REVIEW ARTICLE

Significance of Palatal Rugae in Orthodontics

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ABSTRACT

The palatine rugae have interested orthodontists not only because of their typical pattern of orientation but also because of their usefulness as a reference landmark in various dental treatment modalities. The pattern of orientation is formed by the 12th to 14th weeks of prenatal life and remains stable until the oral mucosa degenerates after death. The palatine rugae possess unique characteristics that could be used in circumstances in which it is difficult to identify a dead person according to fingerprints or dental records. Palatine rugae are permanent and unique to each person, and clinicians and scientists can use them to establish identity through discrimination. If particular rugae patterns could be established for different ethnic groups, they would assist the forensic odontologist in the identification of a person. Because they are a stable landmark, the palatine rugae also can play a significant role in clinical orthodontics.

Keywords: Palatal rugae, Growth, Orthodontic.

How to cite this article: Sivaraj A. Significance of Palatal Rugae in Orthodontics. J Orofac Res 2013;3(3):202-209.

Source of support: Nil

Conflict of interest: None declared

INTRODUCTION

Palatal rugae (PR) or transverse palatine folds 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 midsagittal plane. The earliest references to the palatine rugae are found in various books about general anatomy. Winslow was the first person to describe them. These formations have been used in medicolegal identification processes because of their individual morphological characteristics and stability overtime.[1-4]

As early as 1955, Lysell[5] suggested that the palatine rugae might possess unique characteristics that could be used in paternity identification. However, to date, the study of palatine rugae has not been extensive. The purpose of this article is to review the literature concerning palatine rugae and discuss their significance in orthodontics.

DEVELOPMENT

The palatal rugae appear toward the third month of intrauterine life, from the covering connective tissue in the palatine process of maxillary bone. Its development and growth are mutually controlled by epithelial-mesenchymal interactions, where specific extracellular matrix molecules are spatiotemporally expressed during development. The first rugae is distinguished in human embryos of 32 mm CRL (Butchtová et al, 2003)[6] next to the incisive papilla. Then, in the prenatal stage are relatively prominent (Waterman and Meller, 1974),[7] the palatal rugae are well organized at birth with a typical orientation pattern and adolescence acquire the final feature shape of each individual (Yamazaki, 1962).[8] Once they are formed they may experience changes in their size due to growth of the palate, but its shape is maintained after growth is completed (Jordanov, 1971, Lang and Baumeister, 1984).[9,10]

PHYSIOLOGY

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 (Buchtová et al),[6] it also participated in speech and in the suction in children (Thomas et al, 1987).[11]

The number of rugae on each side of the palate varies between three and five. The palatine rugae do not extend posteriorly beyond the anterior half of the hard palate, and they never cross the midline. The anterior rugae usually are more prominent than the posterior rugae as depicted in Figure 1. Two-third of the rugae are curved and the rest are angular. The last rugae frequently are divided; the medial and lateral parts are not connected and do not continue in their axial orientation. Fragmentary rugae frequently are present, particularly in the posterior half of the rugae territory. The shape, length, width, prominence, number and orientation of palatine rugae vary considerably among people. Variation also exists, although to a lesser extent, in the left and right sides of the same person. The inclination of the rugae to the

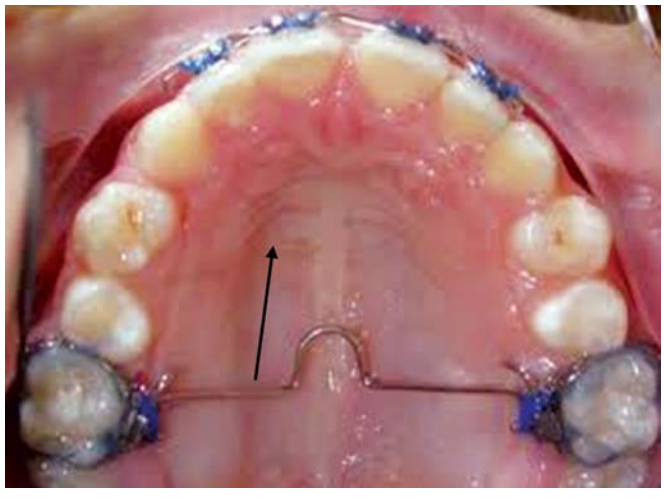

Fig. 1: Palatal rugae

sagittal plane can differ markedly between both sides. In general, no bilateral symmetry exists in the rugae pattern.

