RESEARCH PAPER

Anatomical and Cephalometric Determinants of Posterior Palatal Seal Dimensions: An In-Vivo Study

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ABSTRACT

Background: Accurate identification of the posterior palatal seal (PPS) area is essential for retention, stability, and functional efficiency of maxillary complete dentures. Its dimensions may vary according to vibrating-line position, foveae palatinae, palatal form, sex, and soft-palate angulation.

Aim: To compare the anatomical structures used for establishing the PPS area and evaluate their relationship with palatal shape, sex, and cephalometric angular measurements.

Materials and Methods: This observational in-vivo study included 60 randomly selected dentulous individuals aged 20–60 years, comprising 30 males and 30 females. Maxillary impressions were made using irreversible hydrocolloid, casts were prepared, and custom trays were fabricated. The anterior vibrating line was identified using the Valsalva manoeuvre, whereas the posterior vibrating line was located by short, unexaggerated phonation of "ah." The markings were transferred to the casts, and linear distances were measured at the midline, right and left lateral regions, and in relation to the foveae palatinae. Lateral cephalograms were used to measure the soft-tissue–hard-tissue curve angle and the ANS–PNS/PNS–U angle. Data were analysed using descriptive statistics, independent-samples t-test, and Pearson correlation. $P < 0.05$ was considered statistically significant.

Results: Bow-shaped palates were observed in 51 participants (85.00%), whereas 9 (15.00%) had arch-shaped palates. The mean foveae palatinae–posterior vibrating line distance was 1.30 ± 0.39 mm, while the anterior vibrating line–foveae palatinae distance was 3.39 ± 0.68 mm. Bow-shaped palates demonstrated significantly greater AVL–PVL distances than arch-shaped palates on the right (7.45 ± 0.62 versus 6.68 ± 0.74 mm; $P = 0.028$) and left sides (7.42 ± 0.51 versus 6.70 ± 0.58 mm; $P = 0.001$). The midline difference was non-significant. Significant positive correlations were observed between lateral AVL–PVL distances and the soft-tissue–hard-tissue curve angle in the overall and bow-shaped groups. Males had significantly greater right- and left-sided AVL–PVL distances than females.

Conclusion: The bow-shaped palate was the predominant form. Palatal shape and sex primarily influenced the lateral dimensions of the PPS area, whereas central measurements showed limited variation. Cephalometric soft-palate angulation was positively associated with lateral PPS width, supporting individualized clinical assessment.

Keywords: Posterior palatal seal; vibrating line; foveae palatinae; palatal shape; lateral cephalometry.

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Introduction

Complete edentulism adversely affects mastication, speech, facial appearance, nutrition, and psychological well-being. Although implant-assisted prostheses have widened treatment options, conventional complete dentures remain an important form of rehabilitation. The clinical success of a maxillary complete denture depends on support, stability, retention, accurate jaw relations, suitable occlusion, and harmonious interaction with the surrounding musculature. Retention is especially important because repeated displacement during function may reduce chewing efficiency, speech clarity, confidence, and acceptance of the prosthesis. A continuous peripheral seal, including a properly developed posterior palatal seal, helps maintain contact between the denture base and supporting tissues and improves functional performance.[1] The posterior palatal seal area is the compressible soft-tissue region located at or near the junction of the hard and soft palates upon which controlled pressure may be applied by the posterior border of a maxillary complete denture. It extends from one hamular notch to the other and is related to the anterior and posterior vibrating lines, posterior hard palate, palatine aponeurosis, soft palate, posterior nasal spine, foveae palatinae, mucous glands, and overlying mucosa. Accurate identification of these structures permits an effective seal without excessive tissue displacement, soreness, or restriction of soft-palate movement. It also helps limit food entry beneath the denture and compensates for minor processing changes.[2] The posterior palatal region is dynamic, and its contour changes during respiration, phonation, swallowing, and velopharyngeal movement. The anterior vibrating line generally represents the transition between relatively immovable and slightly movable tissues, whereas the posterior vibrating line indicates the distal limit capable of maintaining functional contact with the denture border. These lines may be identified by phonation, the Valsalva manoeuvre, swallowing, visual examination, and palpation. Their apparent position can vary with head posture, tongue position, tissue resilience, patient cooperation, and examination method. Functional recording is therefore preferable to relying solely on an arbitrary posterior border carved on the master cast.[3] The width and configuration of the posterior palatal seal are influenced by palatal contour and soft-palate inclination. A gradually descending soft palate generally provides a broader area for controlled compression, whereas an abruptly descending palate offers a narrower and more technique-sensitive region. The outline between the vibrating lines may be bow-shaped, arch-shaped, butterfly-shaped, or irregular. Therefore, the seal should not be created as a uniform groove of predetermined width and depth. After the boundaries have been identified, accurate transfer to the impression, record base, master cast, or digital design is essential. Digital workflows can reproduce the seal reliably only when its functional limits are correctly incorporated.[4] The foveae palatinae are paired depressions commonly observed near the midline of the posterior palate and are frequently used as supplementary landmarks. However, they are related to palatal glandular anatomy and do not invariably coincide with either vibrating line. Their presence, symmetry, and relationship to the posterior denture border may vary among individuals. They should therefore be interpreted together with the hamular notches, posterior nasal spine, palatal contour, tissue compressibility, and soft-palate movement. Accurate denture-base adaptation is essential because discrepancies between the tissue surface and processed base can interrupt the peripheral seal even when the posterior border has been clinically positioned correctly.[5] Errors in posterior palatal seal development may arise during impression making, tray extension, recording of tissue displacement, cast preparation, or denture processing. Smudging, displacement of mobile mucosa, incomplete transfer of vibrating-line markings, dimensional alteration of impression materials, and polymerization-related distortion can affect final adaptation. Excessive compression may produce pain, ulceration, or denture displacement, whereas insufficient compression may result in loss of retention. Variations in palatal depth and contour may further influence adaptation after processing. Standardized measurement of the seal at the midline and on both lateral sides can improve reproducibility and permit development of a posterior border suited to each individual.[6]

