Background: Palatal rugae are nonidentical mucosal elevations seen on anterior third of palate. They are arranged in transverse direction on either side of the mid-palatine raphe. Although they are the most stable anatomical structures in the oral cavity, certain conditions such as expansion in orthodontic treatment contribute to some amount of variations in their pattern qualitatively. The aim of this study was to compare the shape of rugae and its positional changes before and after rapid maxillary expansion.

Materials and Methods: Fifteen pairs of pre- and post-maxillary expansion casts showing finer details of palatal rugae from seven males to eight females in the age group of 10 ± 2.5 years were selected for this study with transverse maxillary deficiency reporting to Department of Orthodontics, VS Dental College and Hospital. The shape of rugae and the distance between the median points and lateral points of the first and the last two rugae on either side of the mid-palatal raphe were noted and marked. The data collected was statistically analyzed using SPSS program.

Results: There was statistically significant difference in the distance between medial and lateral points of first two and last two rugae.

Conclusion: During maxillary expansion, there is stability of palatal rugae with respect to its shape, number but not with respect to its position. Clinically, the orthodontist can quantify the palatal separation after expansion of the maxillary arch using the interruga distance.

Keywords: Interlateral, intermedial, palatine raphe, rapid maxillary expansion

INTRODUCTION

Rugae are derived from the Greek word for a seam. It describes the intersection or seam in a tissue or organ between two separate parts when they are embryologically separated from each other. Rugae or plica palatine are the anatomical folds located on the anterior palate behind the incisive papillae, and the study of this palatal patterns is called palatoscopy. It is used in various fields such as sex determination, orthodontics and forensic odontology. Palatal rugae also refer to a series of transverse ridges on the anterior part of the palate; these are present on both the sides of the mid-palatal raphe and behind the incisive papilla. It forms a partition between the mouth.
and nasal passages. The classification of rugae includes shape, length, number and identification pattern. The overall stability and the uniqueness of palatal rugae suggest their use for forensic identification also. The clinical implications of palatal rugae in orthodontics and forensic odontology are as follows. Palatal rugae can be used to evaluate the dental movements in orthodontics. They can be referred as landmarks in various treatment modalities. They can be used in the identification of submucosal clefts and also to assess the amount of anteroposterior tooth movement posttreatment. They can be used as a significant landmark in the superimposition of dental casts for orthodontic purpose. Palatal rugae are also used in forensic identification for postmortem resistance and stability. The morphological pattern is useful in forensic science in cases of mutilation when compared with different parts of the body.

**Classifications of palatal rugae**

There are various classifications of rugae patterns, but for identification purpose, the commonly used classifications are as follows:

1. Martin dos Santos classification (1983) [Figure 1]
2. Thomas classification (Thomas et al. 1983) [Figure 2].

This study was designed to evaluate palatine rugae shape, length and distances between the rugae before and after mid-palatal expansion in Class III skeletal and Class III dental patients and also investigate whether the rugae can be used in forensic identification of skeletal Class III patients.

**MATERIALS AND METHODS**

The study was designed on a prospective sample of 15 patients (8 females, 7 males, age 10 ± 2.5 years) with transverse maxillary deficiency reporting to the Department of Orthodontics, VS Dental College and Hospital. The sample inclusion criteria for our study included young adolescent patients (10 ± 2.5 years) with constricted maxillary arch having anterior crossbite or posterior crossbite or combination and without any previous history of orthodontic treatment. Informed consent was obtained from the parents before the start of treatment. Fixed rapid maxillary expansion (RME) (Bonded and banded) was used for the correction of crossbite in all the cases.

**Materials used**

1. Hygienic rapid maxillary expander (Hyrax) expansion screw (Dentaurum company, Langhorne, PA 19047, USA)
2. Glass ionomer cement (GIC) - GC Fuji IX GP, GC Corporations, Tokyo, JAPAN
3. Preformed molar and premolar bands - Libral Traders Private Limited, Bangalore, Karnataka, India
4. 0.7 mm stainless steel wire - Libral Traders Private Limited, Bangalore, Karnataka, India
5. Poly (methyl methacrylate) - Dental products of india, wallace street, fort, Mumbai, Maharashtra India
6. Flux and solder - captain ortho solder flux 20 ml and G&H Silver Solder Wire. 025 X 6 Ft. 1/pk. Libral Traders Private Limited, Bangalore, Karnataka, India
7. Alginate impression material - Algitex, DPI Company Wallace Street, Fort, Mumbai, Maharashtra India
8. Type III dental stone - Type III, Orthokal, Kalabhai company, Mumbai, Maharashtra, India
9. Graphite pencil - Faber castell, Newyork, USA
10. Digital Vernier caliper - Mitutoyo, Mignada Technology Company, Tokyo, Japan.