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. If palatal rugae are destroyed, are reproduced exactly on the same site that had been destroyed (Almeida et al, 1995).[12] 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 (Peavy and Kendrick, 1967).[13] 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. Furthermore, it has been reported that extractions can produce a local effect on the direction of the palatal rugae (Limson and Julian, 2004).[14]

CLASSIFICATION OF PALATINE RUGAE

The first system of classification was developed by Goria,[15] in 1911 and was rudimentary. The rugae pattern was categorized 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.

Lysell's[5] classification in 1955 is the most important, and it has been used widely in research involving rugae. It is comprehensive and includes the incisive papilla. Rugae are measured in a straight line between the origin and termination and are grouped into three categories:

1. Primary: 5 mm or more (>5 mm);
2. Secondary: 3 to 5 mm;
3. Fragmentary: 2 to 3 mm.

Rugae smaller than 2 mm are disregarded.

The rugae on both sides of the palate are numbered separately from anterior to posterior and classified according to shape, position or origin in relation to the median palatal raphae.

Three categories of unification are recognized in this system:

- Common origin diverging laterally;
- Separate origins converging laterally;
- Separate origins converging laterally but involving one primary and one secondary ruga.

Branching, breaks, papillations, annular formations and spirals are counted, while the rugae directions are measured in degrees relative to the median palatal raphae. The clinician observes the distribution of secondary and fragmentary rugae by noting their proximity to the nearest primary ruga while observing the posterior border relationship with the teeth. The clinician measures the incisive papilla and classifies it according to one of seven shapes.

Carrea[16] 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.

The classification by Basauri[17] 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.

The classification by Lima[18] consists of four main types: punctate, straight, curved and composite.

Each type has a numerical and an alphabetical symbol, one denoting shape and the other position. The author reported that this classification is usable in forensic work when it is part of the identification tetralogy: dactyloscopy, odontoscopy, rugoscopy and hematography.

Caruso[19] subdivided the rugae morphology into lineomorphism and configuration. He noted the volume, direction and number of rugae, along with the relationship between their distal margin and the teeth.

Tzatscheva and Jordanov[20] classified rugae according to their direction, branching, symmetry and radiality. They counted the number of rugae, but if the rugae formed a network, the authors noted this as such.

Thomas[21] used Lysell's classification with minor variations. He added features such as crosslinks. Thomas and Kotze[22] presented a detailed classification of the palatine rugae, as follows.

RUGAE DIMENSIONS AND PREVALENCE

Length: Length is determined according to the greatest rugal dimension, and the rugae are classified according to the system established by Lysell (that is, primary, secondary or fragmentary).

Prevalence: The clinician does not count the total number of rugae on each side of the palate, but he or she counts and records the number in each category (that is, primary, secondary or fragmentary).

Area: The clinician photographs the palate to determine the surface area of the primary rugae.

Annular rugae: To be considered annular, the rugae must form a definite ring.

Papillary rugae: A ruga is termed 'papillate' when three or more clefts traverse the ruga at any depth, but not down to the surrounding mucosal surface.

Crosslink: This is a small ruga that is a distinct entity and joins two rugae, usually at a right angle.

Branches: A branch extends 1 mm or more from its origin (that is, the parent ruga) in a lateral direction.

Unification: This process occurs when two primary rugae are joined at their origination points and then diverge laterally.

Breaks: If a papillation cleft extends down to the level of the surrounding epithelium (less than 1 mm), it becomes a break.