Materials and Methods

This observational study was conducted among 60 randomly selected dentulous individuals, comprising 30 males and 30 females, aged between 20 and 60 years. Before enrolment, the nature, objectives, and procedural details of the study were explained to all participants. Written informed consent was obtained from each participant prior to the commencement of the study. The confidentiality and privacy of the participants were maintained, and accepted ethical principles were followed throughout the study.

Eligibility Criteria: Dentulous individuals between 20 and 60 years of age who had good general and oral health were included in the study. Participants were required to have satisfactory neuromuscular coordination, a clinically healthy palate without any mucosal lesion, and no known allergy or hypersensitivity to the dental materials used during the procedure. Individuals with palatal or other oral lesions, anatomical deformities of the stomatognathic system, uncontrolled systemic or metabolic disorders, psychosomatic disorders, or active periodontal disease were excluded. Individuals with a history of smoking or tobacco chewing were also excluded. Pregnant and lactating women and individuals in whom radiographic exposure was contraindicated were not included in the study.

Impression-Making Procedure: All participants were seated in an upright position in the dental chair during impression making. An appropriately sized maxillary stock tray was selected for each participant. Maxillary impressions were made using irreversible hydrocolloid impression material. The impression material was mixed in a rubber bowl with a mixing spatula according to the water-to-powder ratio recommended by the manufacturer.

After loading the material into the selected tray, the impression was made while ensuring complete coverage of the maxillary dentulous arch and palatal tissues. The impressions were inspected for surface defects, air bubbles, voids, or incomplete recording of the anatomical structures. Defective impressions were repeated whenever necessary.

To minimize dimensional changes and distortion of the irreversible hydrocolloid material, each impression was immediately poured using dental stone. The dental stone was mixed according to the manufacturer's instructions and poured into the impression with the assistance of a dental vibrator to reduce the incorporation of air bubbles. In this manner, a total of 60 maxillary dental casts were prepared.

Preparation of Maxillary Casts and Custom Trays: The dental casts were separated from the impressions after approximately 45 minutes to allow adequate setting of the dental stone. The casts were subsequently inspected and trimmed while preserving the anatomical details of the palate, maxillary tuberosities, and posterior palatal region.

Custom trays were fabricated on the master casts using clear autopolymerizing acrylic resin. The acrylic resin was manipulated according to the manufacturer's instructions and adapted over the casts during the dough stage. After polymerization, the trays were removed from the casts and trimmed according to the contour of the palate. The borders and surfaces of the trays were finished and polished to eliminate sharp or irregular areas.

Preparation of the Palatal Tissues: For recording the posterior palatal seal, each participant was seated in an upright position in the dental chair. The participant was instructed to rinse the mouth thoroughly with mouthwash to reduce the salivary flow and remove the mucin layer from the palatal tissues.

