Review Article

JRAD Journal of Research and Advancement in Dentistry

J Res Adv Dent 2016;5:2:210-218.

Significance of Rugoscopy: A Review

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ABSTRACT

Background: Palatal rugae are irregular, asymmetric ridges of the mucous membrane extending laterally from the incisive papilla and the anterior part of the palatal raphe. Palatal rugae patterns are relatively unique to an individual and are well protected by the lips, buccal pad of fat and teeth. They are considered to be stable throughout life following completion of growth & thus, suggest their use for forensic identification. The purpose of this paper is to identify / recognize the role of dentist as a helping hand in the identification of an individual after a thorough study of one's rugae pattern. Information was collected from scientific articles published on the databases SciELO, MEDLINE and PUBMED in last 25 years, as well as technical books and guidelines of international committees.

Keywords: Palatal Rugae, Human identification, Rugoscopy.

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]. Human identification has become fundamental in all aspects of human relationships, at both social and legal levels. Identification corresponds to a combination of different procedures to individualize a person or an object [2]. Transverse palatine folds or palatal rugae are asymmetrical and irregular elevations of the mucosa located in the anterior third of the palate, made from the lateral membrane of the incisive papilla, arranged in transverse direction from palatine raphe located in the mid-sagittal plane. These formations have been used in medicolegal identification processes because their individual morphological characteristics are stable over time [3].

According to the Glossary of Prosthodontic Terms, 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. They are also called "plica palatinae" or "rugae palatine [4]. Palatoscopy or palatal rugoscopy is the name given to the study of palatal rugae in order to establish a person's identity [5]. The palatal rugae appear towards the third month of intrauterine life, from the covering connective tissue in the palatine process of maxillary bone, and its development and growth is mutually controlled by epithelial-mesenchymal interactions, where specific extracellular matrix molecules are spatiotemporally expressed during development [6]. The first rugae is distinguished in

Received: Feb. 17, 2016: **Accepted**: Mar. 21, 2016
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pISSN 2278-0076
eISSN 2321-9270

human embryos of 32 mm next to the incisive papilla [7] and in the prenatal stage are relatively prominent [8]. The palatal rugae at birth are well trained with a typical orientation pattern and adolescence acquire the final feature shape of each individual [9]. Once they are formed thus, may experience changes in their size due to growth of the palate, but its shape is maintained [10].

Physiologically the palatal rugae are involved in the oral swallowing and help to improve the relationship between food and the taste receptors in the dorsal surface of the tongue, also participate in speech and suction in children [7]. The palatal rugae form elevations, more or less prominent and take various configurations. Its design and structure are unchanged and are not altered by chemicals, heat, disease or trauma, or, if palatal rugae are destroyed, are reproduced exactly on the same site [11]. Usually form, layout and characteristics are not affected by the eruption of the teeth or their loss, but sometimes palatal rugae adjacent to the alveolar arch slightly change their position after tooth extraction [12]. However, some events may contribute to changes in the pattern of palatal rugae, such as finger sucking in childhood and persistent pressure due to orthodontic treatment [13]. Overall palatal rugae has been considered relevant for human identification due to its stability, being equivalent to the fingerprint, unique for each individual [14]. Rugoscopy is also helpful in orthodontic and prosthodontic treatments and diagnosis of diseases.

Researchers have found the task of classification a difficult aspect of studying rugae. Most studies are based on the systems devised by Lysell [15] and Thomas and Kotze [16] although they may differ in detail. The subjective nature of observation and interpretation within and between observers poses a problem. Controversy still exists about the stability of quantitative and qualitative characteristics of rugae during growth, and the extent of differences between ethnic groups and sexes. Hauser et al. have suggested that mean rugae count changes moderately in adolescence, then increases markedly from the age of 35 to 40 years [17]. In contrast, Lysell considered that the number of rugae decreased from 23 years of age onwards [15]. English et al.[5] and Peavy and Kendrick[19] noted that the characteristic pattern of the palatal rugae did not change as a result of growth, remaining stable from time of development until the oral mucosa degenerated at death [18, 12]. However, some events can contribute to changes in rugae pattern, including trauma, extreme finger sucking in infancy, and persistent pressure with orthodontic treatment and dentures [15, 19].