Unification with nonprimary rugae: This is a convex or concave unification of a primary ruga and a ruga that is between 1 and 5 mm in length.

Rugae pattern dimensions: Incisive papilla to anterior-most point (AP) (IP-AP). This is the distance between the most anterior point on the incisive papilla and the most anterior point on the rugae pattern, regardless of side (Fig. 2).

Incisive papilla to posterior border of last primary or secondary ruga (PB3) (IP-PB3): This is the distance between the incisive papilla and the most posterior point on the last primary or secondary ruga (Fig. 3) (a-c).

Incisive papilla to posterior border of last ruga (PBA) (IP-PBA): This is the distance between the Incisive papilla and the most posterior point on the last ruga (including fragmentary rugae) (Fig. 3) (a-d).

Angle of divergence: The clinician measures the angle of divergence of the rugae pattern in degrees between the line formed by the median palatal raphae and the line joining the incisive papilla with the origin of the most posterior primary or secondary ruga on one side of the palate. He or she measures the angle of divergence for the other side in the same manner.

Dental arch and palate dimensions: Width [mesiopalatal cusp of first permanent molar (MP6)–MP6 or mesiopalatal cusp of second primary molar (MPE)–MPE]. A line joining the tips of the mesiopalatal cusp of the first permanent molars

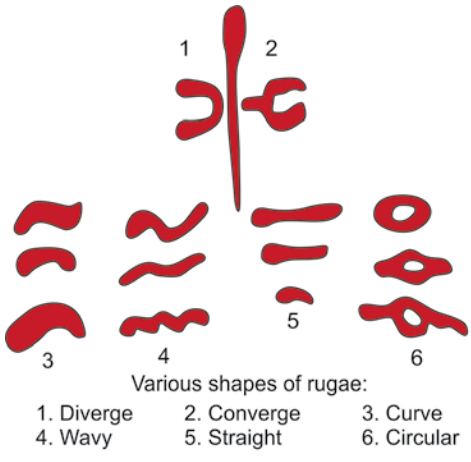

Fig. 2: Various shapes of rugae

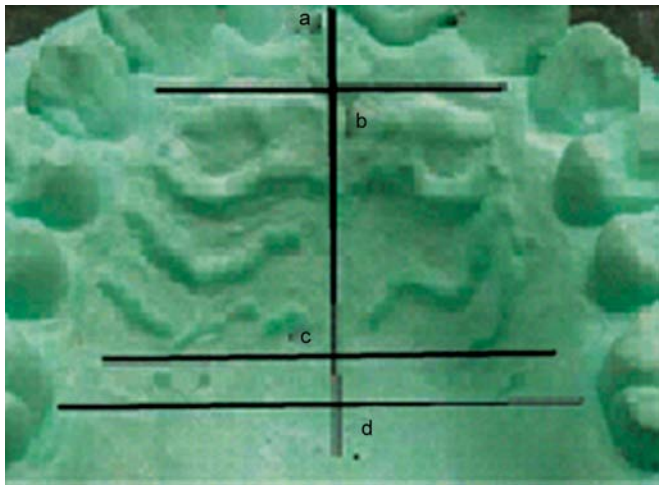

Fig. 3: Rugae pattern dimensions

or, if these are absent, of the second primary molars is used to project a point below and perpendicular to it (at a right angle to the occlusal plane) on the gingival margin. This point is labeled MP6 or MPE, respectively, and the clinician measures the distance between the points on both sides of the palate (Figure 4) (a-b).

Depth: [median palatal raphae in relation to first permanent molar (MR6)–MP6 or median palatal raphae in relation to second primary molar (MRE)–MPE]: The same intercuspal line for the width (above) is used to project a point below and perpendicular to it on the median palatal raphae (MR6 or MRE). The clinician then measures the distance between MP6 and MR6 or between MPE and MRE (Fig. 4) (a-c, b-c).

Center: This is the perpendicular distance between the line MP6 to MP6 and the point MR6 (Figure 4) (d-c).