The palatal mucosa was gently cleaned using a cotton swab to remove any residual mucus or saliva associated with the palatine glands. The posterior palatal area was subsequently dried with sterile gauze to improve visibility and facilitate accurate marking of the anatomical landmarks and vibrating lines.

Identification of the Hamular Notches: The hamular processes and pterygomaxillary notches were identified by palpation using a T-burnisher. The T-burnisher was moved gently along the posterior aspect of the maxillary tuberosity until it engaged the pterygomaxillary notch.

After identifying the notch on each side, the marking was extended approximately 3–4 mm in an anterolateral direction toward the mucogingival junction. This marking delineated the pterygomaxillary seal area and represented the lateral extent of the posterior palatal seal.

Recording of the Posterior Vibrating Line: The posterior vibrating line was identified by asking the participants to pronounce "ah" in short and unexaggerated bursts. During phonation, the movement of the soft palate was carefully observed. The junction between the relatively movable and immovable portions of the soft palate was identified and marked using a violet-coloured marking medium.

The marked posterior vibrating line was extended laterally and connected with the previously identified pterygomaxillary seal markings on both sides. Participants were instructed to keep their mouths open during the marking procedure to prevent smudging or displacement of the markings.

Recording of the Anterior Vibrating Line: The anterior vibrating line was identified using the Valsalva manoeuvre. Each participant was instructed to close the nostrils and gently attempt to exhale through the nose. This manoeuvre assisted in identifying the line of flexure between the immovable tissues covering the hard palate and the slightly movable tissues of the soft palate.

The anterior vibrating line was marked using a pink-coloured marking medium. The positions of the anterior and posterior vibrating lines were reconfirmed using both phonation and the Valsalva manoeuvre. To minimize interoperator variability and maintain procedural standardization, all clinical examinations and recordings were performed by a single clinician.

Transfer of the Vibrating-Line Markings: A 1-inch-wide micropore surgical tape was adapted to the intaglio surface of the fabricated custom tray. The custom tray was then carefully positioned in the participant's mouth to transfer the markings of the anterior and posterior vibrating lines from the palatal mucosa to the tray.

The transferred markings were subsequently reproduced on the corresponding maxillary cast. Care was taken to avoid displacement or distortion of the markings during tray placement and removal. The transferred lines represented the clinically identified anterior and posterior boundaries of the posterior palatal seal area.

Measurement of the Posterior Palatal Seal Area: The distance between the anterior and posterior vibrating lines was measured using a divider and a calibrated scale. Measurements were recorded bilaterally and at predetermined anatomical locations.

The width of the posterior palatal seal area was measured at the mid-palatine suture region, at the point at which the maximum separation between the anterior and posterior vibrating lines was observed, and in the region of the foveae palatinae. All measurements were recorded carefully for subsequent comparison with the lateral cephalometric findings.

Lateral Cephalometric Examination: Lateral cephalograms were obtained for all participants using the Vatech A9 Dental Imaging System, Model PHT-30 CSS, with EZ 3D-i software version 5.2. The radiographic field of view was 18 × 24 cm. The imaging parameters included a tube voltage of 88 kVp and a tube current of 10 mA. The exposure duration and total scan time were 3.9 seconds.

During radiographic examination, the participants were positioned according to the standardized cephalometric protocol. The head was stabilized to minimize movement and positional errors during image acquisition. All radiographic procedures were performed according to the principle of "as low as reasonably achievable" and in compliance with the radiation safety guidelines established by the Atomic Energy Regulatory Board.

Cephalometric Landmarks and Angular Measurement: The cephalometric landmarks selected for the analysis included the anterior nasal spine, posterior nasal spine, tip of the uvula, and radiographic outlines of the hard and soft palates. The anterior nasal spine was identified as the most anterior point of the maxillary bony palate, whereas the posterior nasal spine represented the posterior limit of the hard palate.

The digital lateral cephalograms were analysed using EZ Ortho digital cephalometric software. Tangent lines were drawn along the radiographic contours of the hard and soft palates. The angle formed between these tangent lines was measured digitally. The obtained angular measurements were recorded for each participant and compared with the clinical measurements of the posterior palatal seal area.

