

## ORIGINAL RESEARCH

# Comparison of Palatal Rugae Pattern and Number among Subjects with Different Sagittal Skeletal Relationships Using Extra-oral Scanning of Dental Study Casts: A Cross-sectional Prospective Study

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## Abstract

**Introduction:** There is growing research interest in determining whether a correlation exists between palatal rugae and skeletal malocclusion. This study aimed to assess and compare the pattern and number of palatal rugae, and the shape of the incisive papilla, among patients with different sagittal skeletal relationships visiting the Department of Orthodontics, Dayananda Sagar College of Dental Sciences, Bengaluru. **Methods:** In this cross-sectional prospective study, 159 subjects (age range, 10–22 years) were divided into three equal groups (n = 53 each) based on the ANB angle measured on lateral cephalometric radiographs: Class I (ANB 0°–4°), Class II (ANB > 4°), and Class III (ANB < 0°). Maxillary dental casts were digitized with an intraoral scanner (Prime Scan AC, Connect 5.2 software) and exported as STL files. The shape of the palatal rugae was assessed with the modified Thomas and Kotze classification, and the shape of the incisive papilla was assessed with the Ortman and Tsao classification, using Paint 3D software; the number of palatal rugae (primary and secondary) was assessed with the Lysell classification using Meshmixer software. Chi-square and Kruskal-Wallis tests were used for statistical analysis ( $\alpha = 0.05$ ). **Results:** There were no statistically significant differences among the three sagittal skeletal groups in the number of primary or secondary palatal rugae on either side ( $P > .05$ ), or in the shape of the incisive papilla ( $P = .57$ ). Wavy and Curved rugae patterns were the most common primary rugae patterns in all three groups, whereas Annular and Unification patterns were the least common. Pear-shaped incisive papillae were the most common shape in all three groups. **Conclusions:** Wavy and Curved rugae patterns predominated in all sagittal skeletal malocclusion groups, and primary rugae outnumbered secondary rugae clinically, although this difference was not statistically significant. Pear-shaped incisive papillae were the most common configuration across groups. No statistically significant association was found between palatal rugae pattern/number or incisive papilla shape and sagittal skeletal malocclusion type, suggesting that palatal rugae are more useful for individual identification than for malocclusion prediction.

## KEYWORDS

palatal rugae, malocclusion, incisive papilla, intra oral scanner

## 1 | INTRODUCTION

The anterior portion of the palatal mucosa has a series of transverse ridges called palatal rugae (plica palatinae transverses). These structures are located behind the incisive papilla, on either side of the median

palatal raphe, and range in number from four to six on each side.<sup>1,2</sup> Their growth and development are controlled by interactions between epithelial and mesenchymal cells, and they first appear toward the third month of intrauterine life from the connective tissue covering the palatine process of the maxilla.<sup>2,3</sup> The rugae are already organized with a typical orientation pattern at birth, and each individual acquires the final feature shape during adolescence. Although their size may change with growth of the palate, their shape is maintained once growth is complete.<sup>4</sup> There is growing research interest in determining whether a correlation exists between palatal rugae and skeletal malocclusion, since the number, shape, width, height, and location of the rugae vary between individuals and even between the two sides of the same palate, making the pattern potentially useful for identification.<sup>5</sup> Orthodontists have long used palatal rugae as a stable landmark for superimposing pre- and post-treatment cephalometric tracings and casts, and as a reference for evaluating orthodontic tooth movement.<sup>2</sup> Because the rugae pattern is established early in life, it has been proposed as a non-invasive adjunct for the early detection of malocclusion.<sup>6</sup> Dental casts poured in plaster of Paris have traditionally been used by clinicians and researchers to record the rugae, but they are susceptible to damage and require physical storage space.<sup>7</sup> Digital models obtained by extraoral scanning of study casts allow accurate measurement and analysis of rugae pattern, and several studies have shown that linear measurements on digital models are within acceptable limits of agreement with conventional models.<sup>7,8</sup> The present study was therefore designed to investigate the morphological structure of the palatal rugae – pattern, number, and the shape of the incisive papilla – in a Bengaluru population with different sagittal skeletal relationships, using digital tracing of extraoral-scanned dental study casts. The aim of this study was to assess whether a comparison exists between the pattern and number of palatal rugae, and the shape of the incisive papilla, and sagittal skeletal malocclusion type, among patients visiting the Department of Orthodontics, Dayananda Sagar College of Dental Sciences, Bengaluru. The specific objectives were: (1) to assess the number of primary and secondary palatal rugae in subjects with Class I, Class II, and Class III skeletal malocclusion; (2) to assess the distribution of palatal rugae patterns (Straight, Curved, Wavy, Unification, and Annular) in the three groups; (3) to compare the number and pattern of palatal rugae between the three groups; and (4) to assess the distribution of incisive papilla shape between the three groups.

