	3.45	0.001**
APmR-1/2	4.53 (2.03)	3.72 (1.67)	0.81 (0.23)	3.47	0.001**
APmR-2/3	5.57 (2.17)	4.71 (1.93)	0.86 (0.26)	3.31	0.001**
APmL-1/2	4.93 (1.76)	4.33 (1.59)	0.60 (0.21)	2.84	0.005**
APmL-2/3	5.45 (1.84)	4.74 (1.98)	0.71 (0.24)	2.92	0.004**
APlR-1/2	5.66 (2.46)	5.93 (2.93)	-0.27 (0.34)	-0.79	0.430
APlR-2/3	5.36 (2.43)	5.84 (2.83)	-0.47 (0.33)	-1.43	0.155
APlL-1/2	4.40 (2.14)	4.41 (2.26)	-0.01 (0.28)	-0.05	0.960
APlL-2/3	5.69 (2.34)	4.94 (2.26)	0.74 (0.29)	2.56	0.011*
RDA-out	98.65 (16.22)	99.52 (16.45)	-0.87 (2.06)	-0.42	0.674
RDA-in	38.47 (19.8)	41.20 (20.00)	-2.72 (2.51)	-1.09	0.279
AngR1/MMP	73.80 (22.11)	67.82 (16.86)	5.98 (2.50)	2.39	0.018*
AngR2/MMP	84.75 (25.19)	83.66 (21.52)	1.10 (2.94)	0.37	0.709
AngR3/MMP	91.63 (27.13)	95.87 (26.42)	-4.24 (3.38)	-1.26	0.210
AngL1/MMP	61.88 (15.54)	60.46 (15.95)	1.42 (1.99)	0.71	0.476
AngL2/MMP	62.23 (19.7)	64.60 (17.56)	-2.37 (2.36)	-1.00	0.316
AngL3/MMP	66.73 (18.77)	70.00 (18.29)	-3.26 (2.34)	-1.40	0.164

Notes. Linear measures recorded in millimeters; angular measures recorded in degrees; SD: standard deviation; SE: standard error; [Ŧ]*p* values from Student's t-test at 251 degrees of freedom; [*]statistically significant at $p < 0.05$; [**]statistically significant at $p < 0.01$.

Sex differences in anteroposterior distances between opposing rugae have not been previously assessed. Our data suggest that the larger dimensions observed transversely and also anteroposteriorly, are likely reflective of overall larger anthropometric dimensions of the head in males compared to females.

Combined, four linear and one angular rugae measurements correctly classified nearly three-quarters of the sample into their true sex, well over the 50% expected due to chance. Although pseudo-R^2 values for our model were only moderate, as is generally the case in binary logistic regressions, the model was a good fit for our data and was overall statistically significant. Attempts to predict sex from either right-side or left-side variables alone produced inferior predictability and model characteristics, thus highlighting the importance of examining the entire palatal rugae area for maximum benefit. The

predictive value for sex obtained in our study compares positively to several previous studies using descriptive palatal rugae measures to predict sex, with predictability reported at 55%,[32] 58 to 60%,[29] and 67%.[33] Bharath et al. and Chopra et al., on the other hand, reported predictive values close to, but slightly higher, than ours: 78% and 71-75%, respectively.[25,34] Exceptionally, Saraf et al. were able to predict sex correctly in 99.2% of their sample using "all rugae shapes", although the exact model used in prediction was not presented.[35]

Table 6. Multivariate analysis showing associations between selected palatal rugae variables and sex (n = 252)

Associated variables	Sex (Base category: male)					
	Coef.	Std. Err.	Wald	*p* value	OR	95% CI for OR
Constant	3.25	0.89	13.28	<0.001**	25.911	
R3	-0.13	0.05	7.05	0.008**	0.880	[0.802; 0.967]
APMR12	-0.24	0.08	10.18	0.001**	0.785	[0.667 ; 0.991]
APMR23	-0.24	0.07	11.34	0.001**	0.790	[0.688 ; 0.906]
APLL23	-0.21	0.07	9.60	0.002**	0.808	[0.706 ; 0.925]
AngleL3/MPP	0.02	0.01	6.21	0.013*	1.022	[1.005 ; 1.040]
X^2 (5)	44.18					
Model *p* value	<0.001**					
R^2 (Tjur's; Nagelkerke's)	0.1690; 0.2150					
Percent correctly predicted	71.40					
Goodness of fit *p* value‡	0.245					

Notes. The multivariate regression models the probability of being female compared to being male. Coef.= regression coefficient; Std. Err.= standard error; OR = odds ratio; X^2 (*y*) refers to the Chi square test statistic and the degrees of freedom. ‡Hosmer and Lemeshow test used to assess the model's goodness of fit. Non-significant *p* value indicates adequate goodness of fit.
*Statistically significant at $p < 0.05$; **Statistically significant at $p < 0.01$.

Right-left rugae asymmetry is another area where our data confirm previous reports from non-numeric classification systems. In addition to the vast literature illustrating right-left rugae asymmetry with respect to shape, number, length and/or direction,[29,36-38] our data suggest that morphometrically the palatal rugae are asymmetrical. It must be emphasized that we deliberately excluded patients who presented with posterior crossbite and included only individuals representing the normal spectrum of maxillary/palatal growth, albeit in varying malocclusions. Although not all assessed variables exhibited asymmetry, our data suggest that palatal rugae symmetry is not the norm in the average individual. Although not directly comparable, a number of previous studies describing palatal rugae morphology have failed to show statistically significant differences between right and left sides with respect to shape, divergence or length categorization (primary, secondary, fragmentary).[34,39]

Our data underscore the variability of the palatal rugae and their potential use for sex determination. While not all subjects were correctly classified using our model, the results support the need to further explore the usefulness of palatal rugae dimensions

in sex prediction both separately and as an adjunct to palatal rugae morphological characteristics. Our work is also a first step towards establishing a Lebanese database of palatal rugae characteristics and dimensions with different samples to validate and build on the present findings. The utilization of three-dimensional technology to record measurements from digital maxillary casts is a well-established method with validated accuracy[40-42] and showed a high degree of reproducibility in our sample. The integration of morphometric measurements with the commonly used rugae classification systems should enhance the potential for the use of palatal rugae in sex prediction and accurate population comparisons.

CONCLUSION

1. Palatal rugae dimensions showed wide individual variability, right-left asymmetry, and a moderate potential for sex prediction. The general tendency for larger dimensions in males than females probably reflect parallel findings in dentofacial proportions.
2. Notwithstanding the importance of establishing initial data on palatal rugae in the Lebanese population, similar to findings in other Caucasian groups, the incorporation of morphometric measures as an adjunct to the commonly used rugae classification methods should enhance sex classification using the palatal rugae and facilitate comparability among populations.
3. The addition of palatal rugae to the repertoire of commonly used forensics identifiers is not meant to replace easier better established practices (fingerprints, DNA and dental records). However, at least in specific circumstances, palatal rugae may be the only recourse for identification.

