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A Comparative Analysis of Palatal Ruga Patterns among Gorkha and North-East Indian Population

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Abstract

Background: Palatal rugae are resistant to changes due to trauma or aging. Ruga patterns, being unique to each individual, are valuable for personal identification. The study aims to assess the applicability of palatoscopy for differentiation amongst North-east Indians and Gorkhas in India. **Materials and Methods:** Sample comprised a total of 100 subjects divided into two groups of 50 each for Gorkha (Group I) and North-east Indian (Group II) population. Alginate impressions were made and models were obtained. Data was recorded after tracing palatal rugae on models. Analysis of rugae for number, side-wise distribution, shape, length, and direction was undertaken. Statistical analysis was carried out and probability value was obtained. **Results:** After analyzing the rugae patterns in both the groups, total number of rugae was more in Group I as compared to Group II. Total number of rugae on right and left sides each was more in Group I than in Group II. The curved pattern was found to be predominant in both groups. Divergent rugae were predominant in both groups. Maximum rugae were primary and were forwardly directed. Statistical analysis revealed no significant differences between groups for parameters assessed. **Conclusion:** Palatoscopy independently was not able to differentiate between individuals of the two test populations. Palatoscopy may assist in the identification process in conjunction with cheiloscopy and intraoral photography. Palatoscopy, on the account of its stability and easy reproducibility, should be encouraged among dentists for maintenance of patient records for forensic identification.

Keywords: Forensic Odontology, Human Identification, Palatoscopy, Population Differentiation, Rugoscopy

Introduction

The process of personal identification utilizes the characteristics unique to an individual to establish identity. Personal identification is needed to identify victims of natural and man-made disasters, when establishing the identity of an individual is difficult owing to disfigurement[1]. Forensic science is a multi-disciplinary approach, where traits specific to an individual (DNA, retina, fingerprints, dental characteristics) are analyzed for personal identification. Forensic odontology, on the account of its simplicity and affordability, is gaining recognition in the field of forensic science. This branch employs distinct dental characteristics for the identification of suspects and victims in crime scene investigations and mass disasters[2].

Palatoscopy in forensics is a method for personal identification in which palatal rugae are analyzed[3]. Rugae are folds of palatine mucosa lying lateral to the mid palatine raphe on the anterior palate and running transversely for variable lengths across the palate[4]. Post-development, palatal rugae (like fingerprints) remain unaltered morphologically throughout an individual's lifetime. Palatal rugae are shielded against disfigurement by trauma and extreme temperatures by the dentition

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and buccal adipose tissue. Rugae are preserved well for up to a few days after death. Hence, if antemortem data is available, palatoscopy can be successfully used as a post-mortem identification technique[5].

Considering the potential utility of palatal prints to establish identity, this study investigates the distribution and patterns of palatine rugae in Gorkha and North-east Indian individuals. The Gorkhas and North-east Indians, though are racially, culturally linguistically, and historically varied, are socially similar and co-located in North-east India[6]. Gorkhas migrated to North-east India during colonial rule in the early 19th century[7]. Even though Gorkhas anthropologically resemble north-east Indians, they are considered distinct socially, belonging to different races and nationalities[6]. Current study, thus, aims to assess the applicability of rugoscopy as a tool to differentiate between the North-east Indians and the Gorkhas in India by the intercomparison of palatine ruga patterns among the two populations.

Study Design and Methods

Study groups comprised of 100 individuals in total, 50 each from the Gorkha and North-east Indian population.

Inclusion Criteria:

1. Gorkha population (Group I): Subjects of predominantly Chhetri, Gurung, Tamang, Bahun, Magar, and Bhujel ethnicity living in Nepal, or those whose ancestors have migrated from Nepal in the past and are settled in North-east India.
2. North-east Indian population (Group II): Subjects principally of Mizo, Naga, Kuki, Kom, Khasi, and Garo ethnicity concentrated in the North-eastern states of India.

Exclusion Criteria:

1. Subjects with an ancestral history of inter-community marriages were excluded.
2. Subjects with congenital or acquired deformities of the palate, palatine cysts, inflammatory conditions resulting in palatine swelling, and mucocutaneous lesions involving the palate were excluded.

After obtaining an informed consent from each individual, maxillary alginate impressions of subjects were poured in dental stone (Figure 1). The outline of rugae were marked on the casts (Figure 2), and data were recorded (guidelines by Thomas and Kotze in 1983)[8].