## 2 | MATERIAL AND METHODS

**Sample selection:** Inclusion criteria: Palatal rugae clearly recorded on the cast; palatal rugae accurately captured on the 3-dimensional (3D) scanner; and subjects within the age group of 10–22 years. Exclusion criteria: Dental casts with damaged palatal areas or defects such as bubbles or porosity; patients who had undergone surgery in the palatal area; previous orthodontic treatment; patients with habits such as thumb-sucking or tongue-thrusting; patients who had undergone extractions;



**FIGURE 1** DENTAL CAST

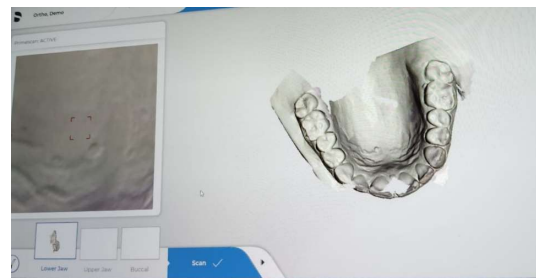


**FIGURE 2** DIGITAL CAST MODEL

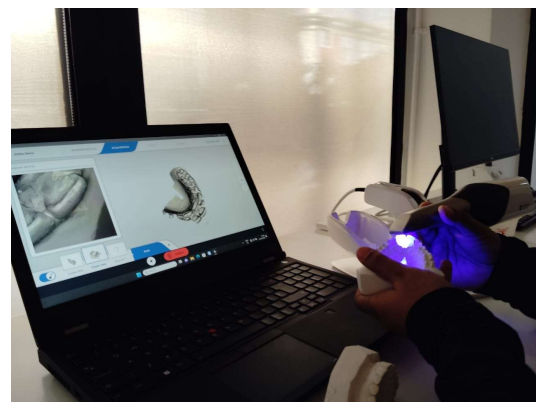


**FIGURE 3** DENTAL CAST SCANNING BEING RECORDED ON THE LAPTOP

any syndromic patients; cleft palate patients; and rugae less than 2 mm in length. Subjects were allocated to three groups according to the ANB angle measured on pretreatment lateral cephalometric radiographs (Carestream machine, approximately 5% magnification): Class I (ANB 0°–4°), Class II (ANB > 4°), and Class III (ANB < 0°). A total of 159 subjects were enrolled, with 53 subjects in each group. **Sample size estimation:** Sample size was calculated with G\*Power software (version 3.0.10) using a point-biserial correlation model (one-tailed t test), with