It has been suggested that changes in the length of rugae with age result from underlying palatal growth [15, 17, 20], however, the anterior rugae do not increase in length after 10 years of age [21]. 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.

Twin studies have revealed that rugae patterns have an underlying genetic basis [15]. Thomas and Kotze were also able to discern different rugae patterns in southern African populations implying different genetic origins [22, 23, 24]

Historical review:

The earliest reference to rugae was In anatomy textbook y Winslow in 1732 and was first illustrated by Santorin In 1975 [18]. Harrison Allen I 1889 suggested that palatine rugae can be used as an alternative method for human identification [25]. Palatal Rugoscopy was first proposed in 1932, by a Spanish investigator called Trobo Hermosa [26]. In 1937, Carrea developed a detailed study and established a way to classify palatal rugae [26]. One year later, Da Silva proposed another classification and, in 1946, Martins dos Santos presented a practical classification based on rugae location. [27]

In 1983, Brinon, following the studies of Carrea, divided palatal rugae into two groups (fundamental and specific) in a similar way to that with the fingerprint. [27] In this manner, dactiloscopy and palatoscopy were united as similar methods based on the same scientific principles and are sometimes complimentary: for instance, palatoscopy can be of special interest in thus cases where there are no fingers to be studied (burned bodies or bodies in severe decomposition). [28]

Classification of rugae

The first system of classification was developed by Goria in 1911 and was rudimentary. He categorized rugae pattern in two ways: specifying the number of rugae and specifying the extent of the rugal zone relative to the teeth. In this system, compound rugae of two or more branches were counted as one, whether they were V- or Y-shaped. Goria further distinguished two types: simple or primitive and more developed.[29].

Lysell's[5] classification in 1955 is the most important, and has been used widely in research involving rugae [15]. 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:

Primary: 5 millimeters or more;

Secondary: 3 to 5 mm;

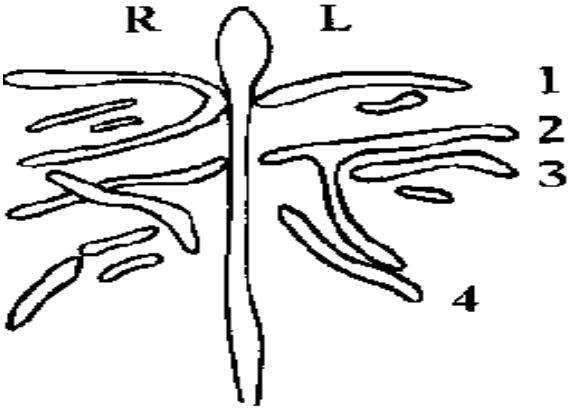
Fragmentary: 2 to 3 mm;

Rugae smaller than 2 mm are disregarded.

This is rather simplified picture of the intricate form that rugae usually present. Therefore, Thomas and Kotze have further detailed the various patterns of primary rugae. These include branched, unified, cross linked, annular, and papillary, among others [16].

In 1955, Carrea categorized four main types of rugae according to direction. They received roman numerals, while the sequence was indicated according to Arabic numerals and the shape denoted by letters [26]. The classification of rugae by Basauri consists of two groups: simple and compound. These, in turn, are subdivided into 10 types that describe particular shapes: 0, pointed; 1, straight; 2, curved; 3,angled; 4, sinuous; 5, circular; 6, Greek; 7, calyx shaped; 8, racket-shaped; 9, branched [30].

The classification by Lima consists of four main types: punctuate, straight, curved and composite [31]. This classification used to describe the rugae patterns was based on those described by Lysell [15] and Thomas and Kotze [16].