The palatal rugae has been considered relevant for human identification due to its stable (Muthusubramanian et al, 2005),[23] being equivalent to the fingerprint, unique for each individual (Limson and Julian),[14] this study on the identification of persons is called palatoscopy or palate rugoscopy (Caldas et al).[3] However, analysis of their shapes and dimensions are poorly described. This classification also divides rugae into two groups: Simple rugae, classified as ABCDEF, where rugaes shapes are well defined, and

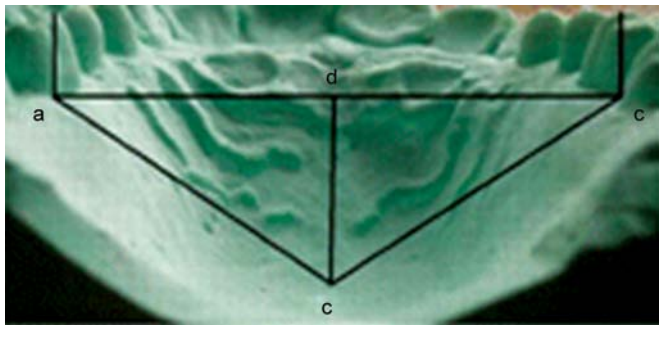

Fig. 4: Dental arch and palate dimensions

composed rugae, classified as type X, with a polymorphisms variety (these rugaes are composed as a result of the union of two or more simple rugaes). This classification is in Table 1. 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.

Number analysis: There were all palatal rugae that were totally bounded in calcorrugoscopy (Fig. 5).

Size analysis: Using a digital caliper (0.01 mm) find the maximum longitudinal diameter of all palatal rugae accounted, according to the corresponding type under the classification of shape (Fig. 6).

Position analysis: To analyze the position of the palatal rugae, standardized photographs of models were obtained and palate was divided into quadrants, with the aim of obtaining the coordinates position of palatal rugae; for this, six horizontal lines are drawn as follows:

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

Fig. 5: Outline of palatal rugae in study model

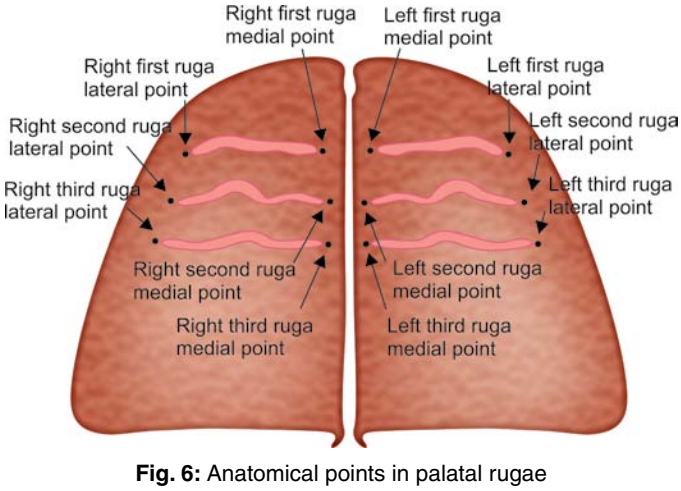

Fig. 6: Anatomical points in palatal rugae

Table 1: Classification of palatal rugae

Classification	*Rugae type*	*Shape*
Type A	Point	
Type B	Line	
Type C	Curve	
Type D	Angle	
Type E	Sinuous	
Type F	Circle	

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.

VARIATION OF RUGAE PATTERN IN DIFFERENT ETHNIC GROUPS

There seems to be a significant association between rugae forms and ethnicity. Kapali et al[24] studied the palatal rugae pattern in Australian Aborigines and Whites. 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[25] compared the palatine rugae and shape of the hard palate in Japanese and Indian children. 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 et al[26] compared the palatine rugae patterns in Indians with those in a Tibetan population. 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.