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SECTION ANTHROPOLOGY

Palatal Rugae Morphology In An Adult Mediterranean Population

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ABSTRACT

Background: The use of the palatal rugae in forensic odontology is based on their unique and individual characteristics. Few studies have assessed the palatal rugae in Mediterranean populations and none in the Lebanese population. Objective: Assess the shape and other morphological features of the palatal rugae in a Lebanese adult population, and compare them with reported similar features in other populations. Materials and methods: Rugae characteristics were assessed on the maxillary dental casts of 217 non-growing subjects (95 males, 122 females, age 25.5 ± 7.6 years) according to guidelines established by Thomas and Kotze (1983) and Lysell (1955). The overall number of rugae and numbers of primary rugae (>5mm in length), secondary rugae (3-5mm) and fragmentary rugae (2-3mm) on either side were recorded. Rugae were classified according to shape, direction and presence of unification. Z-tests were used to compare the proportions between right and left sides and between genders. The mean numbers of rugae in each category were compared with independent samples t-tests between males and females; paired samples t-tests were employed to compare mean numbers of rugae in each category between right and left sides. The data were compared with published reports on other Mediterranean cohorts. Results: The average number of rugae was 7.7 per individual, 3.81 on the right and 3.89 on the left. Curved, wavy and straight rugae patterns were equally common (one third each). The spatial direction of most rugae (49.3%) was backward. Circular, non-specific and convergent rugae were rare (<2% each). Rugae numbers (total, primary, secondary, fragmentary) were symmetrical but shape, direction and the occurrence of convergence were asymmetrical ($p < 0.05$). None of the examined characteristics showed gender dimorphism. Tabulated comparisons disclosed the equality of rugae patterns as major differences with findings from other Mediterranean studies. Conclusions: The palatal rugae in the Lebanese population display shape distinct from other reported Mediterranean and non-Caucasian populations. Studies in large samples and primary comparisons with other Mediterranean populations are warranted.

KEYWORDS: Palatal rugae, morphology, Mediterranean, forensic odontology, human identification

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INTRODUCTION

The palatal rugae may be used in ascertaining an individual's identity when conventional forensic methods (fingerprints, DNA, dental records) prove inadequate for post-mortem identification. These structures comprise a series of transverse folds of mucosa located in the anterior region of the palate on either side of the median palatal raphe.[1] Protected by the teeth, lips, tongue and buccal pads of fat, the palatal rugae have been found to be highly resistant to the physical conditions accompanied by natural and artificial disasters (e.g. fires, chemicals and high-impact trauma) and have been shown to resist decomposition for up to seven days after death.[1-2]

When present, a ante-mortem record of the palatal rugae would enable accurate post-mortem identification in up 90 - 100% of cases.[3] Accordingly, researchers have increasingly attempted to assess palatal rugae morphology in various populations, focusing on specific features such as symmetry and gender differences, to better understand their potential in individual, gender and population identification. Classification systems categorize the rugae on such characteristics as length, shape, direction and the presence of unification or divergence.[4,5,6] The classifications of Lysell[7] and Thomas and Kotze[8] have been the most widely used in research of the palatal rugae, allowing comparative panels for ethnic specificity and racial disparities.[9-12] Regarding gender, research outcome is split between support[13-16] and absence[17-19] of gender dimorphism.

The evaluation of palatal rugae morphology in adult Mediterranean populations has been limited[12,16] and lacking in Lebanon, where the population is qualified as Caucasian. The aim of this study is to assess the morphology of the palatal rugae in a Mediterranean Lebanese adult population and to explore the presence of bilateral symmetry and gender dimorphism.

MATERIAL AND METHODS

This is a cross-sectional study on the pre-treatment orthodontic records of 217 subjects (95 males, 122 females, mean age 25.5 ± 7.6 years) who were selected from the database of patients at the American University of Beirut Medical Center. Included were maxillary dental casts deemed of high quality, taken of non-growing subjects (age > 16 years for females and >18 years for males) who had a complete set of fully erupted permanent teeth (excluding third molars), no posterior cross-bite and crowding < 2mm. Excluded were subjects with systemic disease, craniofacial anomalies, history of orthodontic treatment and/or surgical treatment involving the head and neck were excluded. The study was approved by the Institutional Review Board.

Maxillary dental casts were de-identified by research support personnel not directly involved in the investigation. The principal investigator performed all research procedures, starting with direct visual inspection of the palatal area on each maxillary dental cast, assessing and drawing with a pencil the palatal rugae, then classifying them according to the systems of Lysell[7] and Thomas and Kotze,[8] as described by Kapali et al.[21] (**Table 1, Fig1**).

Table 1. Classification criteria of palatal rugae

Criteria	Description
Length	- primary rugae (>5mm in length); - secondary rugae (3-5mm in length) - fragmentary rugae (2-3mm in length). *Rugae less than 2mm in length were discarded.*
Shape (Fig. 1A)	- curved: simple crescent shape that curves gently in the middle of the ruga - wavy: basic serpentine shape, or presence of slight curves at ruga origin or termination - straight: runs in straight line from origin to termination) - circle: forming a continuous definite ring) or non-specific (not conforming to any of the described shapes).
Angle formed between ruga and a line perpendicular to the median palatal raphe (MPR)- (Fig. 1B)	- forward-directed (positive angle formed with MPR perpendicular); - straight (parallel to MPR perpendicular) - backward-directed (negative angle formed with MPR perpendicular).
Presence of unification (Fig. 1C)	- absent (ruga has one origin and one termination) - diverging (immediate branching of the ruga from a common origin at the medial aspect) - converging (different origins that join in one termination at the lateral aspect).

The length stratification was performed directly on the dental casts; the actual lengths of the rugae were then compared for correspondence with the digital record derived from the scanned models. The visual categorization on length (primary, secondary, fragmentary) was compared with the digital length measures of corresponding rugae on 50 casts using the kappa statistics, which yielded a high correspondence coefficient. Thus, the frequencies of length categories defined on the dental casts were used in the statistical analyses.

Outcome measures: Descriptive statistics of the palatal rugae for each category of length, shape, direction and unification were generated. To provide for the possibility of comparisons with prior studies, we included two sets of outcome measurements:

1- within subjects: incidence of at least one palatal ruga in each category of classification within subjects, as well as the mean numbers of rugae for each classification category, with their respective standard deviations (SDs).
2- across subjects: the proportion relative to the total number of assessed rugae of the overall number of assessed rugae belonging to each morphological category (length, shape, direction and presence of unification).

Statistics: Z-tests for the differences between proportions were used to evaluate the differences in prevalence between right and left sides and between male and female subjects. The mean numbers of rugae in each classification category were compared between male and female subjects with independent t-tests; right/left differences were compared with paired samples t-tests.

Rugae measurements and characterizations were repeated by another investigator (R.H.) on 50 randomly selected casts. The repetitions included the recognition of shape as well as identification of landmarks that served to measure rugae length. Similarly, rugae in 50 randomly selected models were reclassified by the principal investigator (M.S.) at least 14 days after initial assessment. The repeated measures were evaluated with the two-way mixed effects intra-class correlations for absolute agreement on single measures to calculate both inter and intra-examiner errors. The data were computed through the Statistical Package for Social Sciences (IBM SPSS®, version 20.0, Armonk, NY) and Stata Statistical Software (version 11.1, College Station, TX). Statistical significance was set at 0.05.

RESULTS

Reliability of repeated measurements within and between operators was high. The intraclass correlation coefficients in measuring the rugae length varied from 0.897 to 0.996 for the intra-rater and from 0.865 to 0.991 for the inter-rater reliability. When recognizing the different categories of shapes, direction and unification, the intra-rater reliability ranged between 0.892 and 0.968 and between 0.875 and 0.977 for the inter-rater reliability.