FIGURE 4 USING PRIME SCAN SCANNING THE DENTAL CAST



FIGURE 5 STL FILE VIEWED IN MESH MIXER SOFTWARE

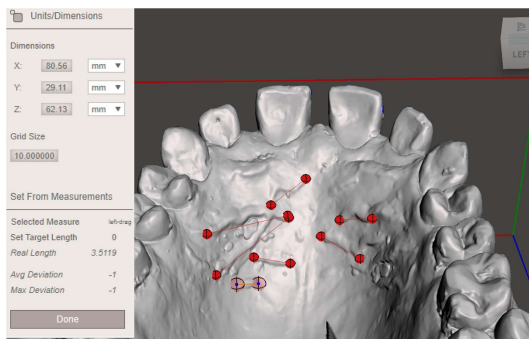


FIGURE 6 USING MESH MIXER SOFTWARE, MEASURING THE LENGTH OF THE PALATAL RUGAE

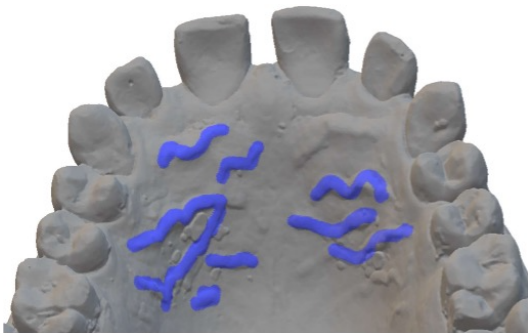


FIGURE 7 USING PAINT 3D, DETERMINATION OF SHAPE OF THE PALATAL RUGAE AND INCISIVE PAPILLA

an effect size ( $d'$ ) of 0.2 (20%),  $\alpha$  error of 0.05 (5%), and power ( $1 - \beta$ ) of 0.80 (80%). The calculated sample size of 148 was rounded up to 150; considering an effect size of 20%, power of 80%, and a 5% margin of error, a final total sample size of 159 (53 per group) was used. Evaluation criteria: Maxillary dental casts were poured in high-quality dental stone (Ortho Kal, Type III) and digitized with an intraoral scanner (Prime Scan AC with Connect 5.2 software), which uses a dynamic autofocus lens to capture fine surface detail. Each digitized cast was exported as a standard triangle language (STL) file. All variables on the 3D digital models were assessed twice, one month apart, for intra-examiner reliability; more than 80% concordance was achieved between the two assessments. Each STL file was opened in Paint 3D (version 6.2003.4017.0; Microsoft, Redmond, Wash) and zoomed to 200% for optimal visibility. The palatal rugae were highlighted with a pixel-pen marker tool (thickness adjusted from 4 to 6 pixels according to rugae size and curvature), tracing from the medial to the most lateral termination point of each rugae. Rugae shape was categorized according to the modified Thomas and Kotze classification<sup>5</sup> as Type A (Straight), Type B (Curved), Type C (Wavy), Type D (Unification), or Type E (Annular). The shape of the incisive papilla was categorized with the Ortman and Tsao classification<sup>9</sup> as Pear, Oval, Irregular, Rectangular, Triangular, Inverted pear, or No papilla. Each STL file was separately opened in Meshmixer (version 3.5), and the length of each rugae was measured linearly from its medial to its lateral termination point. Rugae number and length were classified according to Lysell<sup>10</sup>: Primary rugae (> 5 mm), Secondary rugae (3–5 mm), and Fragmentary rugae (< 2 mm). Fragmentary rugae were excluded from analysis. Primary and secondary rugae number were recorded separately for the right and left sides in each sagittal skeletal group. Statistical analysis: Statistical analysis was performed with IBM SPSS Statistics for Windows, version 25.0 (IBM Corp, Armonk, NY). Continuous variables were expressed as mean  $\pm$  standard deviation. Normality of the data was assessed with the Shapiro-Wilk test. The chi-square test was used to compare categorical distributions between groups, and the Kruskal-Wallis test was used to compare means between groups. The level of significance was set at 5% ( $P < .05$ ).

■ Pear ■ Oval ■ Irregular ■ Rectangular ■ Triangular ■ Inverted papilla ■ No papilla