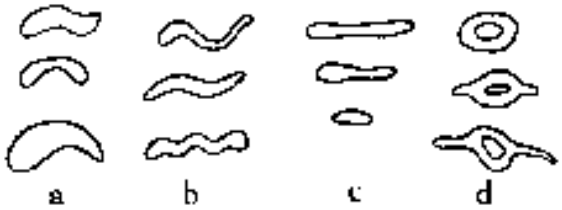
Rugae length was recorded under magnification with a slide calliper to an accuracy of 0.05 mm following the descriptions of Thomas and Kotze.[28] Having determined the length of all the rugae three categories were formed:

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. (All rugae more than 1 mm long were recorded under th fragmentary ruga category).

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 a 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 a curved rugae it was classified as wavy. To be classified as circular, a 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 but immediately diverged were classified as diverging. Rugae with different origins which joined on their lateral portions were classified as converging.

Trobo classified palatal rugae according to shape, number, size and position [32].

Shape analysis. The shape of the palatine rugae was registered according to the classification of Trobo [32]. This classification also divides rugae into two groups: Simple rugae, classified as ABCDEF, where rugae shapes are well defined, and Composed rugae, classified as type X, with a polymorphisms variety (these rugae composed result of the union of two or more simple rugae). Then he made a rugograma, from the right side and then the left side, starting with the main ruga (closest to the palatal raphe), which was classified with a capital letter, and then rugae were classified with lower case letters.

Fig 1: Calcorrugoscopy in plaster model

Number analysis. There were all palatal rugae that were totally bounded in calcorrugoscopy.

Size analysis. Using a digital caliper (0.01mm) found the maximum longitudinal diameter of all palatal rugae accounted, according to the corresponding type under the classification of shape.

Position analysis. To analyze the position of the palatal rugae were standardized photographs of models obtained and using Photoshop software (Adobe ® Photoshop ® CS4) palate was divided into quadrants, with the aim of obtaining the coordinates position of palatal rugae; for this, six horizontal lines:

I. Transverse line passing through the palatal cervical third of the central incisors.

II. Transversal line that goes from the mesial side of the right lateral incisor to the mesial side of the left lateral incisor.

III. Transverse line through the mesial side of the right canine and reaches to the mesial side of the left canine.

IV. Transverse line through the mesial side of the right first premolar and reaching to the mesial side of the left first premolar.

V. Transverse line through the mesial side of the right second premolar and reaching to the mesial side of the left second premolar.

VI. Transverse line through the distal side of the second premolar and reaching to the right side of the distal left second premolar.

Based on these lines between the areas they were named as follows:

A. Between lines I and II.

B. Between lines II and III.

C. Between lines III and IV.

D. Between lines IV and V.

E. Between lines V and VI.

Clinical significance of palatine rugae:

Landmark in orthodontic treatment: Dental casts are three dimensional (3-D) records of malocclusion that have been used successfully during diagnosis and treatment planning for orthodontic patients. The palatine rugae are unique to each patient and are reasonably stable during the patient's growth

thus, they may serve as suitable reference points from which the clinician can derive the reference planes necessary for longitudinal cast analysis. Positional changes of posterior teeth in the anteroposterior direction are relevant to the diagnosis and correction of sagittal occlusal abnormalities and arch length discrepancies. [21]

Hausser observed orthodontically treated patients and concluded that the lateral edges of the rugae moved forward about one half the distance of the migration of the adjacent teeth, while the medial rugae were not affected. [17] In a study of changes occurring in 15 patients who underwent extraction of four premolars, Peavy and Kendrick reported that the lateral ends of the rugae that terminated close to the teeth followed the movement of the teeth in the sagittal plane, but not in the transverse plane.[12] Van der Linden evaluated changes in the position of posterior teeth in relation to palatine rugae in 65 normally growing children (aged 6 to 16 years) and in six orthodontically treated patients. [21] The maximum mean change in distance between the rugae in the anteroposterior plane was 0.41 mm. The authors noted larger movements at both the medial and lateral rugae points in the orthodontically treated patients.