At both the individual and total sample assessment levels, the palatal rugae generally exhibited lateral symmetry with respect to length category, as the mean numbers of primary, secondary and fragmentary rugae were similar on both sides (**Tables 2, 3**). Symmetry was also noted for the presence and mean number of divergent rugae and rugae without unification. On the other hand, rugae shape, direction, and convergent rugae were asymmetrical.

At the individual level, the mean number of rugae per individual was 3.81 ± 0.83 on the right and 3.89 ± 0.86 on the left. The majority of the rugae were primary (100% incidence), 3.23 ± 0.52 and 3.29 ± 0.56 per individual on the right and left sides, respectively **(Table 2)**.

Table 2. Frequency of number of palatal rugae (1 to 7) as described by Thomas and Kotze (n = 217)

	Incidence n (%)		No. per individual Mean (SD)		Total no. rugae n (%)		
	Right	Left	Right	Left	Right	Left	Total
Number							
First	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Second	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Third	217 (100)	217 (100)			217 (26.3)	217 (25.7)	434 (26)
Fourth	127 (58.5)	133 (61.2)	3.81	3.89	127 (15.4)	133 (15.8)	260 (15.6)
Fifth	40 (18.4)	48 (22.1)	(0.83)	(0.86)	40 (4.8)	48 (5.7)	88 (5.2)
Sixth	7 (3.2)	10 (4.6)			7 (0.8)	10 (1.2)	17 (1.0)
Seventh	1 (0.5)	2 (0.9)			1 (0.1)	2 (0.2)	3 (0.2)
Total	217 (100)	217 (100)			826 (100)	844 (100)	1670 (100)

The most commonly occurring shapes were curved, wavy and straight. On average, each subject had around one curved, wavy and straight ruga on each side of the palate (mean values ranging between 1.13 ± 0.95 and 1.4 ±1.06) **(Table 3)**. The incidence and mean numbers of wavy, circular and nonspecific rugae were similar on both sides of the palate. However, the mean

number of curved rugae was greater on the left (p = 0.001) and the mean number of straight rugae was conversely larger on the right (p = 0.04).

With respect to rugae direction (**Table 3**), the right side of the palate included a larger mean number of forward-directing (0.93 ± 1.05 compared to 0.45 ± 0.88 on the left, $p < 0.001$) and straight rugae (1.44 ± 1.09 compared to 1.08 ± 1.14 on the left, $p < 0.001$), whereas the mean number of backward-directing rugae was greater on the left side of the palate (2.35 ± 1.5 compared to 1.44 ± 1.29 on the right, $p < 0.001$). A similar trend was noted for the incidence of palatal rugae direction (p <0.001, 0.001 and 0.003, in forward, straight and backward categories, respectively).

The incidence of rugae without unification was almost universal, 99.5% and 100% on the right and left sides, respectively. Convergent forms were the least occurring, and also asymmetrical in number and incidence (**Table 3**).

When the total of 1670 rugae across subjects was assessed, all subjects were found to have at least 3 rugae on either side of the palate (incidence = 100 %). The incidence of additional rugae gradually decreased with increasing numbers of rugae, less than 5% of the subjects possessing more than 5 rugae on either side of the palate. Fewer than one third of the subjects possessed secondary rugae (27.2% incidence on the right and 29.5% incidence on the left) and around one fifth possessed fragmentary rugae (23.5% on the right and 17.1% on the left) (**Table 2**).

The most occurring shapes were nearly equally the curved (33.1%), wavy (32.6%) and straight (33.7%) rugae, each of them representing around one third of the total number of assessed rugae (**Table 3**). The circular and nonspecific rugae combined formed less than 1% of all counted rugae. The frequency rates per side were also similar.

Backward-oriented rugae were the most common (nearly 50%), equal to the rates of forward-leaning (17.9%) and straight (32.8%) rugae combined. While the majority of the latter were more frequent on the right side, the backward-directed were more common on the left side (p<0.001).

The incidence of rugae without unification was highest (88.8%), equal on right and left sides. Rugae that were either divergent or convergent formed 11.2% of all assessed rugae, convergent rugae reflecting an especially rare occurrence (1.8% of all rugae) (**Table 3**).

None of the assessed morphological rugae characteristics (mean number, various shapes, direction, and unification) exhibited gender dimorphism (p = 0.128 – 0.850; **Table 4**). When assessed for symmetry, the same patterns described above for within and across subjects were observed. In both genders, asymmetry was noted among curved, forward/straight/backward directed, and convergent rugae (Table **5,6**).

Table 3. Differences in palatal rugae characteristics between right and left sides, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual			Total no. rugae			
	Right n (%)	Left n (%)	p^a	Right Mean (SD)	Left Mean (SD)	p^b	Total n (%)	Right n (%)	Left n (%)	p^a
Length										
Primary	217 (100)	217 (100)	-	3.23 (0.52)	3.29 (0.56)	0.19	1414 (84.7)	700 (84.7)	714 (84.6)	0.955
Secondary	59 (27.2)	64 (29.5)	0.595	0.31 (0.54)	0.38 (0.66)	0.214	149 (8.9)	67 (8.1)	82 (9.7)	0.251
Fragmentary	51 (23.5)	37 (17.1)	0.097	0.27 (0.52)	0.22 (0.53)	0.334	107 (6.4)	59 (7.2)	48 (5.7)	0.212
Shape										
Curved	157 (72.4)	178 (82)	0.017*	1.13 (0.95)	1.41 (0.99)	0.001**	552 (33.1)	245 (29.7)	307 (36.4)	0.004**
Wavy	159 (73.3)	171 (78.8)	0.180	1.26 (1.01)	1.25 (0.9)	0.917	544 (32.6)	273 (33.0)	271 (32.1)	0.695
Straight	170 (78.3)	160 (73.7)	0.262	1.40 (1.06)	1.20 (1.02)	0.040*	563 (33.7)	303 (36.7)	260 (30.8)	0.011*
Cirvular	5 (2.3)	5 (2.3)	1	0.02 (0.15)	0.02 (0.15)	1.000	10 (0.6)	5 (0.6)	5 (0.6)	1.000
Nonspecific	0 (0)	1 (0.5)	0.297	0 (0)	0 (0.07)	0.318	1 (0.1)	0 (0)	1 (0.1)	0.363
Direction										
Forward	120 (55.3)	63 (29)	<0.001**	0.93 (1.05)	0.45 (0.88)	<0.001**	299 (17.9)	201 (24.3)	98 (11.6)	<0.001**
Straight	168 (77.4)	132 (60.8)	0.001**	1.44 (1.09)	1.08 (1.14)	<0.001**	548 (32.8)	313 (37.9)	235 (27.9)	<0.001**
Backward	160 (73.7)	185 (85.3)	0.003**	1.44 (1.29)	2.35 (1.5)	<0.001**	823 (49.3)	312 (37.8)	511 (60.5)	<0.001**
Unification										
Absent	216 (99.5)	217 (100)	0.297	3.39 (1.04)	3.45 (1.09)	0.487	1483 (88.8)	735 (89.0)	748 (88.6)	0.796
Divergent	81 (37.3)	65 (30)	0.108	0.40 (0.54)	0.33 (0.54)	0.124	157 (9.4)	86 (10.4)	71 (8.4)	0.161
Convergent	5 (2.3)	24 (11.1)	0.001**	0.02 (0.15)	0.12 (0.33)	<0.001**	30 (1.8)	5 (0.6)	25 (3)	<0.001**

[a]Z- test; [b]paired t test; *significant, p<0.05; **significant, p<0.01.