ORTHODONTIC STUDIES ON PALATAL RUGAE

Bailey et al,[27] studied to determine whether the positions of the palatal rugae were affected by orthodontic therapy, pre- and post-treatment maxillary dental casts of 57 adult patients treated were evaluated. Transverse changes observed overtime were significantly different from zero only for the medial points of the first rugae in the nonextraction group and for the lateral points of the first rugae in the extraction group. None of the changes observed in the transverse measures were statistically different between the two groups. The medial and lateral points of the third rugae appear to be stable landmarks for the construction of anatomic reference points in longitudinal cast analysis (Fig. 7).

Reuer,[28] aimed to evaluate the stability of the palatal rugae area before and after orthodontic treatment, and to suggest whether it could be used in superimposition in order to analyze orthodontic treatment change. The casts were scanned and analyzed. The most reliable points were found to be the lateral third rugae points, which could be used as reference points for cast superimposition.

Almeida et al,[12] studied to determine if the palatal rugae are stable during normal growth, and whether treatment

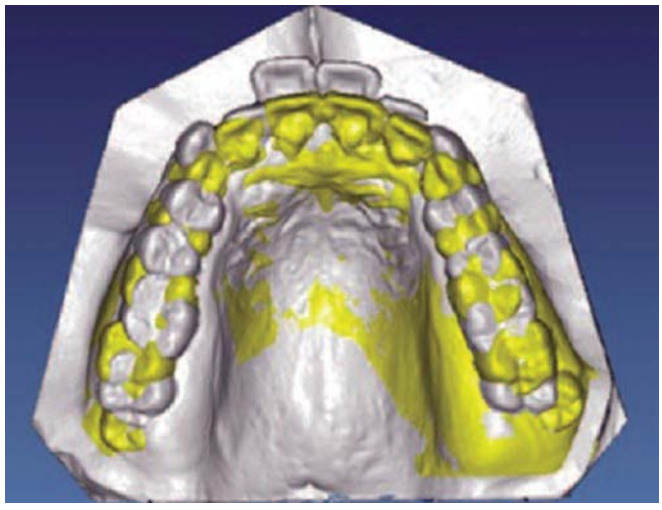

Fig. 7: Rugal superimposition of pre- and postorthodontic treatment study models

with either headgear or functional appliances affects the position of the rugae. Landmarks on the palatal raphe and palatal rugae were recorded using the reflex metrograph. A median palatal plane was constructed using the digitized raphe points as reference. Offsets from this plane to the ruga points and transverse and anteroposterior linear distances between ruga points were obtained for all casts. Transverse offsets and linear distances between medial points of the first rugae and the anteroposterior distances between the medial points of the second and third rugae did not show statistically significant changes in all groups. Significant changes were observed for the lateral points of the rugae, particularly in the headgear group. The medial rugae appear to be suitable anatomic points for the construction of stable reference planes for longitudinal cast analysis.

Brent R Hoggan and Cyril Sadowsky[29] evaluated the use of palatal rugae as reference points for the measurement of tooth movement, in a manner comparable with cephalometric superimpositions. The sample consisted of pretreatment and post-treatment maxillary study models and lateral cephalometric radiographs from 33 patients who had received orthodontic treatment that involved the extraction of the maxillary first permanent premolars. No statistical differences were found between the mean molar movement that was measured cephalometrically and the mean molar movement that was relative to the medial and lateral ends of the first and second palatal rugae or relative to the medial end of the third palatal ruga. Also, no statistical differences were found between the mean incisor movement that was measured cephalometrically and the mean incisor movement that was relative to the medial and lateral end of the third palatal ruga. These findings suggest that ruga landmarks can be used as reliably as cephalometric superimpositions to assess anteroposterior molar movements (Fig. 8).

