RUGAE PATTERNS AS AN ADJUNCT TO SEX DIFFERENTIATION IN FORENSIC IDENTIFICATION

A. Saraf,[a] S. Bedia,[b] A. Indurkar,[c] S. Degwekar,[c] R. Bhowate.[c]

[a] Department of Oral Medicine and Radiology, Bharati Vidyapeeth Deemed University Dental College and Hospital, Kharghar, Navi Mumbai, Maharashtra, India

[b] Department of Prosthodontics, Bharati Vidyapeeth Deemed University Dental College and Hospital, Kharghar, Navi Mumbai, Maharashtra, India

[c] Department of Oral Medicine and Radiology, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Medical Sciences University, Sawangi (Meghe), Wardha, Maharashtra, India

ABSTRACT

It is widely acknowledged that in some forensic situations there are limitations to identification of the deceased by fingerprints, DNA and dental records. Palatal rugae pattern of an individual may be considered as a useful adjunct for sex determination for identification purposes. The aim of this study was to identify and compare the rugae pattern in Indian males and females, as an additional method of differentiating the sexes in various postmortem scenarios. Dental stone casts of 120 Indians: 60 males and 60 females were obtained. The method of identification of rugae patterns was that of Thomas and Kotze (1983) and Kapali et al (1997) which includes the number, length, shape and unification of rugae. Our study revealed no significant difference in the total number or various length measurements of rugae between the two sexes which conforms to previous results. However, in terms of the different types of rugae shape, the converging type of rugae were statistically greater in number in females whilst the circular type of rugae were statistically greater in number in males, which contrasts with earlier studies. The use of logistic regression analysis (LRA) enabled highly accurate sex prediction (>99%) when all the rugae shapes were analyzed. It may be concluded that rugae pattern through the use of LRA can be an additional method of differentiation between the Indian male and female and assist with the identification process in conjunction with other methods such as visual, fingerprints and dental characteristics in forensic sciences.

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Running title: Sex assessment using palatal rugae patterns

INTRODUCTION

Forensic Odontology is a specialty in dentistry which occupies a primary niche within the total spectrum of methods applied to medico-legal identification. Forensic odontology can be defined as a branch of dentistry which deals with the appropriate handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of justice.[1]

Identification of the deceased is a prime requisite for certification of death and for personal, social and legal reasons. DNA, fingerprint and dental record comparisons are the most commonly used scientific methods of forensic identification.[2,3] Limitations to the use of fingerprints occur in situations where the hands are charred or mutilated and while teeth are more durable, identification using dental records may also prove to be inconclusive, since many antemortem dental records may be inaccurate or incomplete.[4] Also, additional dental treatment might have been performed in the time interval between the creation of a dental record and death of the individual.[5]

Palatal rugae have been shown to be highly individual and consistent in shape throughout life.[6-10] The anatomical position of the rugae inside the oral cavity (surrounded by cheek, lips, tongue and the buccal pad of fat) also give some protection in cases of trauma or incineration. When identification of an individual by other methods is difficult, palatal rugae may thus be considered as an alternative source of information (usually if comparative material is available) enabling the search field to be narrowed.

Palatal rugae in mammals are transversely running crests, which are exclusively formed by the mucosa of the hard palate except where an ossified base can be distinguished. According to the Glossary of Prosthodontic Terms-8, rugae are anatomical folds or wrinkles (usually used in the plural sense); the irregular fibrous connective tissue located on the anterior third of the palate.[11] They are also called “plica palatinae” or “rugae palatine.”