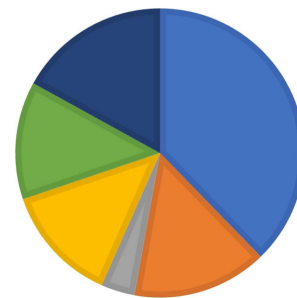


FIGURE 8 DISTRIBUTION OF SHAPE OF INCISIVE PAPILLA IN CLASS I

**TABLE 1** Distribution of shape of primary rugae in different sagittal skeletal relationships

|                            | Groups    | Straight | Curved | Wavy | Annular | Unification |
|----------------------------|-----------|----------|--------|------|---------|-------------|
| <b>Right</b>               |           |          |        |      |         |             |
| Primary Palatal Rugae I    | Class I   | 06       | 13     | 26   | 03      | 05          |
|                            | Class II  | 03       | 16     | 05   | -       | 06          |
|                            | Class III | -        | 09     | 43   | -       | 01          |
| Primary Rugae II           | Class I   | 07       | 12     | 15   | -       | 01          |
|                            | Class II  | 02       | 16     | 15   | 01      | 06          |
|                            | Class III | 10       | 27     | 05   | -       | -           |
| Primary Rugae III          | Class I   | 03       | -      | 01   | -       | 01          |
|                            | Class II  | 02       | 01     | 02   | 01      | -           |
|                            | Class III | 03       | 01     | -    | -       | -           |
| Secondary palatal Rugae I  | Class I   | 01       | 02     | 01   | -       | -           |
|                            | Class II  | 07       | 13     | 10   | -       | -           |
|                            | Class III | 03       | 10     | 14   | -       | -           |
| Secondary palatal Rugae II | Class I   | 03       | 03     | 02   | -       | -           |
|                            | Class II  | 02       | 04     | -    | -       | -           |
|                            | Class III | 04       | 03     | -    | -       | -           |
| <b>Left</b>                |           |          |        |      |         |             |
| Primary palatal Rugae I    | Class I   | 06       | 15     | 26   | 03      | 03          |
|                            | Class II  | 02       | 14     | 31   | 01      | 05          |
|                            | Class III | -        | 10     | 40   | 01      | 02          |
| Primary palatal Rugae II   | Class I   | 02       | 15     | 13   | 03      | 05          |
|                            | Class II  | 06       | 10     | 16   | -       | 06          |
|                            | Class III | 13       | 17     | 07   | 01      | 04          |
| Primary palatal Rugae III  | Class I   | 03       | 03     | 02   | 01      | 01          |
|                            | Class II  | 08       | 03     | 01   | 01      | 02          |
|                            | Class III | 05       | -      | 03   | -       | -           |
| Secondary palatal Rugae I  | Class I   | 09       | 10     | 07   | -       | -           |
|                            | Class II  | 05       | 09     | 15   | -       | -           |
|                            | Class III | 11       | 09     | 14   | -       | -           |
| Secondary palatal Rugae II | Class I   | 02       | 04     | 01   | -       | -           |
|                            | Class II  | 04       | 03     | -    | -       | -           |
|                            | Class III | 04       | 06     | 01   | -       | -           |
| Secondary palatal Ruga III | Class I   | 01       | -      | -    | -       | -           |
|                            | Class II  | -        | -      | -    | -       | -           |
|                            | Class III | -        | -      | -    | -       | -           |

**TABLE 2** Distribution of primary and secondary rugae number in different sagittal skeletal relationships

| Rugae           | Class I (53) Mean (SD) | Class II (53) Mean (SD) | Class III (53) Mean (SD) | p value |
|-----------------|------------------------|-------------------------|--------------------------|---------|
| <b>Right</b>    |                        |                         |                          |         |
| Primary rugae   | 3.28(0.84)             | 3.43(0.99)              | 3.54(1.15)               | 0.39    |
| Secondary rugae | 0.73(0.94)             | 0.88(1.08)              | 0.67(0.77)               | 0.51    |
| <b>Left</b>     |                        |                         |                          |         |
| Primary rugae   | 3.64(0.92)             | 3.51(1.12)              | 3.56(1.01)               | 0.81    |
| Secondary rugae | 0.83(1.01)             | 0.81(0.87)              | 1.05(0.96)               | 0.34    |

### 3 | RESULTS

A total of 159 digital models (53 in each sagittal skeletal group) were assessed for the shape and number of primary and secondary palatal rugae and for the shape of the incisive papilla. More than 80% concordance was achieved between the two assessments performed one month apart. Wavy and Curved rugae patterns were the most common patterns in all three sagittal skeletal groups, whereas Annular and Unification patterns were the least common. In Class I and Class III, the Wavy pattern predominated for primary rugae I on both sides; in Class II, the Curved pattern predominated on the right side and the Wavy pattern on the left side. For primary rugae III, the Straight pattern predominated

in all three groups. Among the secondary rugae, the Curved pattern was generally more common, except in Class III secondary rugae I, where the Wavy pattern predominated on both sides. There was no statistically significant difference among the three sagittal skeletal groups in the mean number of primary or secondary palatal rugae on either the right or the left side (all  $P > .05$ ). Pear-shaped incisive papillae were the most common configuration in all three groups, followed by rectangular and oval shapes; there was no statistically significant difference in the distribution of incisive papilla shape between the groups. ( $P = .57$ )