DISCUSSION

This investigation is the first to describe palatal rugae morphology in the Lebanese population, typically a Caucasian population, and one of very few describing the rugae in the Mediterranean basin.[12,16]

Our data complement the literature defining palatal rugae in different ethnic and racial backgrounds. Comparisons with other studies are limited by our inclusion of only English publications, and the prevalence of studies from Asian populations. Nevertheless, the methods used in these studies originated from classifications of subjects of Caucasian origins, underlying the fact that rugae have universal characteristics.[7]

Table 4. Differences in palatal rugae characteristics between males and females, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual		
	Males (n = 95)	Females (n = 122)		Males (n = 95)	Females (n = 122)	
	n (%)	n (%)	p^a	Mean (SD)	Mean (SD)	p^b
Length						
Primary	95 (100.0)	122 (100.0)	-	6.57 (0.87)	6.48 (0.73)	0.393
Secondary	26 (27.4)	38 (31.1)	0.553	0.67 (0.90)	0.7 (0.88)	0.850
Fragmentary	20 (21.1)	31 (25.4)	0.459	0.41 (0.64)	0.56 (0.77)	0.128
Shape						
Curved	80 (84.2)	98 (80.3)	0.459	2.67 (1.55)	2.44 (1.44)	0.258
Wavy	74 (77.9)	97 (79.5)	0.775	2.37 (1.32)	2.61 (1.46)	0.200
Straight	72 (75.8)	98 (80.3)	0.425	2.57 (1.53)	2.61 (1.51)	0.824
Cirvular	2 (2.1)	3 (2.5)	0.846	0.04 (0.25)	0.05 (0.25)	0.837
Nonspecific	0 (0)	1 (0.8)	0.382	0 (0)	0.01 (0.09)	0.379
Direction						
Forward	53 (55.8)	70 (57.4)	0.813	1.28 (1.50)	1.45 (1.67)	0.447
Straight	72 (75.8)	96 (78.7)	0.612	2.38 (1.57)	2.64 (1.82)	0.260
Backward	85 (89.5)	100 (82.0)	0.122	3.99 (2.15)	3.64 (2.34)	0.258
Unification						
Absent	95 (100)	122 (100)	-	6.72 (1.51)	6.93 (1.84)	0.368
Divergent	38 (40)	43 (35.2)	0.468	0.78 (0.79)	0.68 (0.9)	0.4
Convergent	13 (13.7)	11 (9)	0.273	0.16 (0.40)	0.12 (0.4)	0.52

[a]Z test; [b]Independent samples t test; *significant, p<0.05; **significant, p<0.01

Table 5. Differences in palatal rugae characteristics between right and left side in females, according to Thomas and Kotze classification (n = 122)

	Incidence			Number per individual		
	Right	Left		Right	Left	
	n (%)	n (%)	p^a	Mean (SD)	Mean (SD)	p^b
Length						
Primary	122 (100.0)	122 (100.0)	-	3.21 (0.55)	3.26 (0.50)	0.469
Secondary	34 (27.9)	38 (31.1)	0.584	0.30 (0.49)	0.40 (0.68)	0.139
Fragmentary	31 (25.4)	23 (18.9)	0.222	0.31 (0.58)	0.25 (0.57)	0.391
Shape						
Curved	86 (70.5)	98 (80.3)	0.076	1.09 (0.97)	1.35 (0.96)	0.026*
Wavy	92 (75.4)	97 (79.5)	0.444	1.28 (1.00)	1.34 (0.96)	0.629
Straight	98 (80.3)	92 (75.4)	0.357	1.43 (1.03)	1.19 (1.01)	0.056
Cirvular	3 (2.5)	3 (2.5)	1.000	0.02 (0.16)	0.02 (0.16)	1
Nonspecific	0 (0.0)	1 (0.8)	0.322	0.00 (0.00)	0.01 (0.09)	0.319
Direction						
Forward	70 (57.4)	37 (30.3)	<0.001**	0.95 (1.06)	0.50 (0.95)	<0.001**
Straight	96 (78.7)	70 (57.4)	<0.001**	1.51 (1.12)	1.13 (1.26)	0.007**
Backward	84 (68.9)	100 (81.9)	0.018*	1.36 (1.33)	2.28 (1.59)	<0.001**
Unification						
Absent	121 (99.2)	122 (100.0)	0.322	3.42 (1.11)	3.51 (1.17)	0.460
Divergent	43 (35.2)	33 (27.0)	0.167	0.38 (0.55)	0.30 (0.53)	0.171
Convergent	3 (2.5)	11 (9.0)	0.029*	0.02 (0.16)	0.10 (0.33)	0.012*

[a]Z- test; [b]paired t test; *significant, p<0.05; **significant, p<0.01

Table 6. Differences in palatal rugae characteristics between males and females, according to Thomas and Kotze classification (n = 217)

	Incidence			Number per individual		
	Males (n = 95)	Females (n = 122)		Males (n = 95)	Females (n = 122)	
	n (%)	n (%)	p^a	Mean (SD)	Mean (SD)	p^b
Length						
Primary	95 (100.0)	122 (100.0)	-	6.57 (0.87)	6.48 (0.73)	0.393
Secondary	26 (27.4)	38 (31.1)	0.553	0.67 (0.90)	0.7 (0.88)	0.850
Fragmentary	20 (21.1)	31 (25.4)	0.459	0.41 (0.64)	0.56 (0.77)	0.128
Shape						
Curved	80 (84.2)	98 (80.3)	0.459	2.67 (1.55)	2.44 (1.44)	0.258
Wavy	74 (77.9)	97 (79.5)	0.775	2.37 (1.32)	2.61 (1.46)	0.200
Straight	72 (75.8)	98 (80.3)	0.425	2.57 (1.53)	2.61 (1.51)	0.824
Cirvular	2 (2.1)	3 (2.5)	0.846	0.04 (0.25)	0.05 (0.25)	0.837
Nonspecific	0 (0)	1 (0.8)	0.382	0 (0)	0.01 (0.09)	0.379
Direction						
Forward	53 (55.8)	70 (57.4)	0.813	1.28 (1.50)	1.45 (1.67)	0.447
Straight	72 (75.8)	96 (78.7)	0.612	2.38 (1.57)	2.64 (1.82)	0.260
Backward	85 (89.5)	100 (82.0)	0.122	3.99 (2.15)	3.64 (2.34)	0.258
Unification						
Absent	95 (100)	122 (100)	-	6.72 (1.51)	6.93 (1.84)	0.368
Divergent	38 (40)	43 (35.2)	0.468	0.78 (0.79)	0.68 (0.9)	0.4
Convergent	13 (13.7)	11 (9)	0.273	0.16 (0.40)	0.12 (0.4)	0.52

[a]Z test; [b]Independent samples t test; *significant, p<0.05; **significant, p<0.01

The mean number of palatal rugae per individual recorded in our sample is comparable to averages reported in Caucasian, European and Middle Eastern populations (Swedes[7], Central Europeans[7], Australian[21], Bosnian[16], Jordan[27], Saudi Arabian[22]), lower than those from Asian and African countries (India, Sudan[23]; **Table 7**). An arbitrary cut-off between the higher and lower frequencies may be set at a mean of 9 total rugae per individual, only as a guideline to be tested in future research.[4,24,25]

