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RUGAE ANALYSIS: AID IN FORENSIC ODONTOLOGY-A REVIEW

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ABSTRACT

Identification is essential not only for legal but also for humanitarian grounds. In situations where finger print, dental records or biometric examination of teeth pose a difficulty in arriving to confirmatory conclusion, palatal rugae analysis can act as useful adjunct in human identification. Palatal rugae analysis (Rugoscopy) can take center-stage in certain situation such as when edentulous person's identity is concerned. In the present review, an overview of palatal rugae and its analysis along with its application in forensic odontology has been disussed.

KEYWORDS: Palatal rugae, rugoscopy, palatoprints, forensic odontology.

INTRODUCTION

Forensic odontology is an important branch of forensic sciences. Over the past few decades, forensic odontology has shown incredible growth and has achieved key position in the investigations. Forensic odontology plays an important role in the establishment of an identity of a person or human skeletal remains by dental means. The word forensic is derived

from Latin word forensis, which means before the forum (court of law) and odontology refers to the study of teeth.[1]

The apprehension and subsequent prosecution of the perpetrator(s) is essential to maintain law and order. Through the specialty of forensic odontology, dentistry plays a significant role in this process.[2] Forensic odontology is the practice related to law. It can be considered as an area of specialization under dentistry as well as forensic medicine because knowledge of both the fields is vital for its activities.[3] Apart from teeth and their restorations, soft tissues of oral cavity may help for personal identification. Anatomical structures like rugae, lip prints remain constant and this could be added in the ante-mortem records.

Rugoscopy

Palatal rugae are the ridges situated in the anterior part of the palatal mucosa on each side of the median palatal raphae and behind the incisive papilla. Rugae patterns have been studied for various purposes, published reports being mainly in the fields of anthropology, comparative anatomy, genetics, forensic odontology, prosthodontics and orthodontics.[4] Kuppler suggested the use of Palatal rugae as a method of identification for the first time as early as 1897.[5] Goria first defined the rugae as the ridges that extend at least one-half the distance from the median palatal raphae to the dental arch.[6] Trobo Hermosa, a Spanish investigator was the first to introduce palatal rugoscopy.[7] Brinon, divided palatal rugae into two groups (fundamental and specific) in a similar way to that with the fingerprint.[5] Rugoscopy can play a crucial role in cases where there are no fingers/ fingerprint data to be studied.[8]

The advantages of palatal rugae as an ideal method of post mortem identification include:

1. They are protected from trauma by their anatomical location. Also, they are insulated from heat by the tongue and buccal fat pads
2. No two palates are alike in their configuration.
3. Palatoprints do not change during growth.

Palatal rugae on maxillary cast.

Development of palatal rugae

A histological study of the development of palatal rugae in mice has shown that they develop as localized regions of epithelial proliferation and thickening even before the elevation of the palatal shelves. Subsequently, fibroblasts and collagen fibers accumulate in the connective tissue beneath the thickened epithelium and then assume a distinctive orientation. The collagen fibers running antero-posteriorly within the curve and in concentric curves across the base of each rugae determine the orientation of the rugae.[9]

The rugae are first seen in the intra-uterine life formed by 12th to 14th week of prenatal life and remains stable throughout the life, until the oral mucosa degenerates, up to 7 days after death[10] & thus can be utilized for personal identification[11] In human embryos, rugae are relatively prominent and occupy most of the length of the palatal shelves at the time of their elevation.[12] At the 550 mm stage of embryonic development, there are five to seven rather symmetrically disposed ridges, with the anterior ones beginning at the raphae, the others more laterally. Towards the end of intra-uterine life, the pattern of rugae becomes less regular, posterior ones disappearing and those anterior become considerably more pronounced and compressed. The development and differentiation of rugae are more advanced in rats than humans and while they are probably involved in oral function in animals, rugae seem to be attenuating in humans.[6]

Classification of rugae

The first ever classification on rugae pattern was put forth by Goria in 1911. According to him rugae pattern was categorized in two ways: the number of rugae and the extent of the rugae area relative to the teeth. In this system, compound rugae of two or more branches were counted as one. Goria further distinguished two types: simple or primitive and more developed.[13]

Lysell in the year 1955 [14] put forth classification that has been used widely in rugae based researches. It is comprehensive and includes the incisive papillae. Rugae are measured in a straight line between the origin and termination and are grouped into three categories:

1. Primary: 5 millimeters or more.
2. Secondary: 3 to 5 mm.
3. Fragmentary: 2 to 3 mm.

Rugae smaller than 2 mm are disregarded

This was rather a simple classification. Thomas and Kotze modified this classification and added specification as **branched, unified, cross-linked, annular, and papillary.**[15]

Lo pez de Leone classification (1924)[5,8]

This classification is no longer in use now. The author proposed the existence of a link between a person's personality and palatal rugae morphology. In this manner, there were four known types of palatal rugae: **B— bilious personality rugae; N—nervous personality rugae; S—sanguinary personality rugae; L—lymphatic personality rugae**. The letters B, N, L, and S, stand for the different personalities. The letters l and r stand for the left and right side of the palate, and are followed by a number, which specifies the palatal rugae number on each side.

