



## Comparative Evaluation of Nasal Parameters in Various Vertical Skeletal Dimensions Amongst Malay Female Orthodontic Patients

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### Research Article

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### ABSTRACT

**Objectives:** To establish cephalometric norms for various nasal parameters in skeletal normodivergent Malaysian Malay adult females, and to compare nasal parameter differences across normo-, hypo-, and hyperdivergent vertical skeletal dimensions.

**Materials and Methods:** This retrospective study analysed 156 pre-orthodontic lateral cephalometric radiographs of skeletal Class I Malay females aged 18 to 30 years (mean age = 24.12 ± 3.38). Cephalograms were categorised into normodivergent (MMPA: 24.8° ± 6.7°), hypodivergent (<18.1°), and hyperdivergent (>31.5°). Sixteen nasal parameters were manually traced, comprising nine linear (nasal depth 1, nasal depth 2, nasal bone length, nasal length, columella convexity, nasal dorsum axis, nasal tip protrusion, nasal height, and hump) and seven angular (nasomental, nasofrontal, nasofacial, nasolabial, nasal tip, soft tissue facial convexity, and nasal bone angles) parameters. One-way ANOVA with Bonferroni post-hoc test ( $p < 0.05$ ) was used to compare mean nasal parameters across the three vertical skeletal groups. Intra- and inter-examiner reproducibility was assessed using the Intraclass Correlation Coefficient (ICC) with remeasurements made after one week.

**Results:** ICC analysis demonstrated excellent intra- and inter-examiner reliability (0.93 and 0.91, respectively). No significant differences were observed in linear nasal parameters across all groups except nasal depth 2 ( $p = 0.02$ ) which was significantly greater in normodivergent than hyperdivergent group. No significant differences were found in angular nasal parameters.

**Conclusions:** Nasal cephalometric norms in normodivergent Malaysian Malay female were established, providing an essential reference data for nasal assessment. Nasal depth 2 varied significantly across groups, suggesting that vertical skeletal pattern can influence this specific nasal variable, which is crucial for improving orthodontic and surgical treatment planning in the Malay population.

**Keywords:** Cephalometry, nose, orthodontics, vertical dimension

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### Introduction

The nose serves as the central anatomical feature of the face, playing a pivotal role in determining facial aesthetics and overall appearance.<sup>1</sup> It is composed of bone and cartilage, not only provides structural integrity but also contributes to individual facial identity.<sup>2,3</sup> Additionally, the nose is intricately linked to the overall harmony of facial features and is one of the most attractive parts of the face.<sup>4</sup> Since the nose poses a great influence on overall symmetrical facial perception, minor alterations in nasal morphology may result in noticeable variances in facial harmony and appearance.<sup>5</sup>

Nasal cephalometric analysis is a cornerstone of modern craniofacial diagnostics, providing a comprehensive framework for understanding nasal anatomy and its implications for health and aesthetics. It serves as a valuable tool in various fields, from orthodontics to nasal reconstructive surgery, making it essential for accurate diagnosis and

treatment planning. The shape of the nose can be analyzed through specific nasal anthropometric measurements, including nasal length, depth, width, and projection.<sup>6</sup> Commonly studied nasal parameters include the nasal dorsum axis, nasal height, nasal depth, hump, and columella convexity.<sup>7</sup> Bhandari et al.<sup>8</sup> emphasized that nasal morphology is unique to each ethnicity, necessitating the establishment of normative values tailored to the demographic background of the patient. For instance, the nasal bridge length in Korean females was 38.39 mm, which was significantly shorter than that observed in Caucasian females (42.9 mm).<sup>9</sup> These differences are crucial in procedures like dorsal augmentation, as applying inappropriate reference values may lead to disproportionate nasal modifications that do not align with the patient's ethnic facial harmony. To date, there remains scanty research focusing on nasal cephalometric norms specific to the