Statistical Analysis

The clinical measurements of the distance between the anterior and posterior vibrating lines and the angular measurements obtained from the lateral cephalograms were entered into a data collection sheet. The data were checked for completeness and accuracy before statistical analysis. The collected data were coded, tabulated, and statistically analysed using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). The findings were presented using appropriate descriptive and inferential statistical methods according to the nature and distribution of the variables.

Results

Table 1 presents the distribution of the study participants according to sex and palatal shape. A total of 60 dentulous individuals were included in the study, comprising an equal number of males and females, with 30 participants (50.00%) in each group. This equal distribution minimized gender-related sampling bias and allowed meaningful comparison between male and female participants. Evaluation of the palatal morphology demonstrated that the bow-shaped palatal pattern was the predominant form, being observed in 51 participants (85.00%), whereas only 9 participants (15.00%) exhibited an arch-shaped palate. These findings indicate that the bow-shaped posterior palatal seal configuration was considerably more common than the arch-shaped configuration in the study population.

Table 2 summarizes the mean linear distances among the foveae palatinae, anterior vibrating line (AVL), and posterior vibrating line (PVL). The mean distance between the foveae palatinae and the posterior vibrating line was 1.30 ± 0.39 mm, indicating that the posterior vibrating line was situated in close proximity to the foveae palatinae. In contrast, the anterior vibrating line was positioned farther anteriorly, with a mean distance of 3.39 ± 0.68 mm from the foveae palatinae. The distance between the anterior and posterior vibrating lines measured 4.96 ± 1.58 mm at the midline, while greater mean distances were observed laterally, measuring 6.79 ± 1.00 mm on the right side and 6.83 ± 0.89 mm on the left side.

Table 3 compares the linear measurements between participants with bow-shaped and arch-shaped palatal forms. The mean distance between the foveae palatinae and the posterior vibrating line was 1.28 ± 0.38 mm in the bow-shaped group and 1.41 ± 0.42 mm in the arch-shaped group. Similarly, the distance between the anterior vibrating line and the foveae palatinae measured 3.35 ± 0.66 mm in the bow-shaped group compared with 3.62 ± 0.74 mm in the arch-shaped group. However, these differences were not statistically significant ($P = 0.214$ and $P = 0.163$, respectively), indicating that palatal shape had little influence on the relationship of the vibrating lines to the foveae palatinae.

In contrast, statistically significant differences were observed for the lateral measurements between the anterior and posterior vibrating lines. On the right side, the bow-shaped group demonstrated a significantly greater mean distance (7.45 ± 0.62 mm) than the arch-shaped group (6.68 ± 0.74 mm) ($P = 0.028$). Likewise, the left-sided measurement was significantly greater in the bow-shaped group (7.42 ± 0.51 mm) than in the arch-shaped group (6.70 ± 0.58 mm) ($P = 0.001$). The midline measurement showed no statistically significant difference between the two groups (4.90 ± 1.52 mm versus 5.28 ± 1.76 mm, $P = 0.332$). These findings suggest that palatal shape predominantly influenced the lateral extent of the posterior palatal seal rather than its midline dimension.

Table 4 presents the descriptive statistics of the cephalometric angular measurements. The mean angle between the soft-tissue curve and the hard-tissue curve was 150.68 ± 6.49°, while the mean angle formed between the ANS–PNS line and the PNS–U line measured 129.35 ± 4.94°. The relatively small standard deviation values for both angular measurements indicate limited variability among the study participants and suggest that the cephalometric measurements were relatively consistent across the sample.

Table 5 illustrates the correlation between the clinical linear measurements and the cephalometric angular measurements according to palatal shape. The distance between the foveae palatinae and the posterior vibrating line demonstrated weak positive correlations with the angle between the soft-tissue and hard-tissue curves in the overall sample ($r = 0.090$), the arch-shaped group ($r = 0.112$), and the bow-shaped group ($r = 0.085$). However, all these correlations were statistically non-significant ($P > 0.05$). In contrast, weak negative correlations were observed between this linear measurement and the angle formed by the ANS–PNS and PNS–U lines in all three groups, although none of these relationships reached statistical significance.

Similarly, the distance between the anterior vibrating line and the foveae palatinae exhibited weak positive correlations with the soft tissue–hard tissue curve angle and weak negative correlations with the ANS–PNS to PNS–U angle. None of these relationships reached statistical significance, indicating that the position of the anterior vibrating line relative to the foveae palatinae was not associated with the cephalometric angular measurements.