Trobo classification (1932)[5,8]

This classification also divides rugae into two groups: Simple rugae, classified from A to F and composed rugae, classified with the letter X. Composed rugae result from two or more simple rugae unions. The rugogram is made from right to left, beginning with the principal rugae (the one closest to the raphae), which is classified with a capital letter. The following rugae are classified with small letters. Finally, the left side of the palate is described using the same criteria (Table-1).

Carrea classification (1937)[5,8]

In this classification, the author divides palatal rugae into four different types, as shown in below **(Table 2)**. Palatal rugae are classified only according to their form and no formula (rugogram) is developed.

De Silva Classification (1938)[5,8]

In this classification, palatal rugae are divided into two groups: simple, from 1 to 6 and compound, resulting from two or more simple rugae. They are named according to each rugae number. Although it is possible to classify each rugae individually (describing its form), but also to describe all the palatal rugae system (describing each rugae type number), making this a difficult classification to be used. **(Table-3)**

Martins dos Santos classification (1946)[5,8]

Santos presented a practical classification based on rugae location. This classification indicates and characterizes the following:

1. One Initial rugae; the most anterior one on the right side is represented by a capital letter.
2. Several complementary rugae; the other right rugae are represented by numbers.
3. One sub-initial rugae; the most anterior one on the left side is represented by a capital letter.

Several sub-complimentary rugae; the other left rugae are represented by numbers.

Cormoy System[5,8]

This system classifies palatal rugae according to their size:

1. Principal rugae (over 5 mm in length).
2. Accessory rugae (ranging from 3 to 4 mm in length).
3. Fragmental rugae (with less than 3 mm length).

The form (line, curve, and angle), origin (medial extremity) and direction of each rugae are also described. Possible ramifications are also pointed out. Rugae that share the same origin, interrupted rugae and the incisive papilla are described as well. It is a very complete system. However, its use does not lead to rugogram elaboration, which makes the managing and processing of data difficult.

Basauri classification (1961)[5,8]

Like the Trobo classification, this is a very easy classification to use. It distinguishes between the principal rugae, which is the more anterior one (labelled with letters) and the accessory

rugae, which concerns all the remaining rugae (labelled with numbers). The rugogram is elaborated beginning from the right side of the palate. **(Table-5).**

Thomas and Kotze classification (1983)[15]

Rugae length is recorded under magnification with a slide caliper to an accuracy of 0.05 mm following the descriptions of **Thomas and Kotze**. Having determined the length of all the rugae, three categories were formed:

1. Primary rugae: (A-5 to 10 mm; B-10 mm or more)
2. Secondary rugae: 3-5 mm
3. Fragmentary rugae: less than 3 mm.

Shape of rugae

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; however, if there was a slight curve at the origin or termination of curved rugae it was classified as wavy. To be classified as circular, rugae needed to display a definite continuous ring formation.[9]

Direction of rugae

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 but immediately diverged were classified as diverging. Rugae with different origins, which join on their lateral portions, were classified as converging.[9]

Analysis of rugae pattern

Methodology

The uniqueness and stability of palatal rugae makes it one of the suitable landmarks in forensic identification. Thomas and Van Wyk initiated identification of a severely burnt body by comparing the rugae to the pattern on the victim's old denture.[16] Muthusubramanian et al. examined subjects with pan facial third-degree burns within 72 hours after their accident and concluded that the palatine rugae could be used as a reference landmark during forensic identification of an individual.[17]

For examination of palatal rugae, Intraoral examination is considered as easiest and cheapest method of identification however; future comparison becomes difficult with this method. Oral Impression and photography makes future comparison possible. An overlay print of maxillary cast, that is, Calcurorrugoscopy used for comparing rugae pattern. This is most reliable technique and is widely used because it is less complex and cost effective. Other complex techniques are also available, which includes Stereoscopy through which three-dimensional image of palatal rugae can be obtained for analysis. Another technique is the sterophotogrammetry, which records length and position of palatal special device called Traster marker, allows for an accurate determination of the length and position of every single palatal rugae.[5]

Software based analysis, which is recent in trends, eases data management, online access and free availability of the program. Lorton described in detail about Computer Assisted Post-Mortem Identification System (CAPMI) software. Currently, the principal computer programs are **CAPMI4 and WinID2**.[10] The results can be enhanced by the use of computer software such as **Adobe Photoshop**.[4] Computer software programs such as **RUGFP-ID** match are available for palatal rugae analysis.[1] Limsons and Julian, studied rugae pattern using computer software, reported that the percentage of correct matches ranged from 92 to 97% based on four computer operators.[18]

Ethinic Effect

There seems to be a significant association between rugae forms and ethnicity. Earlier studies performed by Hauser to determine rugae patterns in two genetically and environmentally distinct populations (Swazis and Greeks) showed that the distribution of the number of main ridges in Swazi was significantly different from that among the Greeks, with a greater proportion of Swazi having higher main ridge numbers.[19]