Data on pattern, distribution, and number of palatine rugae in each subject were recorded. Ruga patterns were classified based on their side-wise distribution, shape, primary-ruga length, unification pattern, and direction on palate.

A. The greatest dimension of rugae from their origin to termination was measured, and they were categorized according to length as follows:

- Primary when rugae were greater than five millimetres linear dimension

Figure 1. Intraoral photograph showing palatine rugae.

Figure 2. Outline of rugae marked on cast.

- Secondary when rugae were three to five millimetres linear dimension
- Fragmentary when rugae were two to three millimetres linear dimension
- Rugae less than two millimetres in linear dimension were omitted

B. Rugae shape was identified as follows:

- Curved: Rugae having curvilinear shape. Rugae bending even slightly at origin or termination were categorized as curved rugae.
- Wavy: Rugae having a sinusoidal pattern were categorized as wavy.
- Straight: Rugae following linear course from origin to termination were categorized as straight.
- Branched: Rugae that originate from near mid palatine raphe and bifurcate or unify before termination laterally were categorized as branched.
- Circular: Rugae that curved uninterrupted in form of a ring were categorized as circular.

C. The pattern in which the rugae merged at their origin or in their course laterally on the palate was used to categorize rugae as divergent or convergent. Rugae were classified as divergent if two rugae sharing common origin bifurcated on their course laterally. Rugae which originated separately but merged on their lateral path were categorized as convergent.

D. Direction was dictated by the angle that origin-termination axis of each ruga made with the perpendicular to the mid palatine raphe. Rugae were classified as forwardly directed (positive angles), backwardly directed (negative angles) and zero degree (perpendicular to median palatine raphe).

The data obtained were recorded and subjected to Chi-Square tests for intergroup comparative evaluation. Probability value less than 0.05 was set for statistical significance (Tables 1 and 2).

Results

The comparative study of palatal ruga patterns among the Gorkha (Group I) and North-east Indian (Group II) population included 50 individuals in each study group. There were 37 males and 13 females in Group I, while Group II comprised 32 males and 18 females. Mean age of subjects was 31.0 ± 9.39 years and 31.9 ± 7.69 years in Groups I and II, respectively. There were 446 rugae in Group I and 437 rugae in Group II. In total, the number of rugae was higher in Group I versus Group II, but the intergroup comparison was non-significant (P=0.797). The number of rugae on the right (n=231 for Group I vs n=226 for Group II) and left side (n=215 for group I vs n=211 for Group II) each was higher in Group I versus Group II. The differences, however, were not significant statistically (Tables 1 and 2).

Curved rugae were predominant in both groups (n=196 and n=188 for groups I and II, respectively) followed by the wavy pattern (n=142 and n=153 for group I and II, respectively). Apart from the predominant curved and wavy patterns, straight rugae were more common in Group I (n=63), while branched rugae were more common in Group II (n=50). Circular pattern rugae were the fewest in both groups (n=3 and n=2 for Groups I and II, respectively). Intergroup comparison for all patterns, however, yielded non-significant results (Tables 1 and 2). Divergent rugae were common in both groups (n=31 and n=41 for Group I and Group II, respectively) with a non-significant intergroup difference (Tables 1 and 2).

Amongst 446 rugae in Group I, 381 were primary, 61 were secondary, and four were fragmentary. In Group II, amongst 437 rugae, 376 were primary, 60 were secondary, and one was fragmentary. The chi-square value and P-value, respectively, for intergroup comparison were 0.020 and 0.887 for primary rugae and 0.000 and 1.000 for secondary rugae (Table 1).

The analysis for the direction of rugae in Groups I and II populations showed that the forwardly directed pattern was more frequent in study groups, followed by the zero-angle and backwardly directed pattern (intergroup comparison non-significant) (Tables 1 and 2).

Results of the present study indicate comparable ruga attributes (in terms of distribution, shape, type, unification, and direction) among the study populations.