Malaysian Malay population. Although normative nasal cephalometric values are available for the Caucasian population, they cannot be directly applied to the Malay population due to significant anthropometric differences across ethnic groups.<sup>6</sup>

Vertical skeletal dimensions, often defined by the Maxillary-Mandibular Planes Angle (MMPA), are classified into three categories: hypodivergent, normodivergent, and hyperdivergent patterns. These skeletal patterns significantly influence overall facial proportions and harmony and are often affected by factors such as age, gender, ethnicity, trauma, and disease.<sup>7</sup> Despite growing interest in facial aesthetics and craniofacial morphology, there remains a paucity of research specifically examining nasal characteristics in relation to vertical skeletal patterns.<sup>10</sup> Vertical skeletal patterns are important considerations, for instance, when planning orthodontic and surgical interventions involving the nose. However, the interplay between vertical skeletal patterns and nasal parameters, including height, width, and projection remains largely unexplored. Previous studies have focused mainly on the association between nasal parameters and anteroposterior (Class 1, Class 2 and Class 3) skeletal relationships, resulting in limited nasal variables in relation to vertical skeletal dimensions.<sup>11</sup> Understanding nasal morphology variations across different vertical skeletal patterns is essential for improving diagnostic accuracy, treatment planning, and population-specific clinical applications in orthodontics and facial surgery. Thus, this study aimed to establish cephalometric reference values for various nasal parameters in skeletal normodivergent Malaysian Malay adult females, and to compare nasal parameter differences across different vertical skeletal groups (hypo-, normo-, and hyperdivergent) in this population.

## Materials and Methods

### Study Design

This retrospective study involved 156 pre-orthodontic lateral cephalometric radiographs from two private dental clinics in Kuantan city of Pahang state: Dr Fatain's Dental Clinic Taman Tas and Dr Fatain's Dental Clinic Indera Mahkota 3.

### Ethical Approval

Ethical approval was obtained from IIUM Research Ethics Committee (IREC 2024-043) dated 20 February 2024. The ethical standards of the Helsinki Declaration were followed.

### Sample Size Calculations

The sample size was calculated using an F-test one-way ANOVA in G\*Power 3.1.9.7 software, based on nasal bone angle values from three vertical skeletal pattern groups reported by Gülşen et al.<sup>12</sup>:  $170.00 \pm 7.00$  for normodivergent,  $165.00 \pm 8.36$  for hypodivergent, and  $171.00 \pm 6.93$  for hyperdivergent subjects. The required total sample size was 156, with an effect size of 0.29, a power of 0.90, and  $\alpha = 0.05$ . To establish the nasal norms for the Malay female population, 52 lateral cephalometric radiographs from normodivergent subjects were analysed. Subsequently, all 156 radiographs were evaluated to compare nasal values across the three vertical skeletal relations.

### Inclusion and Exclusion Criteria

This study included Malay female subjects aged 18 to 30 years (mean age =  $24.12 \pm 3.38$ ) with three generations of pure Malay descent without any inter-racial marriages to ensure genetic homogeneity. Only female subjects were included to minimise biological variability related to known sex-based differences in craniofacial growth patterns and nasal morphology, thereby allowing the establishment of more homogeneous nasal cephalometric reference values specific to the Malaysian Malay female population.

All subjects had a Class I skeletal pattern, characterized by an ANB angle of  $3.2^\circ \pm 1.2$ .<sup>13</sup> Those with a history of facial trauma, surgical interventions (e.g., orthognathic or plastic surgery), congenital diseases, developmental defects (e.g. cleft lip and palate) affecting normal growth, or previous orthodontic treatment were excluded.