It is assumed that the rugae facilitate food transport through the oral cavity, prevent loss of food from the mouth, and participate in food crushing. Because of the presence of tactile and gustatory receptors, rugae contribute to perception of taste, mechanical food qualities, and tongue position.[12]

Despite being protected by their internal position within the head, some events can contribute to changes in rugae pattern, including trauma, extreme finger sucking in infancy and persistent pressure with orthodontic treatment and dentures. In one study, it has been reported that no two palates are alike in their configuration and that the palatal print did not change with time or age. Even between twins, the studies indicated that the patterns are similar but not identical.[13]

It has been suggested that changes in the length of rugae with age result from underlying palatal growth.[6,14,15] However, the anterior rugae do not increase in length after 10 years of age according to Van der Linden.[16] Other qualitative characteristics such as shape, direction and unification remain stable throughout life. Despite the ongoing problem of describing palatal rugae patterns qualitatively and quantitatively, their uniqueness to individuals has been recognized in forensic science as providing a potentially reliable source of identification.[9]

Many studies have been carried out on the rugae patterns in the populations of Australia, South Africa and Japan.[17–20] Kapali et al[20] in their study did not reveal any significant differences in the number of primary rugae between Australian Aboriginal males and females. However, Dohke and Osato[19] indicated that among the Japanese, the females had fewer rugae than males. Only one study on palatal rugae pattern in two different populations of India has been performed by Nayak et al,[21] who reported lack of sex dimorphism in their sample.

The purpose of the present investigation was to study the rugae pattern in an Indian male and female sample and to compare the patterns between the two groups, which may assist with differentiating the sexes.

MATERIALS AND METHOD

The study was conducted at the Department of Oral Medicine, Diagnosis & Radiology, Sharad Pawar Dental College & Hospital, Datta Meghe Institute of Medical Sciences University, Sawangi (Meghe), Wardha, Maharashtra, India.

A. Selection of patients

A total number of 120 Class I dentate subjects (n=120), 60 males and 60 females**,** were selected from among the students of the college. All subjects were of Indian origin and between the age group of 22-26 years. All subjects were healthy, free of congenital abnormalities, inflammation, trauma or orthodontic treatment. Subjects were briefed regarding the procedure and written consent was obtained.

B. Impressions

An irreversible hydrocolloid was used as an impression material on an appropriate perforated metal tray for the maxillary dental arch for all subjects. The impressions were then poured with Type III dental stone. All instructions by the manufacturer were followed such as water/powder ratio, vacuum mixing and the use of a vibrator. All casts were free of air bubbles or voids.

C. Method of identification

The method of rugae recording used in this study was based on the classification given by Thomas & Kotze[17] and Kapali et al.[20] These classifications include number, length, shape and unification of rugae. The rugae were highlighted by a black pen marker on the cast under spotlight and a magnification lens. A brass wire was adapted over the rugae and the length of wire recorded using a digital caliper (*Absolute Digimatic, Mitutoyo, Japan)* calibrated to 0.1 mm.

Those rugae which have a length of more than 5 mm are referred to as primary rugae. Secondary rugae are those which have a length between 3-5 mm, whilst fragmentary rugae are those which have a length between 2-3 mm. The shapes of individual rugae were classified into four major types: curved, wavy, straight and circular. Straight types ran directly from their origin to termination. The curved type had a simple crescent shape which curved gently. Evidence of even the slightest bend at the termination or origin of rugae led to a classification as curved. The basic shape of the wavy rugae was serpentine. To be classified as circular, rugae needed to display a definite continuous ring formation. The direction of each primary rugae was determined by measuring the angle between the line joining its origin and termination and a line perpendicular to the median raphe. Forward-directed rugae were associated with positive angles, backward-directed rugae with negative angles and perpendicular rugae with angles of zero degrees. Unification occurs when two rugae are joined at their origin or termination. Unifications in which two rugae began from the same origin medially but immediately diverged laterally were classified as 'diverging'. Rugae with different origins medially which joined on their lateral portions were classified as 'converging'.

In this study, the secondary and fragmentary types of rugae were ignored when the median value of the total number of rugae was calculated. All the identification and measurements were done by one examiner. To assess intra-observer variation in interpretation, the readings were determined twice for 20 subjects. The data thus obtained was organized and prepared for statistical analysis.