**Fabrication of rapid maxillary expansion appliance**

Pretreatment impressions of all the cases were taken with alginate, and casts were poured in Type III dental
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Stone for study model and working model. Hygienic rapid maxillary expander (Hyrax) expansion screw (Dental Morelli, São Paulo, Brazil) of size 9 or 11 mm depending on the amount of expansion required in each case was selected. Two types of appliances were fabricated (banded and bonded).

1. For banded appliance, separators were placed between maxillary premolars and molars a week before banding. Preformed bands (3M Unitek victory series™) were adapted to the premolars and molars and impressions were made with alginate and were used as working cast. Hyrax screw was soldered to the bands approximately 2 mm from the palatal surface along the midpalatal suture and was cemented on to the upper posterior teeth with GIC [Figure 3].

2. For bonded appliance, a 0.7-mm stainless steel orthodontic wire framework was fabricated around the buccal and palatal surfaces of maxillary posteriors, crossing the occlusal surface between the canines and lateral incisors, then the expansion screw was soldered to this wire framework between primary molars or premolar and first molar, approximately 2 mm from the palatal surface. An acrylic occlusal splint extending over the middle-third of the vestibular surfaces and the occlusal surfaces of all the teeth with thickness limiting to the freeway space was made and then bonded with GIC [Figure 4].

The activation of appliance was started 1 week of insertion with a protocol of two turns of activations twice/day (0.5 mm/day). The expansion was discontinued once the maxillary lingual cusp of the upper first molars contacted the occlusal aspect of buccal cusp of the mandibular lower first molars incorporating additional 2–3 mm of overexpansion to compensate for the relapse. Then, the expansion appliances were debanded, and impressions were made again for posttreatment measurements and casts were poured.

Methodology

Cast analysis and measurements

Pre-and post-expansion casts were traced with a 0.3-mm graphite according to the classification given by Kapali et al[12] i.e., the medial and lateral points of rugae were marked on medial and lateral ends of first, second, third rugae and then traced. The distance between the first and second and the second and third rugae was measured and recorded. The intermedial and interlateral rugae were also measured with the help of Vernier calipers and the readings were recorded. The shape of the rugae was also assessed [Figures 5 and 6].
Statistical analysis
Pre- and post expansion readings of intermedial and interlateral distances for the first, second and third primary rugae were subjected to statistical analysis using SPSS software for Windows (statistical package for the social sciences, version 19.0, IBM, Armonk, NY, USA). Pre- and post-treatment differences in inter-medial, inter-lateral distance are shown in the following [Graphs 1-4].

RESULTS
There was statistically significant difference in the distance between medial and lateral points of the first two and last two rugae [Table 1].

There was statistically significant change in any of the variables when the data from male [Table 2] and female [Table 3] samples were compared.

DISCUSSION
Palatal rugae are considered as the most stable anatomic landmark in the oral cavity. However, there is more likelihood for the changes in the shape, number and position of the rugae following expansion in the maxillary arch, as there is a significant increase in the arch perimeter. Such changes in the rugae patterns were studied in the past by several investigators.[13-15] The rugae landmarks are also used reliably as reference points for cephalometric superimposition when assessing the anteroposterior tooth movement during pre- and post-orthodontic treatments.

Metric changes in the transverse plane between the medial ends and the lateral ends of the two opposing rugae were observed in maxillary expansion cases.

A study was done on Egyptian patients suggested that the lateral 3rd rugae points were the most reliable points for superimposition while comparing the pre- and post-orthodontically treated casts.[16] In our study, we measured the transverse distance between the medial ends of the first two and the last two rugae on both the sides of mid-palatal raphe found a significant difference in the measurements in the pre-treatment and posttreatment casts.