### Cephalometric Analysis: Tracing & Measurement

All radiographic exposures were performed at the private dental clinic equipped with the HDX WILL Eco-X radiographic machine (HDX Will Corp, Chungcheongbuk-do, Korea). The exposure settings were standardized at 85 kVp, 10.0 mA and 6.5 seconds. Written consent and demographic forms were obtained from all patients prior to radiographic acquisition. Radiographs were obtained following standard protocols, with all procedures performed by the same operator to ensure consistency. Patients were positioned with their heads in a natural position, with the Frankfort horizontal plane parallel to the floor, and the nasal rod tip aligned with the soft tissue nasion. Only pre-treatment lateral cephalometric records of diagnostically acceptable quality ('A' grade), according to the Public Health England and Faculty of General Dental Practice guidelines 2020 were included.

Prior to cephalometric tracing, calibration training was conducted under the supervision of an experienced orthodontist with eight years of clinical experience to ensure consistent landmark identification. Cephalometric tracing was performed in a dark room using a light viewing box with a 2B sharp pencil, a 15 cm plastic ruler, and a protractor on an acetate paper for measurements. The Frankfort plane of the lateral cephalometry was placed parallel to the upper horizontal border of the light box. Manual cephalometric tracing was used in this study in accordance with established cephalometric protocols. Tracings were performed by trained examiners following calibration procedures to ensure consistency in landmark identification and measurement. Measurement reliability was subsequently assessed using intra- and inter-examiner agreement analyses, as detailed in the Statistical Analysis section.

The ANB value was calculated by subtraction of SNB from SNA value ( $SNA - SNB = ANB$ ). In extreme SNA cases, where the normal SNA value for Malays is  $84.5^\circ \pm 4.0$ ,<sup>13</sup> and the angle between Sella-Nasion (SN) and maxillary plane (SN-MxPI) must be within  $5^\circ$ - $11^\circ$ , the Eastman correction was applied. If SNA increased,  $0.5^\circ$  was subtracted from the calculated ANB for each degree above the normal SNA value. Conversely, if SNA decreased,  $0.5^\circ$  was added for each degree below the normal SNA value.

The radiographs were categorised into three groups based on vertical skeletal patterns: normodivergent, hypodivergent

and hyperdivergent, with MMPA values of  $24.8^\circ \pm 6.7^\circ$ , less than  $18.1^\circ$ , and greater than  $31.5^\circ$ , respectively.<sup>13</sup> The skeletal and nasal landmarks were traced on the acetate paper by two

examiners (N.S. and S.N.A.) to measure 16 nasal parameters consisting of nine linear and seven angular parameters, as described by Gülşen et al.<sup>12</sup> (Tables 1 and 2; Figures 1-3).

Table 1. Skeletal and nasal landmarks

Terminology	Abbreviation	Description
<b>Skeletal Landmark</b>		
Nasion	N	Most concave intersection points from the frontonasal suture.
Porion	Po	Most superior point at the external auditory canal.
Sella	S	Centre point of the sella turcica.
Subspinale Point A	A	Most posterior point on the anterior maxilla.
Subspinale Point B	B	Most concave point on the anterior mandible, between pogonion and alveolar crest.
Gonion	Go	Bisecting angle formed by intersection of tangent line at posterior and inferior borders of the mandible.
Glabella	G	Most prominent point on the frontal bone.
Anterior Nasal Spine	ANS	Anterior limit of the nasal floor.
Posterior Nasal Spine	PNS	Posterior limit of the nasal floor.
Menton	Me	Most inferior point of the symphysis of the mandible.
<b>Skeletal Planes</b>		
Maxillary Plane	MxPI	Plane formed by the ANS and PNS.
Mandibular Plane	MnPI	Plane formed by Menton (Me) and Gonion (Go).
Maxillary-Mandibular Planes Angle	MMPA	Angle formed between Maxillary Plane (MxPI) and Mandibular Plane (MnPI).
<b>Nasal Landmark</b>		
Pronasale	Pr	Most prominent point at the lower half of the nose.
Subnasale	Sn	Intersection points of columella with upper lip in the midsagittal plane.
Midnasale	Mn	Midpoint on nasal dorsum that separates the upper and lower parts.
Columella	Cm	Most convex point at the Subnasale-Pronasale curve line.
Supratip	St	Midway point between Midnasale and Pronasale.
N1	N1	Most concave point on the nasal bone.
N2	N2	Most convex point on the nasal bone.
Alar Curvature	Ac	Most convex point on the curvature of the nasal alar.
Rhinion	R	Most antero-inferior point at the tip of the nasal bone.
Soft Tissue Nasion	N'	Most concave point between soft tissue Glabella and Subnasale in profile view.
Soft Tissue Glabella	G'	Point on soft tissue at the inferior forehead, between eyebrows.
Soft Tissue Pogonion	Pog'	Most anterior point at the chin in the midsagittal plane.