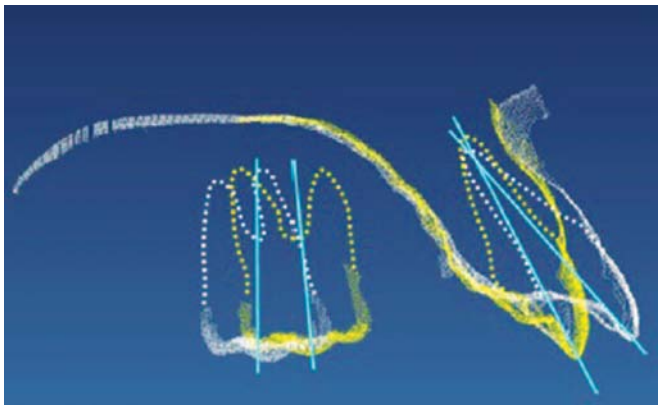

Fig. 8: Cephalometric superimposition with palatal ruga to assess dental movements

Panagiotis Christo and Stavros Kiliaridi[30] studied to assess the long-term stability of the palatal rugae in the vertical dimension, and relate them to possible maxillary incisor posteruptive movements, and validate them as references for the evaluation of longitudinal dental changes. The median palatal contour of each cast and marks corresponding to each ruga were superimposed on the palate of the cephalograms. Changes in rugae positions during the observation period were measured with respect to the palatal plane. Vertical changes were greater for the first rugae (closest to the incisors), less for the second, and even less for the third (farthest from the incisors). The adolescents showed greater vertical changes in rugae position than the adults. There were no statistically significant differences in the anteroposterior changes between the groups. The maxillary central incisor and the first ruga had vertical displacements proportional to the increase of the subject's lower anterior facial height. The third ruga, the farthest from the incisors, can be used as a reliable reference to assess longitudinal dental changes mainly when growth changes are less prominent.

Insan Janga; Motohiro Tanaka et al,[31] evaluated the stability of palatal rugae as landmarks for superimposition of dental casts and to establish a three-dimensional superimposition method of maxillary dental casts for analyzing orthodontic tooth movement. Dental casts were measured by means of laser surface scanning system, and three-dimensional images were reconstructed, the results showed medial points of the third palatal rugae and the shape of the palatal vault were stable throughout the treatment.

Janalt Damstra et al,[32] investigated the stability of the medial aspects of the rugae in patients where rapid maxillary expansion (RME) was performed in addition to fixed appliance therapy. The addition of RME to fixed appliance therapy caused a change in transverse measurements between the medial aspects of the bilateral rugae. There was no change in anteroposterior measurements (APM). The transverse changes were more marked for the third, less for the second rugae, and the least for the first rugae. They concluded that the medial aspects of the third rugae cannot be considered as stable reference landmarks for dental cast analysis when RME is performed in addition to fixed appliance therapy.

DISCUSSION

The palatal rugae like fingerprints do not change during the life of the individual, are protected from trauma and high temperatures for its internal position in the oral cavity, surrounded and protected by lips, cheeks, tongue, teeth and bone, they are unaffected by prosthetic devices. Once formed, it only changed in its length, due to normal growth, staying in the same position throughout the life of a person, even disease, trauma or chemical attack, seem not able to change the shape of the palatal rugae (Almeida et al).[12]

There are different ways to analyze the palatal rugae. Intraoral inspection is probably the most used and most easy and economical method. However, this can create difficulties if a future comparative review is required. A more detailed and accurate, and the need to preserve evidence may justify the use of photographs or impressions (Utsuno et al, 2005).[33] While observing the shape of the rugae is a subjective process, it is relatively easy to record and does not require complex instrumentation.

Some authors suggest the presence of sexual dimorphism in the biometric features of the palatal rugae, in the limited literature of the subject, is clear a lack of uniformity in nomenclature, making it more difficult to compare the results, it is the majority of methods developed individually, and not validity information reported, with low reproducibility, and due to the importance of describing the rugoscopy characteristics in dental-forensic expertise, we suggest developing a standard method for evaluation of palatal rugae.