A different pattern was observed for the anterior vibrating line–posterior vibrating line distances on the lateral sides. On the left side, the correlation coefficient between the AVL–PVL distance and the angle between the soft-tissue and hard-tissue curves was 0.410 in the total sample (P = 0.001) and 0.440 in the bow-shaped group (P = 0.002), both of which were statistically significant. Likewise, on the right side, significant positive correlations were observed in the total sample (r = 0.390, P = 0.001) and in the bow-shaped group (r = 0.420, P = 0.003). These findings indicate that an increase in the lateral width of the posterior palatal seal was associated with an increase in the angle between the soft and hard palate in individuals with bow-shaped palates. Conversely, the arch-shaped group demonstrated only weak and statistically non-significant correlations on both sides.

The midline anterior vibrating line–posterior vibrating line distance exhibited only weak positive correlations with the soft tissue–hard tissue curve angle and weak negative correlations with the ANS–PNS to PNS–U angle across the total sample as well as the bow- and arch-shaped groups. None of these correlations were statistically significant, suggesting that the midline width of the posterior palatal seal was not influenced by the cephalometric angular measurements.

Gender-wise Comparison

Gender-wise comparison of the linear and cephalometric measurements revealed that the distances between the foveae palatinae and the posterior vibrating line, the anterior vibrating line and the foveae palatinae, the midline AVL–PVL distance, and both cephalometric angular measurements did not differ significantly between male and female participants (P > 0.05). However, statistically significant gender differences were observed in the lateral dimensions of the posterior palatal seal. The mean right-sided AVL–PVL distance was significantly greater in males (7.08 ± 0.58 mm) than in females (6.50 ± 0.52 mm) (P = 0.002). Similarly, the left-sided AVL–PVL distance was significantly higher in males (7.16 ± 0.54 mm) compared with females (6.48 ± 0.49 mm) (P = 0.001).

Table 1. Distribution of participants according to sex and palatal shape (N = 60)

Characteristic	Category	Number (n)	Percentage (%)
Sex	Male	30	50.00
	Female	30	50.00
Palatal shape	Bow-shaped	51	85.00
	Arch-shaped	9	15.00

Table 2. Mean distances among the anterior vibrating line, posterior vibrating line, and foveae palatinae (N = 60)

Distance measured	Mean (mm)	Standard deviation (mm)
Foveae palatinae–posterior vibrating line	1.30	0.39
Anterior vibrating line–foveae palatinae	3.39	0.68
Anterior vibrating line–posterior vibrating line at the midline	4.96	1.58
Anterior vibrating line–posterior vibrating line on the right side	6.79	1.00
Anterior vibrating line–posterior vibrating line on the left side	6.83	0.89

Table 3. Comparison of linear measurements between bow-shaped and arch-shaped palatal forms

Distance measured	Bow-shaped palate (n = 51), mean ± SD (mm)	Arch-shaped palate (n = 9), mean ± SD (mm)	p-value	Statistical significance
Foveae palatinae – posterior vibrating line	1.28 ± 0.38	1.41 ± 0.42	0.214	Non-significant
Anterior vibrating line–foveae palatinae	3.35 ± 0.66	3.62 ± 0.74	0.163	Non-significant
Anterior vibrating line–posterior vibrating line on	7.45 ± 0.62	6.68 ± 0.74	0.028	Significant

the right side				
Anterior vibrating line–posterior vibrating line at the midline	4.90 ± 1.52	5.28 ± 1.76	0.332	Non-significant
Anterior vibrating line–posterior vibrating line on the left side	7.42 ± 0.51	6.70 ± 0.58	0.001	Significant

Statistical test: Independent-samples t-test; $p < 0.05$ was considered statistically significant.

Table 4. Descriptive statistics of cephalometric angular measurements (N = 60)

Cephalometric angular measurement	Mean (degrees)	Standard deviation (degrees)
Angle between the soft-tissue curve and hard-tissue curve	150.68	6.49
Angle between the ANS–PNS line and PNS–U line	129.35	4.94

ANS: anterior nasal spine; PNS: posterior nasal spine; U: tip of the uvula.