Table 2. Linear and angular nasal parameters

Linear nasal parameters (mm)		
Nasal depth 1	Pr $\perp$ N'-Sn	Perpendicular distance from Pronasale (Pr) to line formed by Soft Tissue Nasion (N') and Subnasale (Sn).
Nasal bone length	N-R	Distance between Nasion (N) and Rhinion (R).
Nasal length	N'-Pr	Distance between Soft Tissue Nasion (N') and Pronasale (Pr).
Nasal tip protrusion	Sn-Pr	Distance between Subnasale (Sn) and Pronasale (Pr).
Columella convexity	Sn-Pr $\perp$ Cm	Perpendicular distance from Nasal Tip Protrusion (Sn-Pr) to the most convex point on Columella.
Axis of nasal dorsum	N'-St	Distance from Soft Tissue Nasion (N') to the point of Supratip (St).
Nasal depth 2	Pr-Ac	Length between Pronasale (Pr) and Alar Curvature (Ac).
Nasal height	N'-Sn	Distance between Soft Tissue Nasion (N') and Subnasale (Sn).
Hump	N'-St $\perp$ Superior nasal dorsum	Perpendicular distance from Axis of Nasal Dorsum (N'-St) to the most superior point at the upper part of the nasal dorsum.
Angular nasal parameters ( $^\circ$ )		
Angle of nasomental	N'-St $\angle$ Pr-Pog'	Angle formed between Axis of Nasal Dorsum and line from Pronasale (Pr) to Soft Tissue Pogonion (Pog').
Angle of nasofrontal	G'-N' $\angle$ N'-Pr	Angle formed between the line from Soft Tissue Glabella (G') to Soft Tissue Nasion (N') and from Soft Tissue Nasion (N') to Pronasale (Pr).
Angle of nasofacial	G'-Pog' $\angle$ N'-Pr	Angle formed between the line from G'-Pogonion (Pog') and N'-Pr line (Nasal Length).
Soft tissue facial convexity	G'-Sn $\angle$ Sn-Pog'	Angle formed by G'-Sn and Sn-Pogonion (Pog') lines.
Angle of nasolabial	Tangent of columella $\angle$ Upper lip	Angle formed between the tangent of the columella and the upper lip.
Angle of nasal tip	N'-Pr $\angle$ Sn-Pr	Angle formed between Nasal Length (N'-Pr) and Nasal Tip Protrusion (Sn-Pr).
Angle of nasal bone	N1-N2 $\angle$ N2-R	Angle at the posterior part of N1-N2 and N2-R.