In the majority of the various studies, regardless of geographic origin, one or two dominant palatal rugae shapes appear characteristic of the population, such as the prevalence of curved and straight patterns in Bosnia and Herzegonina[15], or the wavy pattern in Jordan and Serbia.[27,28] However, in the assessed Lebanese sample, the three major rugae forms (curved, wavy and straight) were remarkably equally prevalent. This rare occurrence has only been recorded by a study of an Indian population in Central Kerala.[18] Yet, we join the majority of populations in the infrequent presence of unification (convergence or divergence), with the exception of Nigerians where mean numbers of diverging and converging rugae per individual were many folds greater.[21, 26] Our data confirm earlier studies that illustrate the asymmetric nature of the palatal rugae, including rugae number, length, shape and/or direction.[17,27,29-31] The fact that rugae symmetry does not seem to be the norm in the average individual may be a major discriminant for the individual “finger print” nature of palatal rugae. Nonetheless, despite side-related differences in rugae form

and direction, palatal rugae number appears to be symmetric, a finding supported by some previous studies[19,32] but not others.[29,31] It must be emphasized that patients who presented with posterior crossbite were deliberately excluded from our sample to restrict inclusion to individuals representing the normal spectrum of transverse maxillary/palatal growth.

Table 7. Comparison of selected studies assessing palatal rugae morphology in various populations

Study (year)	Population (n)	Total/Primary/ secondary/ fragmentary (right+left) *(mean number)*	Curved/wavy /straight *(% or mean number)*	No unification/ diverging/converging *(% or mean number)*
Alani et al. (2016)[18]	Indian (82)	*/*/*/*	31.7/31.7/34.2	*/*/*
Azab et al. (2015)[12]	Egyptian (108)	*/7.6/1.3/1.0	Means: 1.9/3.2/2.2	Means: */0.6/1.5
Babu et al. (2013)[25]	Indian (100)	M: */7.5/2.8/1.9 F: */6.9/3.4/2.6	Means 1.6/4.8/3.9 Means: 1.5/4.7/3.8	*/*/*
Byatnal et al. (2014)[33]	Indian (100)	*/*/*/*	% M: 12/74/12.8 % F: 12.4/72.4/14	Unification present in: M: 1.2% F: 1.2%
Chopra et al. (2013)[13]	Indian (100)	M: */5.6/2.5/* F: */5.4/2.6/*	Means M: 2.2/2.7/1.0 Means F: 3.2/2.1/1.0	Means M: */0.4/0.9 Means F: */0.7/0.5
Dawasaz & Dinkar (2003)[34]	Indian (120)	11.3/*/*/*	%: 12.6/46.0/3.0	%: 97.6/*/*
Elamin et al. (2015)[23]	Sudan (300)	M: 11.2/8.2/1.8/1.9 F: 11.5/8.6/1.9/1.0	Means M: 1.4/4.6/2.8 Means F: 1.4/ 5.6/2.4	*/*/*
Fahmi et al. (2001)[22]	Saudi Arabia (120)	M: 7.3/3.7/1.3/* F: 7.2/3.6/1.6/*	% M: 26.1/45.4/12.0 % F: 24.0/43.7/14.1	% M: 89.6/1.8/8.6 % F: 83.7/1.2/15.1
Hermosilla et al. (2009)[35]	Chilean (120)	*/*/*/*	%: 27.0/43.0/14.9	*/*/*
Ibeachu et al. (2014)[26]	Nigerian, Igbo and Ikwerre (140)	*/*/*/*	% Males: Ikwerre: 45.1/35.6/9.9 Igbo: 27.9/51.1/6.1 % Females: Ikweree: 34.3/40.5/11.8 Igbo: 26.1/59.9/4.8	Mean M: 1: */3.9/2.1 2: */5.1/3.2 Mean F: 1: */6.2/1.9 2: */2.4/1.6
Kapali et al. (1997)[21]	Australian Caucasian (220) and Australian Aboriginal (110)	Caucasian: M: 8.6/*/*/* F: 8.6/*/*/* Aboriginal: M: 10/*/*/* F: 9.8/*/*/*	Caucasian: %: 23.2/55.8/3.6 Aboriginal: %: 25.8/40.6/15.2	Unification present in: Caucasian: 15.6% Aboriginal: 13.9%
Lysell et al. (1955)[7]	Central Europeans (100) and Swedes (100)	Central Europeans: M: 8.5/*/*/* F: 8.7/*/*/* Swedes: M: 8.9/*/*/* F: 8.2/*/*/*	Swedes: M and F: Approx. 2/3 are curved/wavy	Swedes: Means M: */0.1/0.2 Means F: */0.1/0.2
Madhankumar et al. (2013)[24]	Indian (135)	M: 9.5/7.7/1.8/* F: 10.2/8.2/2.0/*	Means M: 2.3/2.0/4.8 Means F: 1.7/ 2.0/5.1	*/*/*
Manjunath et al. (2012)[30]	Indian (63)	M: 8.2/*/*/* F: 8.4/*/*/*	Means M: 1.8/5.7/1.2 Means F: 1.9/5.3/1.8	*/*/*
Mathew et al. (2016)[4]	Indian (50)	M: 10.9/7.6/2.4/0.8 F: 11.2/8.3/2.0/1.0	Means M: 5.0/2.8/2.7 Means F: 5.2/1.6/3.9	*/*/*
Muhasilovic et al. (2016)[16]	Bosnia and Herzegovina (250)	M: 5.8/5.3/0.5/0.02 F: 5.9/5.1/0.7/0.02	Means M: 1.5/3.2/0.8 Means F: 1.5/3.0/1.0	*/*/*
Shetty & Premalatha (2011)[36]	Indian (100)	*/*/*/*	%: 20.8/59.6/16.4	*/*/*
Present study	Lebanese (217)	7.7/6.5/0.7/1.1	Means: 2.5/2.5/2.6 %: 33.1/32.6/33.7	Means: 6.8/0.7/0.1 %: 88.8/9.4/1.8

Notes. M: males; F: females.

* Morphological feature not assessed/reported by referenced study

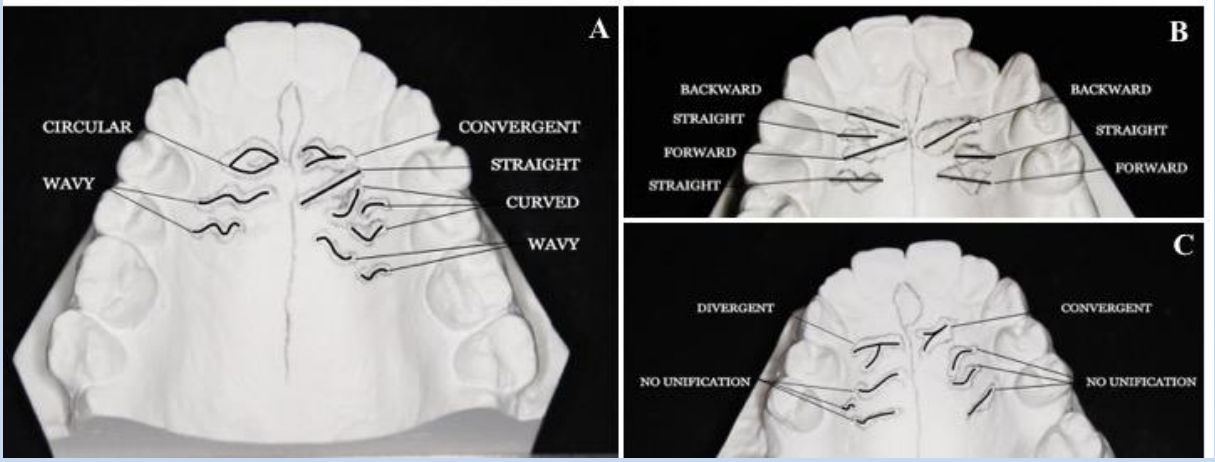

Fig. 1: Classification of palatal rugae based on shape (A), direction (B) and unification (C)