Shriram C Bansode et al. analyzed only some changes in the rugae pattern during orthodontic treatment by evaluating the preoperative and postoperative orthodontic casts of 60 patients. They also assessed that the morphology of palatal rugae remains stable throughout life and carefully assessed rugae pattern has definite role in forensic practice. [32]

Palatine rugae in speech and palatal prostheses: The significance of palatine rugae in relationship to speech has not been established. These characteristic soft-tissue ridges are present in all primates, and no experimental evidence exists to support their consideration as a speech organ. [33] Palatography has been used to determine the optimum thickness and shape of the palatal surfaces. This approach was developed in a study of phonetics to determine the contact position of the tongue relative to the palate in the production of specific sounds essentially, application of these techniques ensured contact between the tongue and palate during articulation of these sounds. [34] The "s" and "sh" phonemes have received particular attention. Palatography frequently has served as the basis for determining the shape of the anterior palatal vault most conducive to satisfactory sound articulation. [35]

Palatal vault shape: The shape of the palatal vault is of particular interest to prosthodontists. Snow described the significance of adequate but not excessive contour in the anterior palatal and premolar areas. Central and lateral lisping may develop when the contours of the prosthesis are incorrect. [36] Patients whose speech is sensitive to a changed relationship of the tongue to a palatal prosthesis may require surface texture to orient the tongue. The palatine rugae and the incisive papillae often can serve as a cue. [37] Because the lack of texture on the palatal portion of a complete denture can impede proper articulation, one solution is to add palatine rugae. Unfortunately, the addition of rugae to a prosthesis is not a fool proof method of eliminating speech problems. Landa reported that rugae in dentures are ineffectual or sometimes detrimental to speech if they add unnecessary thickness to the anterior palatal region. [38]

Antero-posterior tooth movement: Hoggan and Sadowsky investigated the use of the palatine rugae as reference points for measuring tooth movement in a manner comparable with cephalometric superimpositions. The authors evaluated the anteroposterior movement of the maxillary first molars and central incisors with the use of two cephalometric variables and six study model variables, and they combined the right and left sides of the palate. The results showed no statistical differences between the mean incisor and molar movement measured cephalometrically and the tooth movement measured relative to the medial and lateral end of the third palatine ruga. Thus, the authors concluded that palatine rugae could be used reliably to assess anteroposterior tooth movements. [39]

Palatine rugae in cleft palate patients: Early diagnosis of submucosal cleft palate is important. In children too young to tolerate nasendoscopy and video fluoroscopy, the diagnosis depends on the patient's clinical history and intraoral examination findings. Kratzsch and Opitz investigated the relationship of palatine rugae to points(landmarks)

and distances on the cleft palate during the period from birth to the time of early mixed dentition. [40] The authors identified changes in the distances from the lateral palatine rugae points of the first and third rugae to the incisal point, the canine point and the tuberosity line. The results of their study indicated that a comparison of distances from the palatine rugae with distances between equivalent points revealed the changes that occurred in the anterior palate during various stages of orthodontic therapy and growth.

Variation of rugae pattern in different ethnic groups: There seems to be a significant association between rugae forms and ethnicity. Kapali and colleagues studied the palatal rugae pattern in Australian Aborigines and whites. [41] They observed the number, length, shape, direction and unification of rugae. The authors concluded that the mean number of primary rugae in Australian Aborigines was higher than that in whites, although whites had more primary rugae that exceeded 10 mm in length. The most common shapes in both ethnic groups were wavy and curved forms, while straight and circular forms were least common.