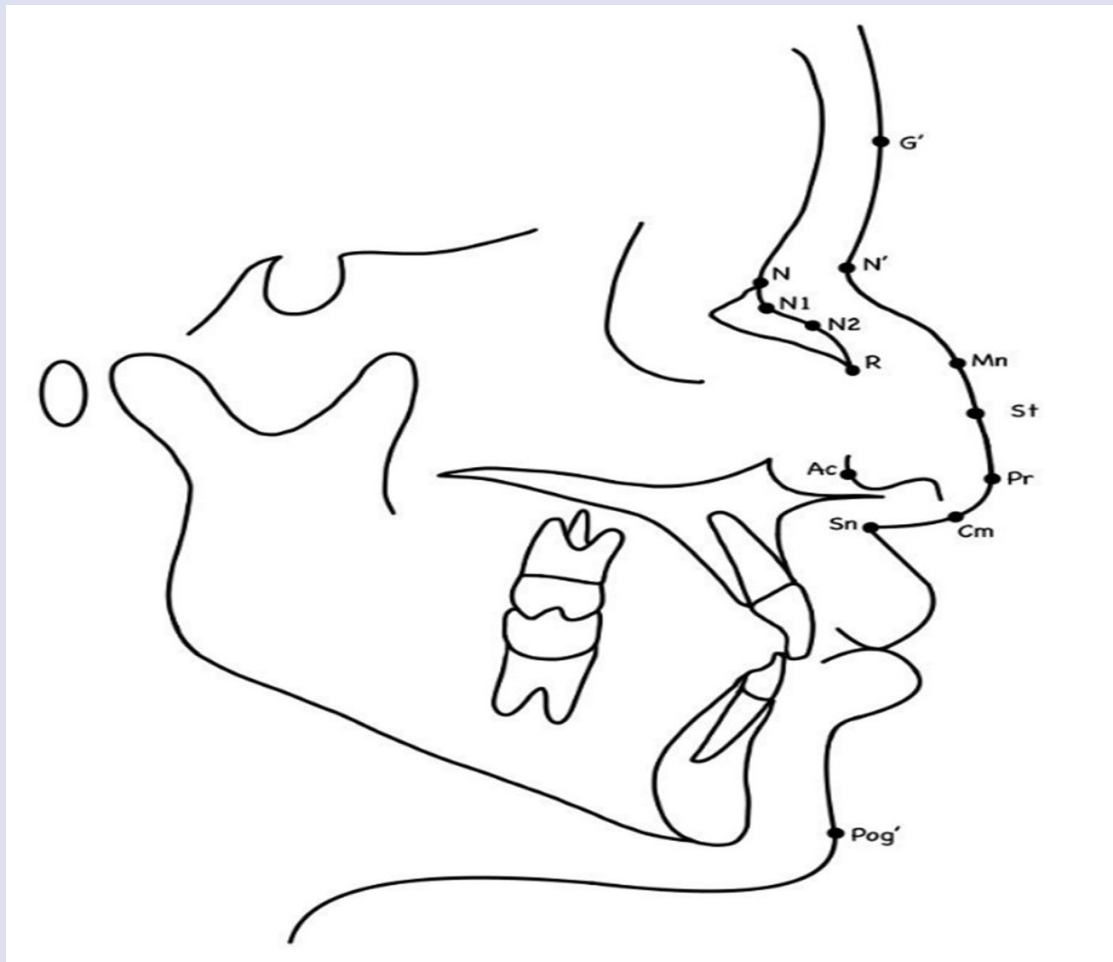


Figure 1. Landmarks used for lateral cephalometric tracing to measure nasal parameters.