The palatoscopy is a technique that can be of great interest in human identification. In fact, contrary to the lips that are printed, it is possible to obtain antemortem data stable overtime, such record that are in dental practice in its various forms (dental casts, intraoral photographs and dental prostheses). However, palatoscopy might not be as useful in investigations of crime scenes and in linking suspects to crime scenes because such tests are not expected to find in such circumstances. It is also possible to consider the possibility of falsification of the pattern of rugae in cases toothless. Gitteet al (1999)[34] described a method that palatal rugae are added to the palate maxillary complete dentures to improve the patterns of verbal expression and phonetics in some patients.

It is important to note the existence of abnormal patterns and shapes on palatal rugae, these anomalies are considered as a reflection of alterations in the normal growth of the palate. It has been suggested that these abnormal patterns can be used as an additional feature or sign in the diagnosis of cleft palate in humans (Ikemi et al, 2001)[35] and have been used as benchmarks when testing in pre-and postsurgical cleft palate surgery (Park et al 1994).[36]

CONCLUSION

The palatal rugae are very important in dental, prosthodontic and forensic practice. They can be used to evaluate the dental movements in orthodontics, as they remain stable over a person's life without any change. Located in the anterior half of the roof of the mouth, the palatine rugae have much to offer the orthodontist. They serve as a reference landmark in various dental treatment modalities and can be used in the identification of submucosal clefts. In addition, clinicians can use the palatine rugae 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 ethnicity. Finally, palatine rugae can be a significant landmark which can be used as a reliable guide in superimposition of dental casts for orthodontic purpose.