**TABLE 3** Distribution of shape of incisive papilla in different sagittal skeletal relationships

| Shape of incisive papilla | Class I (53) | Class II (53) | Class III (53) | p value |
|---------------------------|--------------|---------------|----------------|---------|
| Pear                      | 20           | 26            | 17             | 0.57    |
| Oval                      | 08           | 06            | 05             |         |
| Irregular                 | 02           | 01            | 0              |         |
| Rectangular               | 07           | 07            | 11             |         |
| Triangular                | 0            | 0             | 01             |         |
| Inverted papilla          | 07           | 05            | 05             |         |
| No papilla                | 09           | 08            | 14             |         |

■ Pear ■ Oval ■ Irregular ■ Rectangular ■ Triangular ■ Inverted papilla ■ No papilla

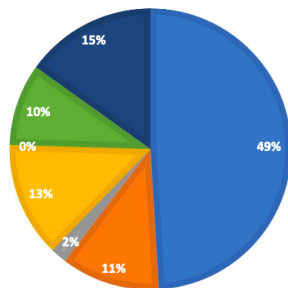


**FIGURE 9** DISTRIBUTION OF SHAPE OF INCISIVE PAPILLA IN CLASS II

■ Pear ■ Oval ■ Irregular ■ Rectangular ■ Triangular ■ Inverted papilla ■ No papilla

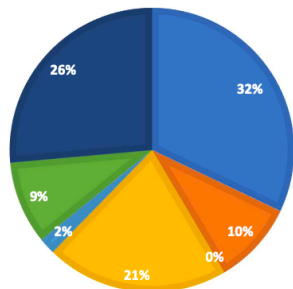


**FIGURE 10** DISTRIBUTION OF SHAPE OF INCISIVE PAPILLA IN CLASS III

## 4 | DISCUSSION

The term rugae is derived from the Greek word for “seam,” describing the intersection between tissues that were embryologically separate.<sup>11</sup> The palatal rugae begin to form as early as the third month in utero from the connective tissue covering the palatal bone, with their orientation and pattern established by the fourth month.<sup>12</sup> Histologically, the rugae resemble the adjacent palatal tissue, consisting of stratified, largely parakeratinized squamous epithelium on a connective-tissue base.<sup>13</sup> Peterkova and Peterka, using scanning electron microscopy on murine