D. Statistical Analysis

Chi-Square test was used for comparison of medians and relationship between the attributes. A significance level of 5% was considered as critical value. In order to calculate the accuracy of sex allocation using rugae shapes a logistic regression analysis (LRA) was performed with sex (where Male=1 and Female=0) as dependent variable and rugae shape as independent variable. Software used was SPSS 10.0 statistical program (SPSS Inc., Chicago, Illinois, U.S.A.).[22] The fit of the logistic model to the data was assessed by an accuracy of fit statistic represented by the -2 log likelihood (-2LL).

RESULTS

The intra-observer error was found to be negligible since the percentage concordance between repeat observations was found to exceed 95 percent with very few discrepancies involving the exclusion of secondary and fragmentary rugae, perhaps because of their size.

Table 1: *Total number of subjects and the mean value of rugae in males and females.*

Sex	Total number of subjects	Total number of rugae*	Mean	SD
Male	60	438	7.30	0.94
Female	60	435	7.25	0.93
z-test	0.29			
p-value	0.77			

** Secondary and Fragmentary types were excluded.*

The total number of rugae and the mean value for males and females is illustrated in Table 1. The distribution of different types of rugae as well as the descriptive statistics is shown in Table 2.

Table 2: *Descriptive statistics of different types of rugae categorized by sex.*

Type of rugae	Sex	No.	Median	z-value
Diverging pattern	M	60	0	3.80*
	F	60	0	
Converging pattern	M	60	0	19.80*
	F	60	2	
Wavy pattern	M	60	3	4.82*
	F	60	2	
Curved pattern	M	60	2	3.82*
	F	60	2	
Straight pattern	M	60	1	0.17
	F	60	1	
Circular pattern	M	60	1	15.33*
	F	60	0	

** Significantly different at the p<0.05 level.*

The wavy and curved pattern of rugae were found to be statistically different in the sexes but were more common in both males and females. The diverging type also showed statistically significant sexual dimorphism but was the least commonly found in both the sexes. However there was a significant sex difference in the converging type, which was found to be higher in females. There was also a significant sex difference in the circular type which was higher in males. The number and difference in length of rugae are shown in Tables 3 and 4. The chi-square showed no significant difference in number and length between the two sexes.

***Table 3:** Distribution of the different types of rugae length in males and females.*

Sex	From 5-10 mm	More than 10 mm	Total
Male	219(42.60%)	219(42.60%)	514
Female	215(42.49%)	220(43.47%)	506
א^2-value	0.14		
p-value	0.29		

***Table 4:** Sex differences in number of different types of rugae length.*

Type of rugae	Sex	Median	p-value
From 5-10 mm	M	4	0.59
	F	3	
More than 10 mm	M	4	0.90
	F	4	

The accuracy of sex prediction by LRA is depicted in the classification table (Table 5). Application of LRA to all the rugae types yielded a correct sex allocation rate of 99.2%. This may indicate a high power of sex allocation using the rugae shapes. Table 6 shows the accuracy of the statistic: the lower the −2LL statistic, the better the fit of the model to the data.[22] The −2LL for logistic regression model for rugae type was 5.3, indicating high accuracy of fit of the model to the obtained data.

***Table 5:** Classification table of Logistic regression analysis (LRA).*

	Male		Female		Σ	
	n	%	*n*	%	*n*	%
Rugae pattern	60/60	100	59/60	98.3	119/120	99.2

***Table 6:** Accuracy of fit statistic (-2LL).*

	-2 Log likelihood
Rugae pattern	5.307

DISCUSSION

It is widely acknowledged that there are limitations in identification by fingerprints, dental records and DNA in some forensic situations and the palatal rugae pattern of an individual may be considered as a useful adjunct for identification purposes. The present study was carried out to study the rugae pattern in an Indian sample and to compare the patterns between the males and females, which may be an additional method of differentiating the sexes, especially if other indicators are missing antemortem.