REFERENCES

1. Thomas CJ, van Wyk CW. The palatal rugae in an identification. J Forensic Odontostomatol 1988;6(1):21-27.
2. English WR, Robison SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal rugae. J Forensic Sci 1988;33(3):718-726.
3. Caldas IM, Magalhães T, Afonso A. Establishing identity using cheiloscopy and palatoscopy. Forensic Sci Int 2007;165(1):1-9.
4. Patil MS, Patil SB, Acharya AB. Palatine rugae and their significance in clinical dentistry: a review of the literature. J Am Dent Assoc 2008;139(11):1471-1478.
5. Lysell L. Plicae palatinae transversae and papilla incisiva in man: a morphologic and genetic study. Acta Odontol Scand 1955; 13(Suppl 18):5-137.
6. Buchtová M, Tichy F, Putnová I, Mísek I. The development of palatal rugae in the European pine vole, Microtus subterraneus (Arvicolidae, Rodentia). Folia Zoo 2003;52(2):127-136.
7. Waterman RE, Meller SM. Alteration in the epithelial surfaces of human palatal shelves prior to and during fusion: a scanning electron microscope study. Anat Rec 1974;180:111-136.
8. Yamazaki Y. Cross-sectional study of plicae palatinae transversae in the Japanese. Anthropol Rep Niigata 1962;34:59-76.
9. Jordanov JA. Growth of the hard palate in man. Anthropological characteristics. Z Morphol Anthropol 1971;63(2):230-237.
10. Lang J, Baumeister R. Postnatal development of the width and height of the palate and the palate foramina. Anat Anz 1984;155(1-5):151-167.
11. Thomas CJ. Incidence of primary O rugae in Bushman juveniles. J Dent Res 1972;51(2):676.
12. Almeida MA, Phillips C, Kula K, Tulloch C. Stability of the palatal rugae as landmarks for analysis of dental casts. Angle Orthodont 1955;65(1):43-48.
13. Peavy DC Jr, Kendrick GS. The effects of tooth movement on the palatine rugae. J Prosthet Dent 1967;18(6):536-542.
14. Limson KS, Julian R. Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification. J Forensic Odontostomatol 2004;22(1):1-4.
15. Goria C. Le rughe del palato in speciale rapportcoll'anthropologia criminale e la psichiatria. 1911. Cited by: Lysell L. Plicae palatinae transversae and papilla incisiva in man. Acta Odontol Scand 1955;13:(suppl 18):5-137.
16. Carrea JU. Gaumenfalten-Fotostenogramme, ein neues identifizierungsverfahren (Fotostenograms of palate folds, a new identification technic). Dtsch Zahnarztl Z 1955;10(1):11-17.
17. Basauri C. Forensic odontology and identification. Int Crim Police Rev 1961;16:45.
18. Lima OC. Rugoscopia [Rugoscopy (Correia Lima's process)]. Rev Bras Med 1968;25(12):806-807.
19. Caruso GP. Le pliche palatine. Risultani di uno studio sucentomodelli di palatoumanodall'etaprenatalaallasenili ta (The palatine folds: results of a study of 100 models of the human palate from prenatal to old age). RivItalStomatol 1969;24(5):423-492.
20. Tzatscheva L, Jordanov J. Plicae palatinae transversae und papilla incisive bei den Bulgaren (Plicae palatinae transversae and papilla incisiva in Bulgarians). Z Morphol Anthropol 1970;62(3):276-284.
21. Thomas CJ, Kotze TJ. The palatal ruga pattern: a new classification. J Dent Assoc S Afr 1983;38(3):153-157.
22. Thomas CJ, Kotze TJ, Van der Merwe CA. An improved statistical method for the racial classification of man by means of palatal rugae. Arch Oral Biol 1987;32(4):315-317.
23. Muthusubramanian M, Limson KS, Julian R. Analysis of rugae in burn victims and cadavers to simulate rugae identification in cases of incineration and decomposition. J Forensic Odontostomatol 2005;23(1):26-29.
24. Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian Aborigines and Caucasians. Aust Dent J 1997;42(2):129-133.
25. Kashima K. Comparative study of the palatal rugae and shape of the hard palatal in Japanese and Indian children [in Japanese]. Aichi Gakuin Daigaku Shigakkai Shi 1990;28(1 part 2):295-320.
26. Shetty SK, Kalia S, Patil K, Mahima VG. Palatal rugae pattern in Mysorean and Tibetan populations. Indian J Dent Res 2005;16(2):51-55.
27. Bailey LT, Esmailnejad A, Almeida MA, Stability of the palatal rugae as landmarks for analysis of dental casts in extraction and nonextraction cases. J Forensic Sci 1988 May;33(3):718-726.
28. Reuer E. Gaumentleistein und Gaumerferm beidrei lokalen populationen in Osterreich. Mitteilungen der Anthropologischen-Gesellschaft in Wien 1973;103:1-3.
29. Hoggan BR, Sadowsky C. The use of palatal rugae for the assessment of anteroposterior tooth movements. Am J Orthod Dentofacial Orthop 2001;119:482-488.
30. Christou P, Kiliaridis S. Vertical growth related changes in the positions of the palatal rugae and maxillary incisors. Am J Orthod Dentofac Orthop 2008;133:81-86.
31. Janga I, Tanaka M, et al. A novel method for the assessment of three-dimensional tooth movement during. Orthodontic Treatment Angle Orthod 2009;79:447-453.

32. Damstra J, et al. Anteroposterior and transverse changes in the positions of palatal rugae after rapid maxillary expansion. Eur J Orthodontics 2009; 31(3):327-332.
33. Utsuno H, Kanoh T, Tadokoro O, Inoue K. Preliminary study of postmortem identification using lip prints. Forensic Sci Int 2005;149(2-3):129-132.
34. Gitto CA, Exposito SJ, Draper JM. A simple method of adding palatal rugae to a complete denture. J Prosthet Dent 1999;81:237-239.
35. Ikemi N, Otani Y, Ikegami T, Yasuda M. Palatal ruga anomaly induced by all-transretinoic acid in the Crj: SD rat: possible warning sign of teratogenicity. Reprod Toxicol 2001;15(1):87-93.
36. Park S, Eguti T, Kato K, Nitta N, Kitano I. The pattern of palatal rugae in submucous cleft palates and isolated cleft palates. Br J Plast Surg 1994;47(6):395-399.

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