Changes in respect to the shape of palatal rugae on both the sides were observed, and there was no significant change found.

In our study, we did not consider the length of rugae as a parameter; instead, we included the number and the transverse distance between the medial ends and lateral ends of first two and the last two rugae. The metric and the positional stability of 3rd rugae during orthodontic treatment has been documented in several studies. Kratzsch and Opitz,[17] in their series of investigations on palatal rugae, have compared the distances between lateral palatal rugae points and to specific landmarks in the maxilla. They indicated that changes occurred in the anterior palate during various stages of growth and orthodontic treatment. In this study, we measured the distance between two pairs of rugae-first and last pair, pre- and post-RME treatment and found a significant change of 0.84 mm increase in distance between the

### Table 1: Quantitative and metric changes in rugae before and after expansion

| Variable                              | Pre | Post | P value | Significance | Significance |
|---------------------------------------|-----|------|---------|--------------|--------------|
|                                       | n   | Mean | SD      | Min | Max | n   | Mean | SD      | Min | Max | P <=0.05 |                            |
| First for left and right Rugae        | 16  | 2.45 | 0.228  | 2   | 2.88 | 16  | 5.27 | 0.194  | 4.9 | 5.5 | <0.0001 | Significant                  |
| Last for Left and Right Rugae         | 16  | 3.38 | 0.183  | 3   | 3.71 | 16  | 6.03 | 0.311  | 5.3 | 6.6 | <0.0001 | Significant                  |
| Distance between last to first rugae in mm | 16  | 0.94 | 0.165  | 0.4 | 1.81 | 16  | 0.76 | 0.27   | 0.3 | 1.3 | 0.04     | Significant                  |

### Table 2: Mean values of the variables in pre- and post-treatment models of females

| Variable                              | Pre | Post | P value | Significance | Significance |
|---------------------------------------|-----|------|---------|--------------|--------------|
|                                       | n   | Mean | SD      | Min | Max | n   | Mean | SD      | Min | Max | P <=0.05 |                            |
| First for left and right Rugae        | 7   | 2.43 | 0.28   | 2.02| 5.33 | 7   | 5.33 | 0.1    | 5.25| 5.5 | <0.0001 | Significant                  |
| Last for Left and Right Rugae         | 7   | 3.36 | 0.18   | 3   | 6.08 | 7   | 6.08 | 0.22   | 5.78| 6.4 | <0.0001 | Significant                  |

### Table 3: Mean values of the variables in pre- and post-treatment models of males

| Variable                              | Pre | Post | P value | Significance | Significance |
|---------------------------------------|-----|------|---------|--------------|--------------|
|                                       | n   | Mean | SD      | Min | Max | n   | Mean | SD      | Min | Max | P <=0.05 |                            |
| First for left and right Rugae        | 9   | 2.46 | 0.2    | 2.15| 5.22 | 9   | 5.22 | 0.17   | 4.90| 5.5 | <0.0001 | Significant                  |
| Last for Left and Right Rugae         | 9.00| 3.40 | 0.19   | 3.10| 6.00 | 9   | 6.00 | 0.38   | 5.34| 6.6 | <0.0001 | Significant                  |

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Skeletal expansion of the maxillary arch has a triangular pattern with its wider base in the anterior region. This is because the mid-palatal suture opening is always greater in the anterior region than in the posterior region. Garrett et al.,[18] in their study, have shown that 55% of total expansion was at 1st premolar level (P1), 45% was at 2nd premolar level (P2), and 38% was at the 1st molar level (M1). During expansion, there is rotation of the maxillary components in the horizontal and frontal planes. This was proved by Krebs[19] using metallic implants in his study. The fulcrum of maxillary rotation during expansion is at the frontomaxillary suture as well as at the pterygopalatine suture. The increase in distance between the intermedial and interlateral palatal rugae implies that there is a skeletal expansion of the maxillary arch and at the maxillary suture,[20‑22] which is the goal of expansion treatment. This study also found no change in the shape and number of palatal rugae postexpansion treatment. There was no change seen in shape, distances and number of rugae as compared between males and females.