Unlike research on different populations that illustrates gender dimorphism in various traits, especially palatal rugae shapes and unification patterns,[4,12,13,22-24] none of the characteristics assessed in our sample exhibited any significant differences between males and females. Although more scarce, a few studies carried out in India[2], Bosnia and Herzegovina[16], Serbia[28] and Jordan[27] have also noted lack of dimorphism, while one other study carried out in the Mediterranean region did report gender differences.[12]

The above-delineated differences across populations suggest that findings may be specific to certain populations. The scarcity of research in the Mediterranean regions invites additional investigation. Despite the substantial size of our sample, further research shall help validate our findings, which represent a first step towards building a Lebanese database of palatal rugae morphology and a distinct component in the overall representation of the palatal rugae in Mediterranean populations.

Conclusions

1. Our data underscore the variability in palatal rugae morphology across different populations and within individuals and are a valuable addition to the scarce literature on palatal rugae morphology in Caucasian Mediterranean populations.
2. The prevalence of palatal rugae shapes did not differ between genders in the Lebanese population, a distinct finding compared to other Mediterranean, African and Asian populations.
3. The comparisons between populations indicate the importance of generating norms specific to racial, ethnic, or geographic groups, thus the importance of future investigation in larger samples and primary comparisons with other Mediterranean populations.

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I-O-F-O-S

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SECTION ANTHROPOLOGY

Association Among Geometric Configurations Of Palatal Rugae

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The authors declare that they have no conflict of interest.

ABSTRACT

Background: The associations between the length and morphological shape-related characteristics of palatal rugae have not been fully explored. Objective: We aimed to assess the possible association among various geometric configurations of the palatal rugae in an adult population. Materials and methods: The maxillary dental casts of 217 non-growing subjects (95 males, 122 females, mean age 25.5±7.6 years) were scanned (laser scanning system Perceptron ScanWorks® V5) and digitized for linear measurements. The casts were also surveyed for visual categorization into curved, wavy, straight and other topographical forms, along with spatial direction of the rugae and the presence of unification. The rugae were categorized as primary, secondary, and fragmentary based on their lengths (>5mm, 2-3mm, <2mm, respectively). Chi square and one-way ANOVA and post-hoc tests were used to compare the palatal rugae groupings. Results: Primary and backward-directed rugae prevailed in the total sample (84.7% and 49.3%, respectively). Wavy form was dominant among primary lengths, while straight form was associated with the shorter secondary and fragmentary groups (p=0.0042). Absence of unification was the norm (88.8%). Conclusions: Associations of length and shape characteristics among palatal rugae combine wavy patterns with increased length, and straight forms with shorter folds. These features contribute to the definition of ruga individuality in combination rather than separately.

KEYWORDS: Forensic odontology, human identification, palatal rugae, morphology, dimensions, digital models

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INTRODUCTION

Because of fingerprint-like individuality, relative temporal stability, and resistance to external physical and chemical conditions and delayed post-mortem decomposition,[1,2] the palatal rugae have stirred much research in forensic odontology and post-mortem identification.[3-5] Major work has been committed to research in extensive details the morphology and topography of these structures. Their reported stability has been recognized by orthodontic researchers who used the mucosal folds in dental cast superimposition to assess tooth movement.[6-8] In this perspective, more accurate acquisition of palatal dimensions through 3-dimensional digital scanning technology has prompted the development of more reliable digital palatal rugae superimposition techniques.[9-11]

Morphometric evaluations of the rugae have focused on dimensions (e.g. categorization on length or direct length measurements, distances between ruga bands, angulation of rugae) and shapes (e.g. types, unification).[12,13] Various conclusions have been reached from these studies regarding prevalence of types and categories, gender differences, and symmetry.[14-21] Although some findings were not concordant either because of ethnic/racial differences or sampling methodology,[20] particularly regarding the distribution of shape categories (curved, wavy, and straight), all converged on the individuality of the rugae, strengthening their potential forensic use.

While dimensions and shapes have been investigated separately, we hypothesized that they may be associated, such as curvy or wavy rugae being longer than the straight structures. Accordingly, the aim of this study was to assess possible associations between the dimensions and morphology of the palatal rugae in an adult population.

MATERIAL AND METHODS

The study sample consisted of the pre-treatment maxillary dental casts of 217 non-growing subjects (95 males, 122 females, mean age 25.5 ± 7.6 years) recruited from the database of patients treated in the orthodontic division at the American University of Beirut Medical Center. Strict criteria were followed for a-inclusion: casts deemed of high quality from a set of fully erupted permanent teeth, no posterior cross-bite, crowding <2mm, and b- exclusion: subjects with systemic disease, craniofacial anomalies, history of orthodontic treatment and/or surgical treatment involving the head and neck. The study was approved by the Institutional Review Board.

De-identification of maxillary and mandibular dental casts preceded analysis by research support personnel who were not directly involved in the project. The principal investigator (MS) performed all remaining procedures. Dental casts were scanned through the laser scanning system Perceptron (ScanWorks® V5) that included a scanning probe attached to the Cimcore Infinite 2.0 (Seven axis) CMM Arm, complemented by a point cloud handling software (IM Inspect from PolyWorks, InnovMetric Software, Quebec, Canada).

Before saving the 3-dimentsional images for subsequent analysis, they were carefully scrutinized for sufficient surface profile for all relevant anatomical structures. The saved data files were processed (through IMInspect software from PolyWorks®) to generate the polygonal model derived from the point cloud for all anatomical structures at point-to-point resolutions up to 12µm. The same software was used to measure and record the palatal rugae measurements.

The anterior (first), middle (second) and posterior (third) rugae were numbered 1, 2, and 3, respectively, and the right and left

sides identified as R and L (Fig. 1). The following categorizations were generated, after Lysell[7] and Thomas and Kotze,[8] as described by Kapali et al.[21]:

1. Length, which was first estimated for each ruga then measured through correspondence with digital scans on the scanned casts: primary rugae (>5mm in length); secondary rugae (3-5mm in length) and fragmentary rugae (2-3mm in length). Rugae less than 2mm in length were discarded.
2. Ruga direction, based on the angle formed between ruga and a line perpendicular to the median palatal raphe (MPR)- (Fig. 2): forward-directed (positive angle formed with MPR perpendicular); straight (parallel to MPR perpendicular) or backward-directed (negative angle formed with MPR perpendicular).

Following direct visual inspection, the palatal rugae were drawn with a pencil, then classified (also according to Lysell[7] and Thomas and Kotze[8]). Based on shape, the rugae were stratified as (Fig. 3A): curved (simple crescent shape gently bending in the central zone of the ruga); wavy (basic serpentine shape, or presence of slight curves at ruga origin or termination); straight (runs in straight line from origin to termination); circle (forming a continuous definite ring) or non-specific (not conforming to any of the described shapes). Absent unification (ruga has one origin and one termination), the rugae were described as (Fig. 3B): diverging (immediate branching of the ruga from a common origin at the medial aspect) or converging (different origins that join in one termination at the lateral aspect).

