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DIMENSIONAL VARIATIONS IN MORPHOLOGY AND MORPHOMETRY OF PALATAL RUGAE PATTERNS AMONG INDIANS AND AFRICANS: A FORENSIC ODONTOLOGICAL INVESTIGATION

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ABSTRACT

Forensic odontology is one of the recently evolving subjects in forensic science and dental science. It has a number of applications to aid in the administration of the justice. It also has got applications for the societal welfare. Generally, forensic odontology is presumed to be associated with bite mark analysis. There are other areas such as age estimation and gender determination which are more flourishing, as of now, with the examination of eruption of teeth. Though there are a number of studies available on age estimation and sex determination, there are a very few studies on the race determination. In case of major / mass disasters involving individuals from multiple ethnic groups, race could be easily identified from the examination of palate rugae of the intra-oral cavity. Palatal rugae could be easily analysed for the determination of racial affinity. As such the hard palate is the least possible to be destroyed and therefore the scope of its examination is high.

In this communication, an attempt has been made to study the specific features of the morphology and morphometry of the palatal rugae so that it could be used as a better indicator of the race. In this report we have studied the palate rugae patterns of African population and compared it with those of an Indian sample from Gujarat. Moreover, on the morphology and morphometry of the patterns of the palatal rugae can also assist in establishing individuality of remains. A total number of 70 people have been considered for the present study. Two racial groups, viz. Africans (male= 20 , females= 15) and Gujarati Indians (males= 17, females =18), between the age group of 18 years to 28 years have been considered. A total of 70 maxillary impressions were taken with alginate impression material and the casts were prepared (35 for Africans and 35 for Indian). It was found that the palatal rugae patterns showed significant differences in number, length and width between the Indians and Africans, which can serve as an important indicator for forensic identification especially in mass disasters.

Keywords: Palatal rugae, human identification, morphology, morphometry, race, ehnicity

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INTRODUCTION

Post-mortem human identification of the deceased in cases of mass disasters achieved by dental or any other means is one of the most challenging tasks. Forensic odontology is a unique entity dealing with evidence related to dental and oral structures. Various studies have been conducted on the use of teeth in forensic investigations. Besides teeth, use of other methods, such as palatal rugae patterns, lip prints, and bite marks were also reported. Palatal rugae are considered to be as equipotent as fingerprints and bite marks and a powerful tool for identification in medico-legal investigations. Palatal rugae are anatomically transverse, irregular, asymmetrical soft-tissue ridges on the anterior part of the palatal mucosa, located posterior to the incisive papilla on each side of the mid palatine raphae (Kapali et al., 1977). They are also called 'plica palatine.' These are formed in the early intrauterine life during the period from 12th to 14th week and remain stable throughout the person's life, not undergoing any changes, except for increase in the length as a process of normal growth (Byatnal, et al., 2014).These palatal rugae patterns are unique to each individual. The rugae are well protected by the lips, buccal pad of fat, mucosa, teeth and lips, and hence, survive post-mortem insults. Palatal rugae were found to be stable in shape and structure during the life of an individual and are not changed by disease, trauma, chemicals or heat (Janardhanam et al., 2017). Once formed, they remain in the same position and even if they are damaged, are reproduced exactly on their original site (Janardhanam et al., 2017).

Studies done by Hauser et al. in 1989 have suggested that the mean recommended count changes fairly in adolescence, but the count increases markedly from the third to fourth decade onwards (Hauser et al., 1989). But Lysell (1955) concluded that the number of rugae decrease from the second decade onwards. Peavy and Kendrick (1967) in their study identified that the palatal rugae do not change as a result of growth, but remain stable throughout life.

A wide range of forensic science techniques help in positive identification of the deceased victims, some of these are visual identification, use of fingerprints, lip print, denture coding, DNA profiling and odontology. Just like fingerprints, palatal rugae are highly specific to each individual. Identification of the badly mutilated body has been done using rugae patterns on patient's denture in the past (Deeksha et al., 2015). Also, rugae pattern are specific to different racial groups making it convenient for their identification in a mass disaster situation (Deeksha et al., 2015). Several studies reported a significant association between rugae forms and ethnicity which may represent a valuable finding in forensic investigations, especially in disaster (Janardhanam et al., 2017). The present study is an attempt to differentiate between the various rugae patterns on the basis of their shapes, lengths and widths amongst the African and Indian populations to see which rugae pattern is predominant in Africans and Indians population. Through this study, we also aim to highlighting the importance of

palatal rugae pattern in establishing a person's identity and the need of maintaining the ante-mortem record of the same in the form of photographs or digitalised casts, which can be stored in the form of a secured database that can later be used for comparison and identification purposes.

MATERIALS AND METHODS

The present study was conducted in the Gujarat Forensic Sciences University. Informed consent was obtained from each individual before taking impressions. A total of 70 maxillary impressions were taken (35 each for Africans and Indians) with the help of alginate impression material using stainless steel impression trays and the casts were then prepared using dental stone. The age range of the subjects was between 18 and 30 years.Subjects with any congenital abnormality, pathology and orthodontic treatments were excluded from the study.