Table 5. Correlation of linear measurements with cephalometric angular measurements according to palatal shape

Linear measurement	Palatal shape	Soft-tissue curve–hard-tissue curve angle, r	p-value	Significance	ANS–PNS–PNS–U angle, r	p-value	Significance
Foveae palatinae–posterior vibrating line	Overall (n = 60)	0.090	0.492	Non-significant	−0.057	0.666	Non-significant
	Arch-shaped (n = 9)	0.112	0.741	Non-significant	−0.083	0.809	Non-significant
	Bow-shaped (n = 51)	0.085	0.528	Non-significant	−0.049	0.712	Non-significant
Anterior vibrat	Overall	0.051	0.6	Non-signi	−0.024	0.8	Non-signi

ing line–foveae palatinae	(n = 60)		98	ficant		55	ficant
	Arch-shaped (n = 9)	0.072	0.821	Non-significant	−0.041	0.902	Non-significant
	Bow-shaped (n = 51)	0.046	0.734	Non-significant	−0.019	0.887	Non-significant
Anterior vibrating line–posterior vibrating line on the left side	Overall (n = 60)	0.410	0.001	Significant	−0.075	0.569	Non-significant
	Arch-shaped (n = 9)	0.038	0.908	Non-significant	−0.092	0.781	Non-significant
	Bow-shaped (n = 51)	0.440	0.002	Significant	−0.069	0.601	Non-significant
Anterior vibrating line–posterior vibrating line at the midline	Overall (n = 60)	0.060	0.648	Non-significant	−0.069	0.601	Non-significant
	Arch-shaped (n = 9)	0.081	0.802	Non-significant	−0.094	0.771	Non-significant
	Bow-shaped (n	0.054	0.684	Non-significant	−0.061	0.639	Non-significant

	= 51)						
Anterior vibrating line–posterior vibrating line on the right side	Overall (n = 60)	0.390	0.001	Significant	−0.029	0.824	Non-significant
	Arch-shaped (n = 9)	0.032	0.921	Non-significant	−0.051	0.875	Non-significant
	Bow-shaped (n = 51)	0.420	0.003	Significant	−0.026	0.841	Non-significant

Correlation coefficient: Pearson's r; p < 0.05 was considered statistically significant. ANS: anterior nasal spine; PNS: posterior nasal spine; U: tip of the uvula.

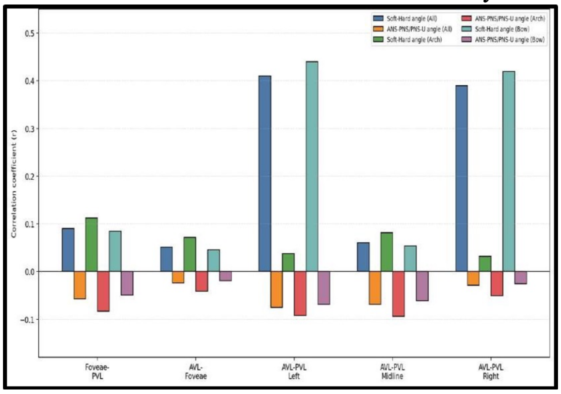

Figure 1.

Discussion

The present study included 60 dentulous participants with equal representation of males and females. The bow-shaped palatal pattern was identified in 51 participants (85.00%), whereas the arch-shaped pattern was observed in 9 participants (15.00%). These findings were almost identical to those reported by Kyung et al. (2014), who observed a butterfly- or bow-shaped posterior palatal seal in 42 of 50 participants (84.00%) and an arch-shaped pattern in 8 participants (16.00%). In the present study, the right and left AVL–PVL distances were significantly greater in the bow-shaped group than in the arch-shaped group—7.45 ± 0.62 versus 6.68 ± 0.74 mm on the right and 7.42 ± 0.51 versus 6.70 ± 0.58 mm on the left. Kyung et al. similarly reported greater lateral distances in the bow-shaped group than in the arch-shaped group on the right side (5.71 ± 1.53 versus 3.00 ± 0.87 mm) and left side (5.74 ± 1.57 versus 3.13 ± 0.93 mm), with both differences being significant at P < 0.001. However, Kyung et al. found a significant difference at the midline—3.18 ± 1.14 mm in the bow-shaped group versus 4.38 ± 0.99 mm in the arch-shaped group—whereas the present study found no significant midline difference (4.90 ± 1.52 versus 5.28 ± 1.76 mm, P = 0.332). This variation may have resulted from differences in participant characteristics and the clinical techniques used to identify and transfer the vibrating lines.[7]