In a study done by Sunita Kapali *et.al.* on rugae patterns in Australian Aborigines and Caucasians, found that the total number of rugae did not change throughout early childhood and adolescence. This study showed that the number of primary rugae in Australian Aborigines was found to be higher than Caucasians. Caucasians tended to show a higher proportion of rugae that are longer than 10mm compared with Aborigines. Analysis of the number of aboriginal primary rugae failed to reveal any significant differences between sides or sexes.[9]

Kashima compared the palatine rugae and shape of the hard palate in Japanese and Indian children. They found that Japanese children had more primary rugae than Indian children, but both groups had the same number of transverse palatine rugae. Also, the two groups differed with regard to primary rugae shapes, the posterior boundary of the rugal zone, and the number and position of the secondary and fragmentary rugae. The palatal raphae of the Japanese children were wider than those Indian children.[20]

Shetty *et.al.* compared rugae pattern in Indian and Tibetian population and reported that the former have significantly higher number of curved rugae while the latter have a higher number of wavy rugae.[21]

Other studies carried out amongst geographically different regions in India such as between Southern and Western regions[22], between Madhya Pradesh and Kerala[23], Karnataka and Manipur[24] found significant difference in rugae pattern.

Age changes in rugae pattern

Hauser *et.al.* suggested that mean rugae count increases markedly from the age of 35 to 40 years.[19] In contrast, Lysell in his study suggested that the total number of rugae remains unchanged upto the age of 23 years and decreases thereafter. In the same study, qualitative changes in rugae that were studied included shape, direction and unification. Although minor changes were noted, only 32 % of rugae changed shape. The subjects were studied where palatal growth, tooth loss and tooth movement were all taking place (changes from primary, through mixed, to permanent dentition), the incidence of change in rugae shape was low.[14]

It seems that the age related primary changes in rugae is limited to the change in their length only. If rugae development is coordinated with differential growth of the palate, it is likely that palatal changes would only affect direction of rugae but not the shape. Studies are

required to overcome this less understood phenomenon; Different regions of palate could be identified according to their pattern of growth and the effect of growth changes on rugae that lie within these zones.[9]

At present, it is unclear whether age changes of palatal rugae are governed by different underlying factors, for eg. rate of cell division during the embryonic period or co-ordination with palatal growth and development later in life.[9]

Gender effect on rugae pattern

Dohke and Osato reported fewer rugae on the right side of the palate than the left, and that females had fewer rugae than males. Dohke and Osato claim that this was due to the phenomenon of regressive evolution dominating the right side of the palate and being more evident in females.[25]

Kapali *et. al.* observed no significant difference in different gender population. Another study was conducted among 120 samples (60 males and 60 females) to identify sexual differences in the palatal rugae pattern and sexual dimorphism was found in the shape of the palatal rugae. No significant differences were observed in the number and the length of the palatal rugae.[26]

Challenges

Rugoscopy might not be so useful in crime scene investigations in the linking of suspects to crime scenes as this form of evidence is highly unlikely to be found at crime scenes.[5] Another hurdle with palatal rugae analysis is possibility of rugae pattern forgery. In a case report, Gitto *et. al.* described a method where palatal rugae were added to a complete denture in order to improve speech patterns in some patients.[27] This process can lead to false identity exclusion due to misleading ante-mortem data.

Thomas and Kotze noted that although primary rugae have been more widely studied than secondary and tertiary rugae, they do not possess strong discriminatory ability between different human populations.[15] Apart from problems of intra-observer discrepancies in reading rugae patterns, there is no doubt that even greater discrepancies could exist between observers the existence of this unreliability brings into question the present usefulness of descriptive rugoscopy in fields such as forensic science.

Table-1 (Trobo classification).

Types	Rugae pattern
Type- A	Point
Type-B	Line
Type-C	Curve
Type-D	Angle
Type-E	Sinuous
Type-F	Circle

Table-2 (Carrea classification).

Types	Direction of rugae pattern
Type I	Posterior anterior directed rugae
Type II	Rugae perpendicular to raphae
Type III	Anterior posterior directed rugae
Type IV	Rugae directed in several directions

Table-3 (De-Silva classification).

Types	Rugae Pattern
1	Line
2	Curve
3	Angle
4	Circle
5	Wavy
6	POINT

Table-4 (Martins dos Santos classification).

Rugae pattern	ANTERIOR POSITION	OTHER POSITIONS
Point	P	0
Line	L	1
Curve	C	2
Angle	A	3
Circle	C	4
Sinuous	S	5
Bifurcated	B	6
Trifurcated	T	7
Interrupt	I	8
Anamoly	An	9

Table-5 (Basauri classification).

Principal rugae pattern	Accesory rugae pattern	Rugae anatomy
A	1	Point
B	2	Line
C	3	Angle
D	4	Sinuous
E	5	Curve
F	6	Circle
X	7	Polymorphic

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