**CONCLUSION**

- Palatal rugae may be considered as a stable anatomical landmark
- The inter-ruga distance, i.e., the intermedial and interlateral between the first and fourth pairs of rugae on either side of the mid-palatine raphe differs significantly when pre- and post-treatment models are compared. This concludes that there is skeletal expansion of the maxillary arch
- Clinically, the orthodontist can quantify the palatal separation after expansion of the maxillary arch using the inter-ruga distance
- Palatal rugae can be used as a significant landmark in superimposition of dental casts for orthodontic purpose
- Palatal rugae can be used in forensic identification for postmortem resistance and stability. The morphological pattern can be useful in forensic science in cases of mutilation when compared with different parts of the body.
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There are no conflicts of interest.

REFERENCES

1. Patil MS, Patil SB, Adharya AB. Palatine rugae and their significance in clinical dentistry: A review of the literature. J Am Dent Assoc 2008;139:1471-8.
2. Hauser E. The palatal ridges in man; their significances and their modifications. Stoma (Heidelb) 1951;4:3-26.
3. English WR, Robison SF, Summitt JB, Oesterle IJ, Brannon RB, Morlang WM, et al. Individuality of human palatal rugae. J Forensic Sci 1988;33:718-26.
4. Shukla D, Chowdhry A, Bahlani D, Jain P, Thapar R. Establishing the reliability of palatal rugae pattern in individual identification (following orthodontic treatment). J Forensic Odontostomatol 2011;29:20-9.
5. Bailey LT, Esmailnejad A, Almeida MA. Stability of the palatal rugae as landmarks for analysis of dental cast in extraction and nonextraction cases. J Forensic Sci 1988;33:718-26.
6. Abdel-Aziz HM, Sabet NE. Palatal rugae area: A landmark for analysis of pre – and post-orthodontically treated adult Egyptian patients. East Mediterr Health J 2001;7:60-6.
7. Goswani R, Garg R, Jolly R. Role of prosthodontics in forensic odontology. Int J Clin Dent Sci 2011;285-9.
8. Mishra SK, Mahajan H, Saloktar R, Jain A. Role of prosthodontist in forensic odontology. A literature review. J Forensic Dent Sci 2014;6:154-9.
9. Thomas CJ, Kotze TJ. The palatal ruga pattern: A new classification. J Dent Assoc S Afr 1983;38:153-7.
10. 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;32:315-7.
11. Timms DJ. The dawn of rapid maxillary expansion. Angle Orthod 1999;69:247-50.
12. Kapali S, Townsend G, Richards I, Parish T. Palatal rugae patterns in Australian aborigines and Caucasians. Aust Dent J 1997;42:129-33.
13. Wertz R, Dreskin M. Midpalatal suture opening: A normative study. Am J Orthod 1977;71:367-81.
14. D’Souza IM, Kumar HC, Shetty KS. Dental arch changes associated with rapid maxillary expansion: A retrospective model analysis study. Contemp Clin Dent 2015;6:51-7.
15. Christou P, Kiliaridis S. Vertical growth-related changes in the positions of palatal rugae and maxillary incisors. Am J Orthod Dentofacial Orthop 2008;133:81-6.
16. Abou El-Fotouh MM, El Sharkawy GZ. A study of palatal rugae pattern in an Egyptian population. J Egypt Dent Assoc 1998;44:3177-84.
17. Kratzsch H, Opitz C. Investigations on the palatal rugae pattern in cleft patients. Part II: Changes in the distances from the palatal rugae to maxillary points. J Orofac Orthop 2000;61:421-31.
18. Garrett BJ, Caruso JM, Rungeharassaeng K, Farrage JR, Kim JS, Taylor GD, et al. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2008;134:8-9.
19. Kerbs A. Expansion of mid palatal sutures studied by means of metallic implants. Eur Orthodont Soc Rep 1958;34:163-71.
20. Damstra J, Mistry D, Cruz C, Ren Y. Antero-posterior and transverse changes in the positions of palatal rugae after rapid maxillary expansion. Eur J Orthod 2009;31:327-32.
21. Oral E, Buyuk SK, Simsek H. Evaluation of palatal rugae pattern in different sagittal skeletal relationship adolescent subjects. Medicine 2017;96. doi: 10.1097/MD.00000000000006440.
22. Hoggan BR, Sadowsky C. The use of palatal rugae for the assessment of anteroposterior tooth movements. Am J Orthod Dentofacial Orthop 2001;119:482-8.