embryos, showed that rugae development is induced through epithelial-mesenchymal interactions that begin along with palatogenesis, and that the rugae form sequentially from anterior to posterior.<sup>14,15</sup> Once formed, the rugae may change in size with growth of the palate, but their shape is preserved once growth is complete, and they are reported to be unaffected by heat, chemicals, disease, or trauma, reappearing at the same location if destroyed.<sup>4,16</sup> The eruption or loss of teeth does not alter their form or arrangement, although rugae adjacent to the alveolar arch may shift slightly in position after extraction.<sup>3</sup> Rugoscopy, the study of palatal rugae for personal identification, was first proposed by Allen in 1889 and later formalized by Trobo Hermosa (1932), Carrea (1937), and subsequently Brinon (1983), who classified rugae into fundamental and specific groups analogous to fingerprint classification.<sup>4</sup> Several classification systems have since been proposed, beginning with that of Gorla in 1911.<sup>17</sup> In the present study, the modified Thomas and Kotze classification was used, being the most widely used and simplest system for categorizing rugae shape,<sup>17</sup> and rugae number was classified according to Lysell into primary (> 5 mm), secondary (3–5 mm), and fragmentary (< 2 mm) categories. In the present study, 159 subjects were divided in equal proportions into three sagittal skeletal groups based on the ANB angle, and the number of primary and secondary rugae was analyzed on both sides; fragmentary rugae were excluded. The number of primary and secondary rugae ranged from two to three per side across groups. In primary rugae I, the Wavy pattern predominated in Class I and Class III, while in Class II the Curved pattern predominated on the right side and the Wavy pattern on the left. In primary rugae II, the Curved pattern was most common in Class III, with both Wavy and Curved patterns common in Class I and Class II. In primary rugae III, the Straight pattern predominated across all groups. Among secondary rugae, the Curved and Wavy patterns were most frequent, with no secondary rugae III recorded on the right side in any group. Overall, there was no statistically significant difference between the sagittal skeletal groups in the number of primary or secondary palatal rugae on either side, consistent with the findings of Oral et al.<sup>5</sup> Multiple studies have supported the stability of the palatal rugae before, during, and after orthodontic treatment, and their consequent value for identification purposes.<sup>5,18,19,20,21,22</sup> English et al and Peavy and Kendrick reported that the characteristic rugae pattern does not change with growth and remains stable from development until degeneration of the oral mucosa after death.<sup>20,21</sup> Van der Linden similarly showed that the anterior rugae do not increase in length after 10 years of age, although Hauser et al reported a moderate change in rugae count during adolescence

with a marked increase from 35 to 40 years of age, while Lysell considered that rugae number decreases from 23 years of age onward.<sup>20</sup> Abdel Aziz and Sabet found the lateral third rugae points to be the most reliable landmarks for cast superimposition.<sup>23</sup> The number and shape of palatal rugae, and their distribution between the right and left sides, differ between populations.<sup>5</sup> Racial differences in rugae shape distribution have also been documented.<sup>24</sup> Kapali et al compared Australian Aborigines and Caucasians and found Wavy and Curved patterns to be more common in both groups, with Straight and Circular patterns less common, although Caucasians had more primary rugae longer than 10 mm.<sup>25</sup> Kashima compared Japanese and Indian children and found that although the total number of transverse rugae was similar, the groups differed in the shape of the primary rugae, the posterior extent of the rugae zone, and the number and location of secondary and fragmentary rugae.<sup>26</sup> Hosmani et al similarly reported more total rugae in an Indian population than in a Tibetan population, with a predominance of the Wavy pattern in Indians and the Curved pattern in Tibetans.<sup>27</sup> In the present study, the Wavy and Curved rugae patterns were the most common in all three sagittal skeletal malocclusion groups, consistent with the findings of Nayak et al, Kotrashetti et al, Kumar et al, Surekha et al, Shanmugam et al, Bajracharya et al, and Kapali et al, in whose studies most populations similarly showed a predominance of Curved and Wavy rugae.<sup>25,28,29,30,31,32</sup> Pear-shaped incisive papillae were the most common shape across all three groups in the present study, a finding also reported by Krishnanand et al in a Bengaluru population.<sup>33</sup> In contrast, Oral et al reported droplet-shaped incisive papillae to be the most common shape across sagittal skeletal groups in a Turkish population,<sup>5</sup> suggesting that incisive papilla shape, like rugae pattern, may vary between populations because of racial differences. The limitations of this study include the relatively wide age range of the sample and an unequal gender distribution, which should be taken into account when generalizing these findings.

## 5 | CONCLUSIONS

Clinically, the number of primary rugae exceeded that of secondary rugae across all three sagittal skeletal malocclusion groups, although this difference was not statistically significant. Wavy and Curved rugae patterns were the most common primary rugae patterns in all three groups, while Annular and Unification patterns were the least common. Secondary rugae showed an almost equal distribution of Wavy, Curved, and Straight patterns. There was no statistically significant difference in the number of primary or secondary rugae, or in incisive papilla shape, between the three sagittal skeletal malocclusion groups. The Pear shape was the most common incisive papilla configuration in all three sagittal skeletal malocclusion groups. Because they are not associated with a specific sagittal skeletal malocclusion, palatal rugae may be more valuable as indicators for population identification and forensic facial reconstruction than as diagnostic predictors of malocclusion.

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