The rugae were delineated using a sharp graphite pencil under adequate light and magnification. [Figure3]. The pattern of rugae was determined using Thomas and Kotze classification. Parameters included in the study were: number, shape, and unification patterns of rugae. In addition, lengths and widths of the rugae patterns were also measured.

The shapes of palatine rugae were classified into four major types:

1. Straight type: The rugae patterns which ran directly from their origin to termination.
2. Curved type: The rugae pattern which has a simple crescent shape, slightest bend at the termination origin of rugae.
3. Wavy type: The basic shape of wavy was serpentine, however, if there was a slight curve at the origin or termination of the curved rugae, it was classified as wavy.
4. Circular type: A rugae needed to display a definite continuous ring formation.

The length of rugae was classified as follows:

1. Primary (>5 mm).
2. Secondary (3–5 mm),
3. Tertiary (<3 mm),

Measurement of the lengths and widths of the rugae was done manually with the help of a divider and the distance between the two end points between the rugae were measured with the help of a scale. A simplified chart was prepared through this study to record all the findings for all the samples. This is easier for the purpose of identification [Figure]. The following criteria were followed for the inclusion and exclusion of subjects: **Inclusion criteria:**

1. Normal subjects within the age limit of 18-28 years.

Exclusion criteria:

1. The subjects with congenital anomalies/malformations.
2. Subjects with any history of previous orthognathic surgery.
3. Subjects with bony and soft tissue protuberances in the palatal aspect.
4. Subjects with active lesions, and trauma of the palate .
5. Subjects who were wearing partial dentures and braces.

RESULTS AND DISCUSSION

Table-1 shows descriptive statistics and results of the t-test for the length and width of the primary and secondary palatal rugae of Indian and African subjects in the present sample taken as. Significant ($p<0.05$) differences were found in the width of the rugae with Africans showing significantly higher mean width. Though the Africans showed slightly higher mean lengths of primary rugae than the Indians, however, differences in lengths were not statistically significant for primary as well secondary rugae. Apart from differences in the number and length and width of rugae patterns, comparison was also made according to the type of rugae, classified on the basis of lengths, and it was seen that primary rugae were more in number in Africans where as secondary rugae patterns were seen slightly more in Indians, as compared to Africans, and tertiary patterns are very rare and were found to be almost same in number in both the population groups.Gender wise comparison of the patterns lengths as well as width for African and Indians was also evaluated (Tables 2 and 3). As can be seen in Table-2, rugae width showed significance racial differences ($p<0.05$) for male straight patterns, female straight patterns, female curved patterns, male wavy patterns, female wavy patterns and male circular patterns. However, differences in lengths of various rugae patterns were not significant ($p<0.05$), except for the male wavy pattern length which showed high significance (Table-3).

Table-1: Descriptive statistics of length and width of primary and secondary palatal rugae of Indian and African subjects in the present sample as a whole

Palatal Rugae Parameter	Ethnicity	N	Mean	S.D.	S.E.	t-value	p-value
Width of rugae	Indian	375	1.72*	1.076	0.056	-8.512	0.000
	African	388	2.67	1.866	0.095	-	-
Length of Primary rugae	Indian	341	10.18	2.953	0.160	-1.233	0.218
	African	343	10.61	5.873	0.317	-	-
Length of Secondary rugae	Indian	32	4.41	.499	0.088	0.112	0.911
	African	56	4.39	.562	0.075	-	-

*Significant difference ($p<0.05$)

Table-2: Descriptive statistics of widths of various patterns of palatal rugae of Indian and African subjects in the present sample, according to sex

Palatal Rugae Parameter	Ethnicity	N	Mean	S.D.	S.E.	t-value	p-value
Male straight pattern width	Indian	95	1.53*	.687	0.071	-5.116	0.000
	African	78	2.44	1.567	0.177	-	-
Female straight pattern width	Indian	113	1.45*	1.057	0.099	-3.026	0.003
	African	49	1.99	1.056	0.151	-	-
Male curved pattern width	Indian	33	1.86	1.747	0.304	-1.841	0.069
	African	63	2.48	1.467	0.185	-	-
Female curved pattern width	Indian	60	1.71*	0.922	0.119	-3.040	0.003
	African	44	2.44	1.533	0.231	-	-
Male wavy pattern width	Indian	26	1.35*	0.596	0.117	-4.330	0.000
	African	78	2.36	1.139	0.129	-	-
Female wavy pattern width	Indian	39	1.62*	0.823	0.132	-2.674	0.009
	African	44	2.07	0.720	0.109	-	-
Male circular pattern width	Indian	11	2.32*	1.601	0.483	-2.087	0.043
	African	35	4.23	2.889	0.488	-	-
Female circular pattern width	Indian	6	2.08	1.530	0.625	-0.320	0.754
	African	9	2.28	.833	0.278	-	-

*Significant difference ($p<0.05$)