The method used in this study[7,17,20] was found to be the most practical and easiest to apply compared with other methods such as those of Hauser et al[14] and of Reuer.[23]

The present study was cross-sectional in nature and included recording of the rugae pattern of a narrow age group sample of 22-26 years selected amongst the students of the college who were of Indian origin. Hence further studies across a wider sample age group, larger sample size and with a longitudinal approach may be performed amongst the Indians to corroborate our results.

Nayak et al[21] in their study on population differentiation using rugae shape have mentioned that discrete variables such as rugae shape are better suited for the purpose than continuous variables such as rugae length. The present study did not show any significant difference in the length of rugae between the sexes, whereas rugae shape did, implying that discrete variables are also better suited for sex differentiation.

Kapali et al[20] in their study did not reveal any significant differences in the number of primary rugae between Aboriginal males and females. The present study also did not show any significant difference in the number of rugae between the Indian males and females. These results do not conform to the results presented by Dohke and Osato[19] who indicated that among the Japanese, the females had fewer rugae than males. This may be due to the fact that secondary and fragmentary rugae were not included in the present study and it is the secondary rugae that Dohke and Osato considered in their study leading to sex differentiation.

Thomas and Kotze[24] have noted that although primary rugae have been more widely studied than secondary and fragmentary rugae, they do not possess strong discriminatory ability between different human populations. Only the primary rugae were considered in the present study. Hence, further studies involving comparisons of patterns of secondary and fragmentary rugae between the sexes and also between different ethnic groups, rather than primary rugae alone, could be worthwhile.
Acharya et al[22] in their study on odontometric sex assessment have shown the advantages

of using LRA for sex prediction and have proved the use of LRA as a better alternative to discriminant function analysis (DA) in dental sex assessment. Hence LRA was used in the present study to check the ability of palatal rugae pattern in determining sex. LRA enabled highly accurate sex prediction (99.2%) when the rugae shapes were analyzed. This shows that using the observed rugae pattern, sex can be predicted correctly with a probability of >99% which is a very high degree of prediction and sex allocation.[22] The −2LL for logistic regression model for rugae type was 5.3, indicating an accurate fit of the model to the obtained data. This indicates that palatal rugae shapes may be extremely useful to predict sex. The descriptive statistics also showed significant difference among the sexes in shapes of primary rugae in the present sample (Table 2). The presence of the converging type was found to be significantly higher in females while the presence of the circular type was found to be significantly higher in males. This means that the power of sex prediction may be higher when the converging and circular types of rugae are used. The results reveal that rugae patterns have use as a sex indicator when multivariate statistics such as LRA is applied.

However, these results do not conform to the results presented by Nayak et al[21] who studied the palatal rugae pattern in two populations of India and by using step-wise DA reported lack of sex dimorphism in their sample. The differences may be precluded by the small sample size (30: 15 males and 15 females), narrow age group sample and lack of use of LRA and further work on larger samples of the Indian population may be required to validate the findings.

In this study intra-observer error was assessed by repeat observations and was found to be negligible. Also, the errors in length were small because measurements were categorized rather than retaining their quantitative scale.

However, this error rate may be reduced further or completely eliminated by development of an intraoral scanning device to capture palatal rugae pattern, with image transfer directly to a computer, with appropriate software, as is presently available for fingerprints. This would eliminate the manual errors as well as time involved in the process of categorization of rugae pattern samples. With the use of interconnected computer networks it would be possible to store a large amount of data, facilitating quick retrieval of information to assist with faster and more effective sex differentiation and hence identification.

CONCLUSION

Within the limitations of the present study it may be concluded that the rugae pattern (through the use of LRA) may be an additional method of differentiation between the Indian male and female. This may help narrow the field for identification and give results in conjunction with the other methods such as visual, fingerprints, and dental characteristics in forensic sciences. Further research may be indicated with a larger sample size and with a wider age range in order to substantiate the findings of the present study. In addition, examining the rugae patterns, including the primary, secondary and fragmentary rugae in other Indian populations may further corroborate the findings.