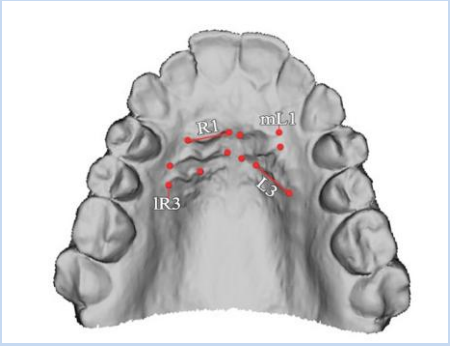

Fig. 1: Rugal digitization and linear dimensions. The most medial (m: mR1/mL1, mR2/mL2, mR3/mL3) and most lateral (l: lR1/lL1, lR2/LL2, lR3/lL3) points were digitized. The lengths of the rugae on right and left sides (R1, R2, R3, L1, L2, L3) were measured from most medial to most lateral points.

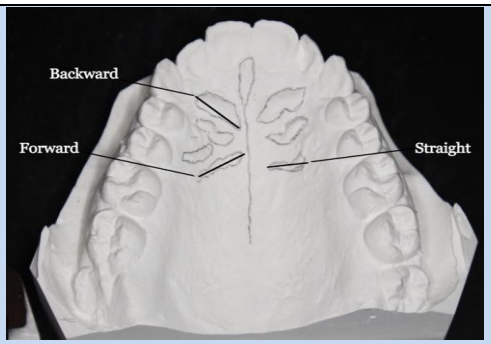

Fig. 2: Description of rugae direction

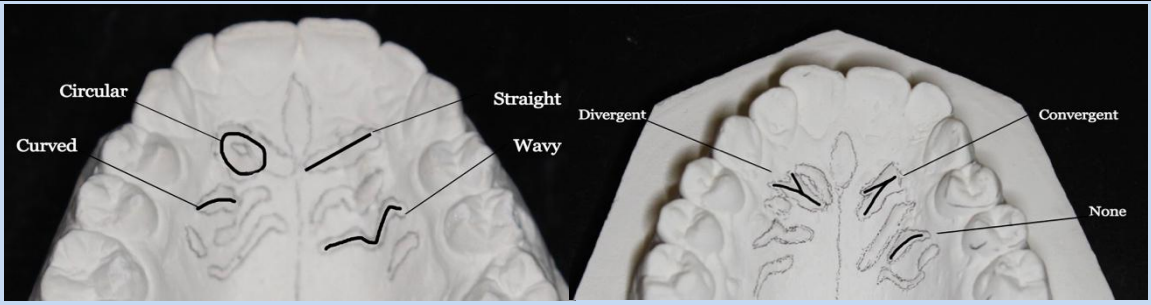

Fig. 3: Palatal rugae classified on shape (A) and unification (B)

The visual classification on length (primary, secondary, fragmentary) was compared with the digital length measures of corresponding rugae (n=350) on 50 casts through kappa statistics, resulting in a kappa coefficient equal to 0.96. Accordingly, the measurements gathered from the visual inspection were computed in the statistical analyses.

The dimensional data were computed within each classification group. Associations between shape categories (curved, wavy, straight, circular, non-specific) and length groups (primary, secondary and fragmentary) were evaluated with the chi-square test. Analyses of variance were applied to determine differences within the length subgroups. Both analyses were followed by a post-hoc analysis with Bonferroni correction to determine statistically significant comparisons.

All measurements (distances) and assessments (shapes) were repeated on 50 randomly selected dental casts at least 14 days after the initial analysis. To evaluate inter-rater reliability, similar computations were conducted on 50 randomly selected models by another investigator (RH). The repeated measures were evaluated with the two-way mixed effects intra-class correlations for absolute agreement on single measures. Data were processed using the Statistical Package for Social Sciences (IBM SPSS®, version 20.0, Armonk, NY) and Stata Statistical Software (version 11.1, College Station, TX). Statistical significance was set at 0.05.

RESULTS

The intraclass correlation coefficients gauging reliability of repeated length measurements within and between operators were high: $0.897<r<0.996$ for the intra-rater computations; $0.865<r<0.991$ for the inter-rater values. For repeated measures of the various shapes, direction and unification characteristics, the ranges were $0.892<r<0.968$ (intra-rater) and $0.875<r<0.977$ (inter-rater).

The prevalence of primary rugae was overwhelming (nearly 85%) compared to the secondary (~8%) and fragmentary (~6%) lengths. However, within each of these groups, the distribution of shape differed significantly (Table 1): nearly equal (about 1/3) curved, wavy and straight in the primary group, but greater percentages of straight in the secondary (49%) and fragmentary (~62%) groups. Within the shape groups, the wavy form was mostly associated with the primary length, the straight pattern mostly with the fragmentary then the secondary categories, whereas the curved rugae were in approximate proportions among the primary (34.5%), secondary (27.2%) and fragmentary (23.1%) types. When secondary and fragmentary forms were pooled (as the rugae shorter than 5mm) and compared with the primary group (rugae >5mm), the same conclusions were confirmed: predominant associations were

between primary and wavy (to a lesser extent curved), and between shorter and straight rugae.

The prevalence of the backward-directed rugae was the highest in the primary, secondary and fragmentary groups. However, in the post-hoc test the rugae in straight direction in fragmentary groupings composed the only statistically significant association (Table 1). Unification was absent in the greatest majority of rugae ($p<0.001$).

Table 1. Association between rugae length categories and other morphological characteristics, according to Thomas and Kotze classification (n =1674)

	1		2		3		A		4	B	
	Primary		Secondary		Fragmentary				< 5 mm	Chi-Square	
	n 1419	% 84.8	n 151	% 9	n 104	% 6.2	Chi-square		n 255	% 15.2	
	n (%)		(n (%)		n (%)		χ^2	*p*	n (%)	χ^2	*p*
Shape											
Curved n=554 (33.1%)	489 (34.5)		41 (27.2)		24 (23.1)		65.81	<0.001	65 (25.5)	60.5	<0.001$^{\mp}$
Wavy n=545 (32.6%)	494 (34.8)*		36 (23.8)		15 (14.4)*				51 (20)*		
Straight n=564 (33.7%)	425 (30)*		74 (49)*		65 (62.5)*				139 (54.5)*		
Circular n=10 (0.6%)	10 (0.7)		0 (0)		0 (0.0)				0 (0.0)		
Nonspecific n=1 (0.06%)	1 (0.1)		0 (0)		0 (0.0)				0 (0.0)		
Direction											
Forward n=299 (17.9%)	249 (17.5)		28 (18.5)		22 (21.2)		9.561	0.049	50 (19.6)	5.13	0.077
Straight n=549 (32.8%)	481 (33.9)		48 (31.8)		20 (19.2)*				68 (26.7)		
Backward n=826 (49.3%)	689 (48.6)		75 (49.7)		62 (59.6)				137 (53.7)		
Unification											
Absent n=1487 (88.8%)	1234 (87)*		149 (98.7)*		104 (10)*		32.86	<0.001	253 (99.2)*	32.74	<0.001$^{\mp}$
Divergent n=157 (9.4%)	155 (10.9)*		2 (1.3)*		0 (0)*				2 (0.8)*		
Convergent n=30 (1.8%)	30 (2.1)		0 (0)		0 (0)				0 (0)		

*statistically significant after Bonferroni correction; $^{\mp}$ Fisher's Exact Test
A- Chi-square test for associations among variables in columns 1, 2, 3.
B- Chi-square test for associations between variables in column 1 (primary rugae) and column 2 (combined secondary and fragmentary rugae from columns 2 and 3).