Table-3: Descriptive statistics of lengths of various patterns of palatal rugae of Indian and African subjects in the present sample, according to sex

Palatal Rugae Parameter	Ethnicity	N	Mean	S.D.	S.E.	t-value	p-value
Male straight pattern Length	Indian	96	9.51	5.186	0.529	0.362	0.718
	African	78	9.26	3.742	0.424	-	-
Female straight pattern Length	Indian	113	8.58	3.368	0.317	-0.820	0.414
	African	49	9.03	2.905	0.415	-	-
Male curved pattern Length	Indian	33	7.85	2.852	0.496	-0.664	0.508
	African	63	8.30	3.331	0.420	-	-
Female curved pattern Length	Indian	60	8.44	2.657	0.343	-1.837	0.069
	African	44	9.43	2.792	0.421	-	-
Male wavy pattern Length	Indian	26	8.87*	2.953	0.579	-4.599	0.000
	African	77	12.35	3.462	0.395	-	-
Female wavy pattern Length	Indian	39	11.29	2.499	0.400	-1.150	0.254
	African	38	12.05	3.246	0.527	-	-
Male circular pattern Length	Indian	11	6.26	2.778	0.837	-0.781	0.439
	African	35	7.31	4.162	0.704	-	-
Female circular pattern Length	Indian	6	6.83	4.191	1.711	-0.118	0.908
	African	9	7.02	1.979	0.660	-	-

*Significant difference ($p<0.05$)

Table-4 shows that Africans have significantly higher number of curved, wavy and circular patterns (pd"0.05) than the Indians. On the other hand, among the Indians the traight patterns are significantly higher in number than the Africans (pd"0.05) as revealed by t-tests.

Table-4: Descriptive statistics of number of various types of palatal rugae among Indian and African subjects in the present sample

Palatal Rugae Type	Ethnicity	N	Mean	S.D.	S.E.	t-value	p-value
Straight	Indian	35	5.89*	2.285	0.386	4.080	0.000
	African	35	3.74	2.105	0.356	-	-
Curve	Indian	35	2.26*	1.738	0.294	-2.079	0.041
	African	35	3.11	1.711	0.289	-	-
Wavy	Indian	35	1.74*	1.358	0.230	-2.872	0.005
	African	35	2.69	1.388	0.235	-	-
Circular	Indian	35	0.46*	.701	0.118	-3.047	0.003
	African	35	1.34	1.571	0.266	-	-
Converge	Indian	35	0.14	0.355	0.060	-0.627	0.533
	African	35	0.20	0.406	0.069	-	-
Diverge	Indian	35	0.74*	0.886	0.150	2.055	0.044
	African	35	0.37	0.598	0.101	-	-

*Significant difference ($p<0.05$)

Based on these results, it can be concluded that there was a significant differences in the width of the patterns in African and Indian population which suggests that Africans have very broad and thick rugae patterns as compared to Indians. Moreover, African rugae patterns are quite elevated, which was visually apparent. Number of straight patterns was found to be more among the Indians as compared to Africans in whom curved, wavy and circular were found to be predominant.

Rugae patterns are specific to different racial groups making it convenient for their identification in a mass disaster situation (Deeksha et al., 2015) Several studies reported a significant association between rugae forms and ethnicity which may represent a valuable finding in forensic investigations especially in cases of disasters (Janardhanam et al., 2017).

Hauser et al., (1989) performed a study to compare the rugae patterns of Swazi and Greek population and they found definite differences in the patterns between the two populations. This could be because of development of rugae and growth of the palate (Hauser et al., 1989). Several studies reported inter-racial differences in palatal rugae even in relatively similar population groups, which may help to identify the population especially in disasters (Kapali et al., 1997; Muthusubramanian et al., 2005) However, no study has been done to distinguish between the Africans and Indians on the basis of their rugae pattern. This study was aimed to analyse the differences in the number of patterns, their lengths and widths among the Indian and African population and significant results were obtained. Gender-wise comparison of various rugae patterns between the two population groups under study revealed significant ethnic differences in some of the patterns, especially their widths. Previous studies on the Indian population as found unification rugae pattern to be very rare (Byatnal et al., 2014). Same was found in this study too for both the population groups. This study has a limitation of less sample size gender wise. Further studies can be done with a

larger sample size to confirm the present findings and to establish much more significant ethnic differences amongst the various populations.

CONCLUSIONS

It can be concluded that rugae patterns are significantly different for Indian and African population groups. The differences are based on the number, shape and dimension, such as length and width of the palatal rugae. African rugae patterns are significantly thick, elevated and broader in width as compared to the Indians. More number of curved, wavy and circular patterns are found in Africans whereas rugae patterns of Indians are very thin and slender and mostly having the straight and wavy patterns. Further studies on larger samples are required to further investigate the racial differences in rugae pattern among various populations. Thus from the results of this study, it is can be concluded that palatal rugae can be used as consistent tool in forensic identification and even serve as a odontological biometric tool.

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