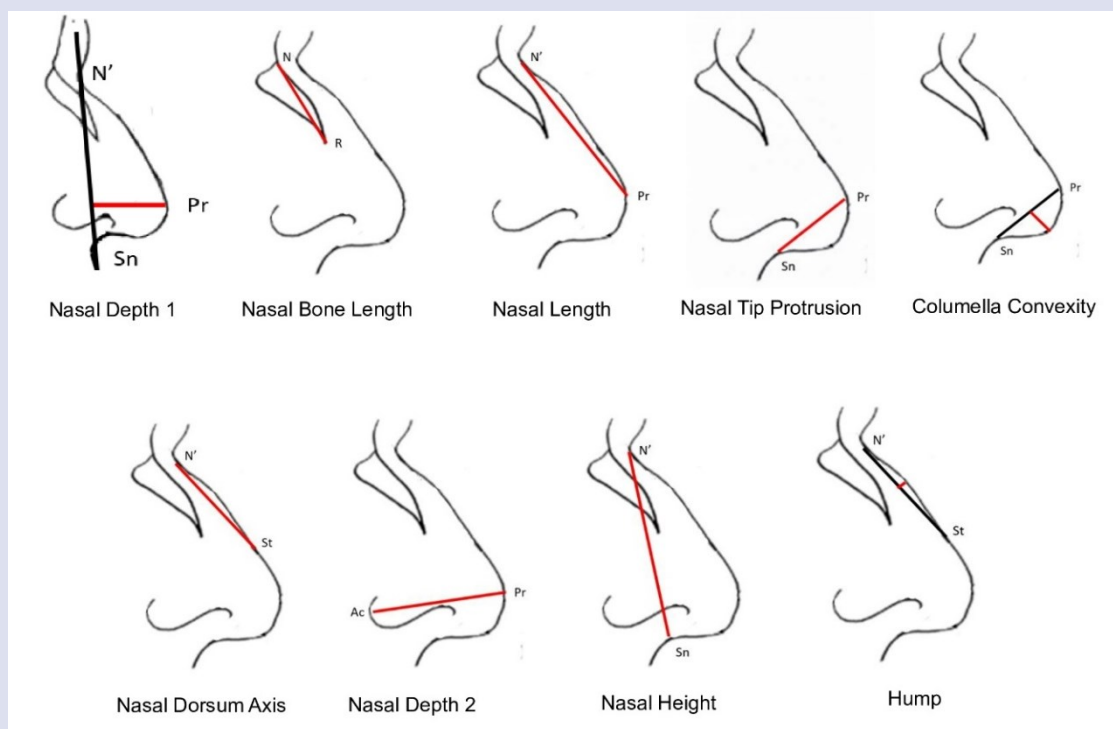


Figure 2. Schematic representation of linear nasal parameters.