Discussion

Ruga patterns, like fingerprints, are unique to individuals. They vary in length due to palatal growth but retain their shape throughout life. Oral hard and soft tissues of the lips, cheek, tongue, teeth, and bone anatomically shelter rugae inside the mouth. Rugae are sheltered by oral hard

Table 1. Comparison of study groups for palatine rugae attributes

	Group 1 (Gorkha) (n=50)	**Group 2** (North-east Indians) (n=50)	**X^2 value**	P-**value**
Parameters assessed				
Total no. of rugae	446	437	0.080	0.797#
No. of rugae on right side	231	226	0.230	0.631#
No. of rugae on left side	215	211	0.020	0.887#
Pattern of rugae				
Curved	196	188	0.120	0.100#
Straight	63	44	0.660	0.416#
Wavy	142	153	0.340	0.559#
branched	42	50	0.540	0.462#
Circular	3	2		
Unification				
Convergent	11	7	0.500	0.479#
Divergent	31	41	1.120	0.289#
Type based on length of rugae				
Primary	381	376	0.020	0.887#
Secondary	61	60	0.000	1.000#
Fragmentary	4	1		
Direction of rugae				
Forwardly directed	273	252	0.760	0.383#
Backwardly directed	76	77	0.000	1.000#
Zero angle	97	108	0.480	0.488#

#Statistically not significant

and soft tissues against trauma and incineration and can be utilized dependably for forensic identification[9].

Jacob and Shalla used dental stone casts to study palatine rugae of edentulous people for post-mortem identification[10]. They stated that palatine rugae can be used reliably for identification, with 79 percent accuracy. Muthusubramanian *et al.*[11] studied the efficacy of ruga analysis for the identification of bodies subjected to incineration and decomposition (burn victims and cadavers). Palatine rugae of burn victims were analyzed within 3 days after the incident. Also, corpses stored for at least 7 days at 5°C were assessed for their palatine rugae. The study showed that palatine rugae (93 percent) were highly assessable among burn victims. Also, no changes in the morphology of rugae were observed in maximum human cadavers. These studies indicate the stability of palatine rugae and prove their reliability for forensic identification.

Investigators have studied palatal rugae in the past and have inter-compared rugae among different ethnic groups worldwide. Kapali *et al.*[12] compared palatal ruga patterns between Australian Aborigines and Whites. In their study, higher number of primary rugae were observed among Australian Aborigines than Whites. Also, similar to the observations put forth in the current study, curved and wavy rugae were most frequent followed by the lesser common straight and circular forms.

Kashima inter-compared Japanese and Indian children for their palatine rugae[13]. Higher number of primary rugae were found in Japanese children as opposed to Indian children. Also, the study groups varied with respect to primary ruga shape, their number and distribution on palate. Pattern and distribution of secondary and fragmentary rugae varied as well. Shetty *et al.*[14] analyzed and inter-compared the Indian and Tibetan populations for their palatine rugae. Side-wise distribution of rugae

Table 2. Descriptive table for t value and *P*-value

Parameters assessed	Group 1 (Gorkha) (n=50) Mean ± SD	Group 2 (North-east Indians) (n=50) Mean ± SD	t -value	P-value
Total no. of rugae	8.92 ± 1.65	8.74 ± 1.88	0.508	0.612#
No. of rugae on right side	4.62 ± 1.12	4.52 ± 1.09	0.451	0.653#
No. of rugae on left side	4.3 ± 0.93	4.22 ± 1.15	0.383	0.703#
Pattern of rugae				
Curved	3.92 ± 1.91	3.76 ± 1.84	0.427	0.671#
Straight	1.26 ± 1.26	0.88 ± 0.82	1.786	0.077#
Wavy	2.84 ± 1.42	3.06 ± 1.49	-0.756	0.452#
branched	0.84 ± 0.89	1.00 ± 0.88	-0.904	0.368#
Circular	0.06 ± 0.24	0.04 ± 0.2	0.455	0.650#
Unification				
Convergent	0.22 ± 0.42	0.14 ± 0.4	0.972	0.334#
Divergent	0.62 ± 0.7	0.82 ± 0.8	-1.333	0.186#
Type based on length of rugae				
Primary	7.62 ± 1.28	7.52 ± 1.36	0.379	0.705#
Secondary	1.22 ± 1.17	1.20 ± 1.23	0.084	0.934#
Fragmentary	0.08 ± 0.4	0.02 ± 0.14	1.009	0.315#
Direction of rugae				
Forwardly directed	5.46 ± 2.41	5.04 ± 2.13	0.924	0.358#
Backwardly directed	1.52 ± 1.52	1.54 ± 1.43	-0.068	0.946#
Zero angle	1.94 ± 1.48	2.16 ± 1.8	-0.668	0.506#

#Statistically not significant

varied amongst males and females of both populations. Curve-shaped rugae were more frequently observed in Indian males, while wavy rugae were more predominant among Tibetan males. In both populations, males, in general, had more rugae when compared to females.