In a comparison of the lengths in the various shapes within the largest group of primary rugae, the wavy form was the longest on average (11.17+2.59 mm), followed by the curved (10.04+2.34 mm) then the straight configurations (9.75+2.39

mm); statistically significant differences were noted between the wavy and both curved and straight folds (Table 2).

The multiple regression showing associations between rugae form and other morphological features revealed that the variables rugae length, direction and unification collectively were significantly associated with rugae shape (p<0.001)- Table 3. However, these morphological features only differentiated the wavy from the curved form; all comparisons between the straight and curved patterns were not significant (p>0.05). The following equation describes the relative log odds of rugae being wavy compared to them being curved:

$$\text{Ln}\frac{p\,(wavy)}{p\,(curved)} = -1.516 + 0.188\,length - 0.132straight - 0.937backward - 0.601divergent - 0.819\,convergent$$

Increasing length was positively associated with greater likelihood of wavy rather than curved patterns, controlling for both rugae direction and the presence of unification (p<0.001). The odds of wavy rugae compared to curved decrease in backward rugae compared to forward direction rugae (p<0.001), and in divergent rugae compared to rugae without unification (p=0.009).

Table 2. Comparison of rugae length among the various shapes within the primary rugae (>5mm) group

Shape	n	Mean	SD	Curved vs Wavy	Curved vs Straight	Wavy vs Straight
Curved	427	10.04	2.34	<0.001*	0.306	<0.001*
Wavy	389	11.17	2.59			
Straight	344	9.75	2.39			

*Statistically significant, p<0.01

DISCUSSION

We report associations heretofore not clearly identified in the rich literature available on palatal rugae:

1. the paramount majority of rugae (nearly 85%) are primary (>5mm in length), as also reported in prior studies[14]; however, they were equally distributed among curved, wavy and straight in our sample. This disparity may be related to either the populations studied or methodological differences.
2. Wavy forms prevailed among the primary rugae; straight patterns are predominant in the lesser groups of secondary and fragmentary forms, understandably reflecting the fact that shorter rugae have less curves or waves. This novel contribution may relate to the specifics of the studied sample, or possibly generalized through various populations, thus possibly related to more genetic influence. Focused research is needed in this perspective.
3. Backward-directed rugae are most prevalent among all length categories of rugae.
4. Rugae are more likely to be curved if backward directed and if without unification.

Previous studies did not evaluate the associations between direction and length, thus investigations in other populations

may provide a basis for future comparisons.

These observations essentially underscore the association of form and length, and form and direction, despite the prevalence of variability of arrangements among mainly the 3 first rugae. Accordingly, individuality may be summed up in the relationship between shape and length, rather than each of these features separately. Several rugoscopy studies have pointed out the prevalence of primary rugae length

Table 3. Multiple logistic regression showing associations between shape and other morphological features, according to Thomas and Kotze classification (n = 1160)

Shape	Coef.	Std. Err.	95% CI	*p* value
Curved	(base outcome)			
Wavy				
Constant	-1.516	0.360	[-2.221; -0.811]	<0.001**
Length	0.188	0.030	[0.129; 0.246]	<0.001**
Direction (*Forward)*				
Straight	-0.132	0.210	[-0.544; 0.280]	0.529
Backward	-0.937	0.203	[-1.335; -0.538]	<0.001**
Unification (*Absent)*				
Divergent	-0.601	0.231	[-1.054; -0.148]	0.009**
Convergent	-0.819	0.553	[-1.904; 0.265]	0.139
Straight				
Constant	0.398	0.357	[-0.300; 1.097]	0.264
Length	-0.485	0.031	[-0.108; 0.012]	0.114
Direction (*Forward)*				
Straight	0.023	0.230	[-0.427; 0.473]	0.920
Backward	-0.182	0.215	[-0.603; 0.239]	0.396
Unification (*Absent)*				
Divergent	-0.286	0.215	[-0.707; 0.135]	0.183
Convergent	-0.226	0.465	[-1.137; 0.685]	0.626
LR Chi^2 (10)	115.87			
Prob > Chi^2	<0.001**			
Pseudo R^2	0.0456			

Notes. Coef. = regression coefficient; Std. Err. = standard error;
LR $Chi^2(x)$ refers to the Likelihood ratio Chi-square test statistic and associated degrees of freedom.
(Base): refers to the base outcome all other categories are compared to
*Statistically significant at $p \leq 0.05$; **Statistically significant at $p < 0.01$

and wavy shape.[15,21] Our findings are similar on the frequency of primary length, but the shape forms in our population were similar (Table 1). While the reported frequencies seem to be independent trends, our data disclose an association between primary and wavy. It is quite possible that the association would have been found in those previous studies had it been tested. In addition, the forward direction was found to be predominant by other investigators,[15] different from our observing a higher rate of backward direction (Table 1), which was also associated with the curved shape (Table 3). It may be argued that the actual length of curved and wavy rugae is greater than the measured value, as digital measurements were between the medial and lateral points of each fold. This observation may yield a difference in interpretation if the straight bands were longer than the curved and

wavy. However, straight configurations were shorter than the other two varieties.

Regarding potential similarities between curved and wavy rugae if stretched out, it would be unlikely that the curved rugae are longer, because they essentially have one curve or wave as opposed to repetitive curves in the wavy form.
The association between dimension and form was confirmed by the multiple regression analysis, reflecting again a certain order of arrangement rather than a confusing array of random variations. Palatal rugae exist to provide a biologic function. Indeed, the rugae are involved physiologically in oral swallowing, enhancing the relationship between food and taste receptors in the dorsal surface of the tongue;[22] they also participate in speech as well as suction in children.[13] We propose that the mechanical advantage provided by the PR is increased friction for the function of the opposing tongue. Research is needed to sort out whether these functions contribute an environmental developmental component to the final disposition of the rugae bands. The predictive value of the multiple regression would underscore the strong genetic role in determining the ruga phenotype.

In summary, the study of associations among geometric configurations proved to be of relevant outcome and forensic significance, as it yielded important knowledge that seems logical, such as the link between straight and short rugae and longer wavy patterns. However, a basic limitation lies in the potential for generalization across populations. The results may be specific to the studied adult group, and would require validation at younger ages and across other geographic, racial and ethnic entities. In addition, the direct manual approach we used prolongs the process of investigation. With the improvements in mouth scanning digital technology, the collection of rugal data should provide faster and readily three-dimensional records.

Molecular forensics, when available, defy the usage of morphological methods such as palatal rugae, which obviously have not risen to routine forensic and medico-legal assessment. Nevertheless, rugoscopy must be explored fully because of its potential need when conventional records (dental, fingerprints) are not available or of limited value.

CONCLUSION

Primary, back directed, and lack of unification are the predominant features of palatal rugae, despite the endless combinations of these features with the main shape characteristics: curved, wavy and straight. These three forms were nearly equal in our population, but the wavy form prevailed in association with the primary longer rugae; the straight configuration dominated in the shorter secondary and fragmentary groups. Accordingly, far from the negation of order in the arrangement of palatal rugae, a scheme of organization appears to emerge from the association of shape and length features. The multiple combinations of the geometric variables bestow a unique fingerprint forensic value to these folds.

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