Kashima compared the palatine rugae and shape of the hard palate in Japanese and Indian children. [42] They found the following: Japanese children had more primary rugae than did Indian children, but both groups had the same number of transverse palatine rugae. 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 of the Indian children. Both groups had many transverse palatine rugae on the left side of the palate. The posterior border of the rugal zone on the left side was shifted farther back than it was on the right side. There were no significant differences between the two sexes in either group. Shetty and colleagues compared the palatine rugae patterns I Indians with those in a Tibetan population. [43] The results of their study showed that males had more rugae on the right side than on the left side in both populations, Indian males had more primary rugae on the left side than did females and vice versa for the Tibetan population, and Indian males had more curved rugae than did Tibetan males.[50] Aparna Paliwal et al. compared the palatal rugae patterns in two different populations in India -Madhya Pradesh and Kerala. [44] The results showed that the straight rugae pattern on the right side of palate in the males was found to be significantly predominant in Madhya Pradesh population, whereas wavy shape was predominant in Keralites; however rugae patterns on the right side of the palate in female subjects exhibited no significant difference. [44]

Forensic identification: Establishment of person's identity can be a difficult task in cases of traffic accidents or acts of terrorism or in mass disaster situations. The application of palatal rugae patterns for personal identification was suggested by Allen in 1889. [25] Visual identification, use of dental records and fingerprints and DNA comparisons probably are the most common techniques used in this context, allowing fast and secure reliable identification. However, visual identification and use of fingerprints are limited by postmortem changes associated with time, temperature and humidity. [45] Although teeth are more durable than other parts of the body, identification via dental records also may prove to be inconclusive, because dental treatment might have been performed between the creation of a dental record and the person's death. Although DNA profiling is accurate, it is expensive and time consuming for use in large populations. It is a well-established fact that the rugae pattern is as unique to a human as are his or her fingerprints and it retains its shape throughout life. The anatomical position of the rugae inside the mouth—surrounded by cheeks, lips, tongue, buccal pad of fat, teeth and bone—keeps them well-protected from trauma and high temperatures. Thus, they can be used reliably as a reference landmark during forensic identification. Thomas and van Wyk successfully identified a severely burnt body by comparing the rugae to the pattern on the victim's old denture. [46]

Burn cases: Muthusubramanian et al. did a study to examine the extent of palatine rugae preservation for use as an identification tool in burn victims and cadavers, thus simulating forensic cases of incineration and decomposition. Patients with panfacial third-degree burns (full thickness burns characterized by multicolored denatured layers, dry and insensitive to pain involving skin, subcutaneous tissues, adnexal structures and nerves and that

usually require skin grafting) were examined within 72 hours after their accident. [14] In addition, human cadavers stored in a mortuary at 5°C with 30 to 40 percent relative humidity and kept for a minimum of seven days were assessed for the condition of the palatine rugae. The authors took photographs of the palatine rugae by using a palatal mirror. The study results showed that among the subjects with third-degree panfacial burns, 93 percent of the palatine rugae were normal. The authors observed no changes in the color or surface anatomy of the palatine rugae in 77 percent of the human cadavers. They concluded that the palatine rugae could be used as a reference landmark during forensic identification of an individual

The core with palatal rugae of humans contain elements that are believed to contribute to the maintenance of its shape the main structure element contains glycosaminoglycans which by hydrophilic nature crosses the tissue to swell and contributes to the maintenance of the shape of rugae throughout life fibroblast and collagen fibers beneath the thickened epithelium contribute to the stability of palatal rugae.

In light of these results, we strongly suggest that palatal rugae patterns can be used in forensic science and also for ante mortem and postmortem identification.

However, we suggest that further studies should be conducted on a large no. of individuals of different races, family members, also a standard and uniform procedure needs to be put forth for the collection , recording and computerized analysis of palatal rugae.

CONCLUSION

Located in the anterior half of the roof of the mouth, palatal rugae serve as a reference landmark in various dental treatment modalities and could be used in the identification of submucosal clefts. Palatine rugae can be used to assess the amount of anteroposterior tooth movement, because they remain stable during a person's life. Moreover, the results of several studies show a significant association between rugae forms and different races. Palatine rugae are unique to individual can therefore be used for individual identification in forensic odontology.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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