The mean AVL–PVL distance in the present study was 4.96 ± 1.58 mm at the midline, 6.79 ± 1.00 mm on the right side, and 6.83 ± 0.89 mm on the left side. Thus, the posterior palatal seal area was narrower centrally and broader laterally, with nearly symmetrical right- and left-sided measurements. Thapa et al. (2016), in a study of 50 individuals, reported two clinically identifiable vibrating lines in 80.00% of the participants and only one vibrating line in 20.00%. Their mean AVL–PVL distances were 5.55 mm on the right side, 6.22 mm at the midline, and 5.40 mm on the left side. Compared with their findings, the present study showed greater lateral dimensions by approximately 1.24 mm on the right and 1.43 mm on the left, but a smaller midline dimension by approximately 1.26 mm. The different dimensional patterns may have been related to population-related anatomical variability, differences in the sites selected for measurement, or variations in identifying the anterior vibrating line through the Valsalva manoeuvre. Nevertheless, both studies demonstrated that the distance between the two vibrating lines was not constant throughout the posterior palatal region and therefore required individual clinical assessment.[8]

In the present study, the mean distance between the foveae palatinae and the posterior vibrating line was 1.30 ± 0.39 mm, whereas the distance between the anterior vibrating line and the foveae palatinae was 3.39 ± 0.68 mm. These measurements showed that the foveae palatinae were located considerably closer to the posterior vibrating line than to the anterior vibrating line. Khawaja et al. (2022), in a study of 250 participants, reported that the foveae palatinae were situated at a mean distance of 1.68 ± 1.11 mm anterior to the vibrating line. Their mean distance was only approximately 0.38 mm greater than the foveae palatinae–PVL distance recorded in the present study. The relatively smaller standard deviation in the present investigation also indicated less variability in this measurement. The similarity between the two studies supports the use of the foveae palatinae as a preliminary anatomical guide for locating the posterior vibrating line. However, because neither study showed complete coincidence between the foveae and vibrating line, the foveae palatinae should not be used as the sole landmark for determining the posterior border of a maxillary denture. Clinical confirmation through phonation, palpation and functional examination of the soft palate remains essential.[9]

The distances from the foveae palatinae to the two vibrating lines were not significantly different between the bow- and arch-shaped groups in the present study. The foveae palatinae–PVL distance was 1.28 ± 0.38 mm in the bow-shaped group and 1.41 ± 0.42 mm in the arch-shaped group ($P = 0.214$), while the AVL–foveae palatinae distance was 3.35 ± 0.66 and 3.62 ± 0.74 mm, respectively ($P = 0.163$). In contrast, palatal shape significantly influenced the lateral AVL–PVL dimensions but not the midline dimension. Chhetri et al. (2019) evaluated 200 participants and found that the vibrating line was anterior to the foveae palatinae in 70.1% of individuals with Class I, 54.2% with Class II and 60.6% with Class III soft palates. It coincided with the foveae in 22.6%, 40.0% and 36.3% of the three respective groups, while only approximately 6.0% of the overall sample had a vibrating line posterior to the foveae. Although their soft-palate classification differed from the bow- and arch-shaped classification used in the present investigation, both studies demonstrated that a fixed relationship between the foveae palatinae and vibrating line could not be assumed. The findings further suggest that soft-palate configuration may have a greater influence on the lateral width of the posterior palatal seal than on the position of the foveae palatinae.[10]

Cephalometric analysis in the present study showed that the mean angle between the soft-tissue and hard-tissue curves was 150.68 ± 6.49°, while the mean angle formed between the ANS–PNS and PNS–U lines was 129.35 ± 4.94°. Sapkota et al. (2021) evaluated 300 lateral cephalograms and reported a mean hard palate–soft palate angulation of 47.05 ± 7.74°. A direct numerical comparison should be made cautiously because Sapkota et al. recorded the acute angle formed by the two tangents, whereas the present study reported the obtuse included angle. If the supplementary acute angle corresponding to the present mean of 150.68° is considered, it would be approximately 29.32°, which is lower than the mean of 47.05° reported by Sapkota et al. The difference may be attributable to the age distribution, racial and anatomical characteristics of the participants, orientation of the cephalometric tangents, head position and functional position of the soft palate during radiographic exposure. Sapkota et al. also found no significant difference in palatal throat-form distribution between males and females ($P = 0.60$), which was consistent with the absence of a significant gender difference in the two cephalometric angular measurements in the present study.[11]