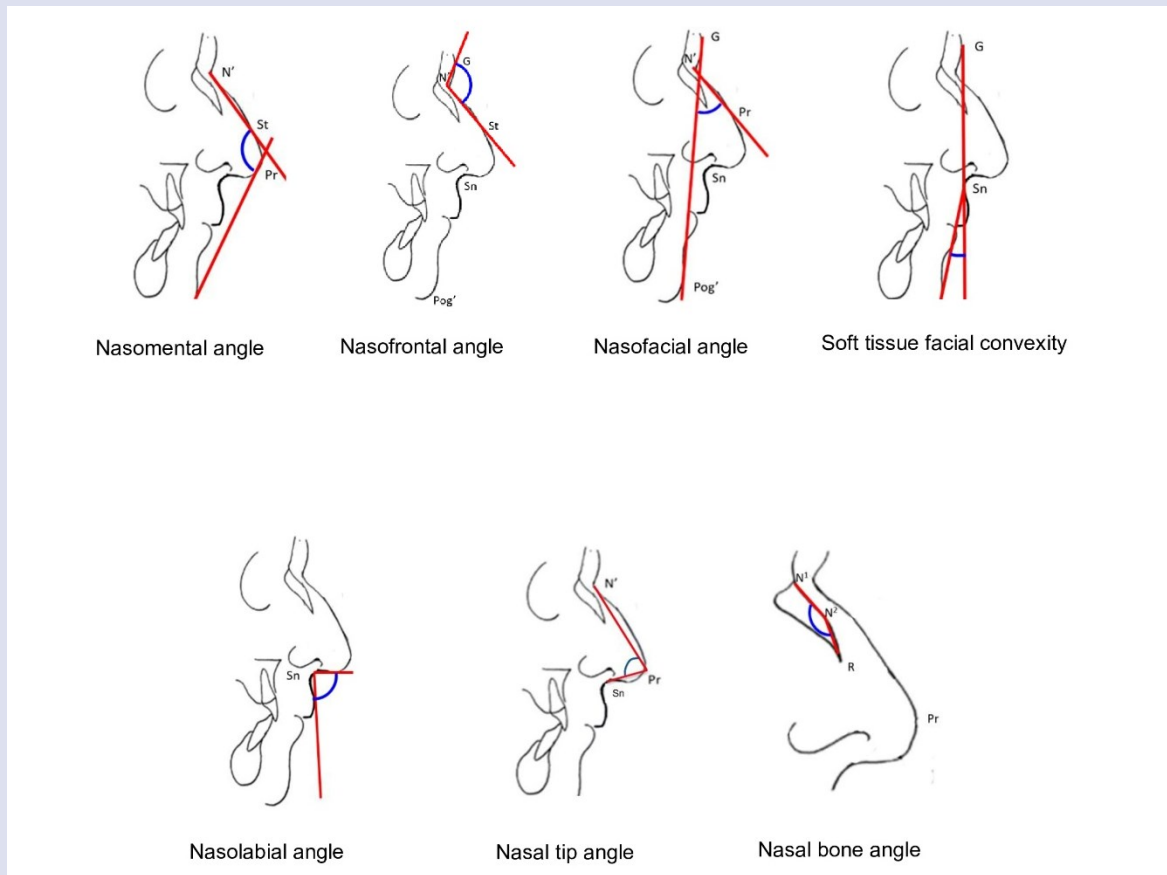


Figure 3. Schematic representation of angular nasal parameters

### Statistical Analysis

Data analysis was performed using IBM SPSS Statistics software version 25.0. Normality of data distribution was assessed using the Kolmogorov–Smirnov test. Descriptive statistics, including means and standard deviations (SD), were computed to establish normative values for nasal parameters in the normodivergent group. Comparative analysis of nasal parameters across the three vertical skeletal patterns (normo-, hypo-, and hyperdivergent) was conducted using a one-way ANOVA. Post-hoc pairwise comparisons were performed using the Bonferroni correction, with statistical significance set at  $p < 0.05$ . To ensure reliability, tracings and measurements were repeated on 20 randomly selected lateral cephalometric radiographs after a one-week interval. Intra-examiner (within examiner) and inter-examiner (between examiners) reliability were assessed using Intraclass Correlation Coefficients (ICC).

### Results

A total of 156 lateral cephalometric radiographs were analyzed and classified into three groups based on the MMPA: normodivergent, hypodivergent, and hyperdivergent, with mean MMPA values of  $27.39^\circ \pm 1.84$ ,  $16.47^\circ \pm 0.17$ , and  $34.97^\circ \pm 3.68$  respectively. The mean ANB value was  $3.04^\circ \pm 1.08$ . Intra- and inter-examiner reliability for cephalometric measurements were assessed,

yielding ICC scores of 0.93 and 0.91, respectively, indicating excellent reliability.

Table 3 shows the mean and standard deviation of the 16 nasal parameters across the three skeletal patterns. Based on the data, no significant differences in nasal size were observed among the three vertical skeletal pattern groups. Specifically, the mean ‘nasal bone length’ was comparable across normodivergent ( $24.25 \pm 3.61$  mm), hypodivergent ( $24.37 \pm 2.53$  mm), and hyperdivergent ( $24.00 \pm 3.15$ ) groups. Similarly, ‘nasal length’ showed minimal variation, with values of  $40.13 \pm 3.53$  mm,  $40.03 \pm 3.33$  mm, and  $39.86 \pm 3.77$  mm for normo-, hypo-, and hyperdivergent groups, respectively. ‘Nasal height’ also depicted the same pattern where the values were  $46.67 \pm 3.79$  mm,  $46.49 \pm 2.80$  mm, and  $46.17 \pm 4.05$  mm across the respective skeletal groups. The findings also indicated that the hyperdivergent group exhibited a flatter nasal profile, with lower values for the ‘axis of nasal dorsum’ and ‘nasal tip protrusion’ compared to the normodivergent group. However, these differences were not statistically significant. In contrast, the ‘columella convexity’ in the hyperdivergent group ( $4.26 \pm 5.67$  mm) was greater than that observed in both the normodivergent and hypodivergent groups, suggesting a more prominent columella, though this variation was also not statistically significant. Interestingly, ‘hump’ was found to be none or minimal in Malay females with values of  $-1.64 \pm 0.94$  mm,  $-1.47 \pm 0.98$  mm, and  $-1.35 \pm 0.98$  mm for normo-, hypo-,

and hyperdivergent group respectively, with no significant differences across the group.