REFERENCES

1. Dayal PK. *Textbook of Forensic Odontology*. 1st edn. Paras Medical Publishers, 1998.
2. Whittaker DK. Introduction to forensic dentistry. *Quintessence Int* 1994;25:723-30.
3. Morlang WM. Forensic dentistry. *Aviat Space Environ Med* 1982;53:27-34.
4. Buchner A. The identification of human remains. *Int Dent J* 1985;35:307-11.
5. Chester D, ed. Forensic dentistry. *Colgate oral care report* 2002;12:1-3.
6. Lysell L. Plica palatinae transversae and papilla incisive in man: a morphological and genetic study. *Acta Odontol Scand* 1955;13:5-137.
7. Thomas CJ, Kotze T. The palatal ruga pattern: a new classification. *J Dent Assoc S Afr* 1983;38:153-7.
8. Harrison A. The palatal rugae in man. *Proc Acad Nat Soc* 1889;6:245.
9. English WR, Robinson SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal rugae. *J Forensic Sci* 1988;33:718-26.
10. Abou EF, Mona M, Gamal ZHES. A study of palatal rugae pattern (rugoscopy) in Egyptian population. *Egypt Dent J* 1998;44:3177-84.
11. The Academy of Prosthodontics. The Glossary of Prosthodontic Terms. 8th edn. CV Mosby, 2005.
12. Buchtova M, Tichy F, Putnova I, Misek I. The development of palatal rugae in the European pine vole, *Microtus subterraneus* (Arvicolidae, Rodentia). *Folia Zool* 2003;52:127-36.
13. Ritter R. Z Morphol Anthropol 1943;40:367-72. Cited in Hauser A, Daponte A, Roberts TS. Palatal rugae. *J Anat* 1989;165:237-49.
14. Hauser A, Daponte A, Roberts TS. Palatal rugae. *J Anat* 1989;165:237-49.
15. Simmons JD, Moore RN, Erickson LC. A longitudinal study of anteroposterior growth changes in the palatine rugae. *J Dent Res* 1987;66:1512-5.
16. Van der Linden FP. Changes in the position of posterior teeth in relation to ruga points. *Am J Orthod* 1978;74:142-61.
17. Thomas CJ, Kotze T. The palatal rugae pattern in Southern African human populations. Part I. A description of the populations and a method for its investigation. *J Dent Assoc S Afr* 1983;38:547-53.
18. Manihara K, Masuda T, Tanaka T. Affinities of dental characteristics in the Okinawa Islanders. *J Anthropol Soc Nip* 1973;82:75-81.
19. Dohke M, Osato S. Morphological study of the palatal rugae in Japanese 1. Bilateral differences in the regressive evaluation of the palatal rugae. *Jap J Oral Biol* 1994;36:125-40.
20. Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian Aborigines and Caucasians. *Aust Dent J* 1997;42:129-33.
21. Nayak P, Acharya A, Padmini A, Kaveri H. Differences in the palatal rugae shape in two populations of India. *Arch Oral Biol* 2007;52:977–82.
22. Acharya A, Prabhu S, Muddapur M. Odontometric sex assessment from logistic regression analysis. *Int J Legal Med* 2011;125(2):199–204.
23. Reuer E. *MAGW* 1973;103:1-13. Cited in Hauser A, Daponte A, Roberts TS. Palatal rugae. *J Anat* 1989;165:237-49.
24. Thomas CJ, Kotze T. The palatal ruga pattern in six southern African human populations, Part II: inter-racial differences. *J Dent Assoc S Afr* 1983;38:166-72.

Address for correspondence:
Dr. Aarti Saraf
C-6, Flat no. 5,
Breezy Apartments,
Jeevan Bima Nagar,
Borivali (West),
Mumbai-400103.
Maharashtra, India.
Email: drarti2000@yahoo.co.in
Phone: +91-22-28935157, +91-9702475437
Fax: +91-22-28935157