The most important correlation identified in the present study was between the lateral AVL–PVL distance and the angle formed by the soft- and hard-tissue curves. In the overall sample, the correlation was significant on the left side ($r = 0.410$, $P = 0.001$) and right side ($r = 0.390$, $P = 0.001$). The relationship was slightly stronger in the bow-shaped group, with $r = 0.440$ on the left ($P = 0.002$) and $r = 0.420$ on the right ($P = 0.003$), whereas no significant relationships were found in the arch-shaped group. The midline distance was not significantly associated with the soft–hard tissue angle ($r = 0.060$, $P = 0.648$). Shah et al. (2016) similarly demonstrated a strong positive correlation between soft-palate angulation and posterior palatal seal width ($r = 0.930$, $P < 0.001$), although their correlation was considerably stronger than that obtained in the present study. They also reported a significant positive correlation between PPS width and the ANS–PNS/PNS–U angle ($r = 0.360$, $P = 0.019$). This differed from the present study, in which correlations with the ANS–PNS/PNS–U angle were weak, negative and non-significant, including $r = -0.075$ on the left and $r = -0.029$ on the right. Differences in sample size, PPS measurement sites and separation of lateral and midline measurements may explain the different strengths of association.[12]

Gender-wise analysis showed that most linear and angular measurements were comparable between males and females. However, males demonstrated significantly greater lateral AVL–PVL distances. The right-sided distance was 7.08 ± 0.58 mm in males and 6.50 ± 0.52 mm in females ($P = 0.002$), while the left-sided distance was 7.16 ± 0.54 mm in males and 6.48 ± 0.49 mm in females ($P = 0.001$). Chaudhary et al. (2022) examined 200 participants, including 94 males and 106 females, and found that the vibrating line was anterior to the foveae palatinae in 65.1% of males and 72.3% of females, coincided with the foveae in 22.6% and 14.9%, and was posterior to the foveae in 12.3% and 12.8%, respectively. The overall association between sex and vibrating-line position was statistically non-significant ($P = 0.37$). Their findings agree with the present observation that the position of the central anatomical landmarks and palatal angulation did not differ significantly by sex. The significantly wider lateral PPS dimensions among males in the present study are not necessarily contradictory because Chaudhary et al. classified the relative position of the line but did not compare its absolute lateral width. The present findings therefore suggest that sex may influence the breadth of the PPS area without substantially altering the location of the vibrating line relative to the foveae palatinae.[13]

The weak and non-significant correlations of the foveae palatinae–PVL distance, AVL–foveae palatinae distance and midline AVL–PVL distance with both cephalometric angles demonstrated that centrally located anatomical landmarks could not reliably predict the complete dimensions of the posterior palatal seal. Only the lateral AVL–PVL measurements were significantly related to the soft tissue–hard tissue curve angle. Elmanaseer et al. (2024) examined 280 edentulous participants and reported that the foveae palatinae could not be clinically detected in 20.36% of the sample. Among participants in whom the foveae were identifiable, they were situated anterior to the vibrating line in 57.85%, directly on the line in 26.01%, and posterior to it in 16.14%. No significant relationship was found between foveal position and soft-palate classification. These observations support the present finding that the foveae palatinae had only weak relationships with the cephalometric angular variables. Therefore, although the present mean foveae palatinae–PVL distance of 1.30 ± 0.39 mm confirms the close proximity of the two structures, the foveae should be regarded as an adjunctive landmark rather than an absolute determinant of the denture border. Individual identification of both vibrating lines through phonation, the Valsalva manoeuvre and careful clinical transfer remains necessary for accurately recording the posterior palatal seal.[14]

Conclusion

the foveae palatinae were found to be reliable anatomical landmarks for identifying the posterior limit of the maxillary denture, owing to their close proximity to the posterior vibrating line. The anterior vibrating line most commonly demonstrated a bow-shaped configuration in the studied population, whereas the arch-shaped pattern was observed less frequently. The study also demonstrated an association between the distance separating the anterior and posterior vibrating lines and the angulation between the hard and soft palatal contours, indicating that palatal inclination influences the extent and configuration of the posterior palatal seal. An increase in the distance between the vibrating lines corresponded with an increase in the angulation between the hard and soft palate curves. Furthermore, a broader posterior palatal seal area was observed in cases exhibiting a moderate transition between the hard and soft palate, which may contribute to improved retention and stability of the maxillary complete denture.

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