Reddy *et al.*[15] analyzed palatal rugae of North Indian, South Indian, and Chinese students in India. The most commonly occurring ruga patterns were wavy and curved. Curved rugae were predominant among North Indian students, while wavy rugae were predominant among South Indian and Chinese students. Indian students had mostly forwardly directed rugae, while the Chinese had both types. Significant differences were noticed between the Indian and Chinese study populations, suggesting the utility of rugoscopy for racial differentiation and identification.

The Indian and Nepali populations have been inter-compared concerning palatine rugae in former studies to assess the significance of palatoscopy in racial identification. Kallianpur *et al.*[16] compared the Indians and Nepalis based on parameters like face height, arch length, and palatal ruga patterns. Contrary to results obtained in the present study, they found a statistically significant interrelation between ruga patterns and ethnicity. Rugae with straight shape were more prevalent in Nepalis than in Indians. Also, the secondary and fragmentary rugae were higher in number in the Nepali population than those in Indian population. More *et al.*[17] analyzed palatine rugae patterns among Indians and Nepalis. Contrary to the present study, straight type and backwardly directed rugae were more common in both groups. Intergroup comparisons, however, similar to the present study, were non-significant.

The Indian population in both Indo-Nepali comparative studies above included Indians in general (Indo-Aryans and Dravidians predominantly) and was not confined to North-east Indians (Indo-Aryan and Indo-Mongoloids predominantly) as in the present study.

This might be a probable explanation for the disparity of results obtained in the present study in comparison to the past Indo-Nepali studies. Literature review revealed no studies in the past that inter-compared palatine rugae among the North-east Indian and Nepali populations.

The eight states of the North-east form the easternmost extent of the nation. Land-locked and sharing penetrable borders with Bangladesh, Nepal, Myanmar, Bhutan, and China, North-east India is linked with the country by the slender 'Siliguri neck'[18]. Porous borders with surrounding countries have favored migration and assimilation of people of different origins over the years (the Mongoloids, Austrics, Negriots, and Aryans) in the North-east[7]. Indo-Aryan and Mongoloid migrants have inhabited this region since pre-historic ages. Indo-Aryans have migrated from the Indian mainland, while the Mongoloids in the North-east have migrated from Southeast Asian countries via the Tibeto-Chinese and the Burmese trade routes[18].

Located at the Himalayan foothills, Nepal has been an assimilation ground for migrants from South-east Asia and India[6]. The Nepali population comprises majorly Indo-Aryans from the Indian mainland and the mongoloids from Tibet and Burma. The Indian population in both Indo-Nepali comparative studies above included Indians in general (Indo-Aryans and Dravidians predominantly) and was not confined to North-east Indians (Indo-Aryan and Indo-Mongoloids predominantly) as in the present study. This might be a probable explanation for the disparity of results obtained in the present study in comparison to the past Indo-Nepali studies. Literature review revealed no studies in the past that inter-compared palatine rugae among the North-east Indian and Nepali populations.

Major migration of Nepalis in North-east India started in the early 19th century with the employment of Gorkhas in the British colonial army. It is believed that, after years of assimilation, ancestors of inhabitants of Nepal and the North-east India region have roots in South-east Asia[19].

Migrations from South-east Asia have influenced both populations evaluated in the present study. Microsatellite indicators have been used in the past to assess the genetic constitution of the Gorkhas. The study showed genetic similarity among the Gorkha and the Tibeto-Burman populations, thus, proving the Mongolian and/or Tibeto-Burman ancestry of the Gorkhas[20]. HLA-A and B antigens were analyzed to demonstrate the genetic similarity of the Gorkhas with that of Mongoloids[21]. Similar HLA comparative studies have shown the genetic affinity of North-east Indians with the Mongoloids from south-east Asia[22]. The Gorkha and North-east Indian populations, both having genetic similarities with the Mongoloids, are two distinct social categories in India. Methods to differentiate between the two populations are, thus, sought to enable forensic identification.

The present study was a step towards the development of a discriminant function utilizing palatoscopy as a tool. Based on the conclusions of this study, palatoscopy independently was not able to differentiate between individuals of the two test populations. Studies with larger representation of the target populations are required to verify or contradict the results of this study. The conclusions of the present investigation indicate that the two populations are comparable with regard to palatal rugae. Methodologies apart from or in conjunction with palatoscopy should be considered to allow discrimination between the test populations. Genetic studies, though are the gold standard for identification, are expensive and are not feasible in small dental setups. Simple and easy to record methods such as cheilioscopy, palatoscopy, and intraoral photography should be practiced; the consolidated dental and orofacial database thus developed should be maintained by dental practitioners for future reference.

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