Among the linear parameters, a significant difference was observed for 'nasal depth 2' ( $F = 4.13$ ,  $p = 0.02$ ) between the groups at the 0.05 level of significance. A Bonferroni post-hoc test revealed that 'nasal depth 2' was significantly longer in the normodivergent group compared

to the hyperdivergent group ( $p = 0.03$ ), while no significant differences were noted between the normodivergent and hypodivergent groups ( $p = 0.07$ ) or between the hypodivergent and hyperdivergent groups ( $p = 1.00$ ; Figure 4). No significant differences were observed in the angular measurements across the three skeletal groups ( $p > 0.05$ ; Figure 5).

Table 3. Mean and standard deviation of nasal parameters across different skeletal divergence groups

Nasal parameters	Normodivergent	Hypodivergent	Hyperdivergent	p value
	Mean ± SD	Mean ± SD	Mean ± SD	
Nasal depth1 (N'-Sn ⊥ Pr)	14.19 ± 3.29	13.61 ± 1.34	13.62 ± 1.37	0.30
Nasal bone length (N-R)	24.25 ± 3.61	24.37 ± 2.53	24.00 ± 3.15	0.83
Nasal length (N'-Pr)	40.13 ± 3.53	40.03 ± 3.33	39.86 ± 3.77	0.93
Nasal tip protrusion (Sn-Pr)	17.14 ± 2.92	16.60 ± 2.38	16.38 ± 1.58	0.24
Columella convexity (Sn-Pr ⊥ Cm)	2.81 ± 0.82	2.99 ± 1.17	4.26 ± 0.92	0.29
Axis of nasal dorsum (N'-St)	30.49 ± 3.14	30.75 ± 2.62	29.89 ± 2.99	0.30
Nasal depth 2 (Pr-Ac)	30.36 ± 3.48	28.89 ± 3.20	28.66 ± 3.10	0.02*
Nasal height (N'-Sn)	46.67 ± 3.79	46.49 ± 2.80	46.17 ± 4.05	0.77
Hump (N'-St ⊥ Superior nasal dorsum)	-1.64 ± 0.94	-1.47 ± 0.98	-1.35 ± 0.98	0.31
Angle of nasomental (N-St ⊥ Pr-Pog')	133.51 ± 6.31	134.71 ± 6.48	132.37 ± 8.28	0.22
Angle of nasofrontal (G'-N' ⊥ N'-Pr)	140.28 ± 5.53	139.93 ± 7.00	139.76 ± 6.12	0.91
Angle of nasofacial (G'-Pog' ⊥ N'-Pr)	30.38 ± 3.61	30.39 ± 3.43	31.61 ± 3.92	0.15
Soft tissue facial convexity (G'-Sn ⊥ Sn-Pog')	170.41 ± 5.07	171.08 ± 4.78	168.73 ± 5.80	0.07
Angle of nasolabial (Tangent of columella ⊥ Upper lip)	99.45 ± 15.58	99.47 ± 15.43	100.41 ± 16.03	0.94
Angle of nasal tip (N'-Pr ⊥ Sn-Pr)	102.87 ± 8.65	102.91 ± 6.97	103.14 ± 7.11	0.98
Angle of nasal bone (N1-N2 ⊥ N2-R)	168.80 ± 10.98	167.63 ± 11.31	170.04 ± 10.38	0.53

\* indicates significant differences at  $p < 0.05$

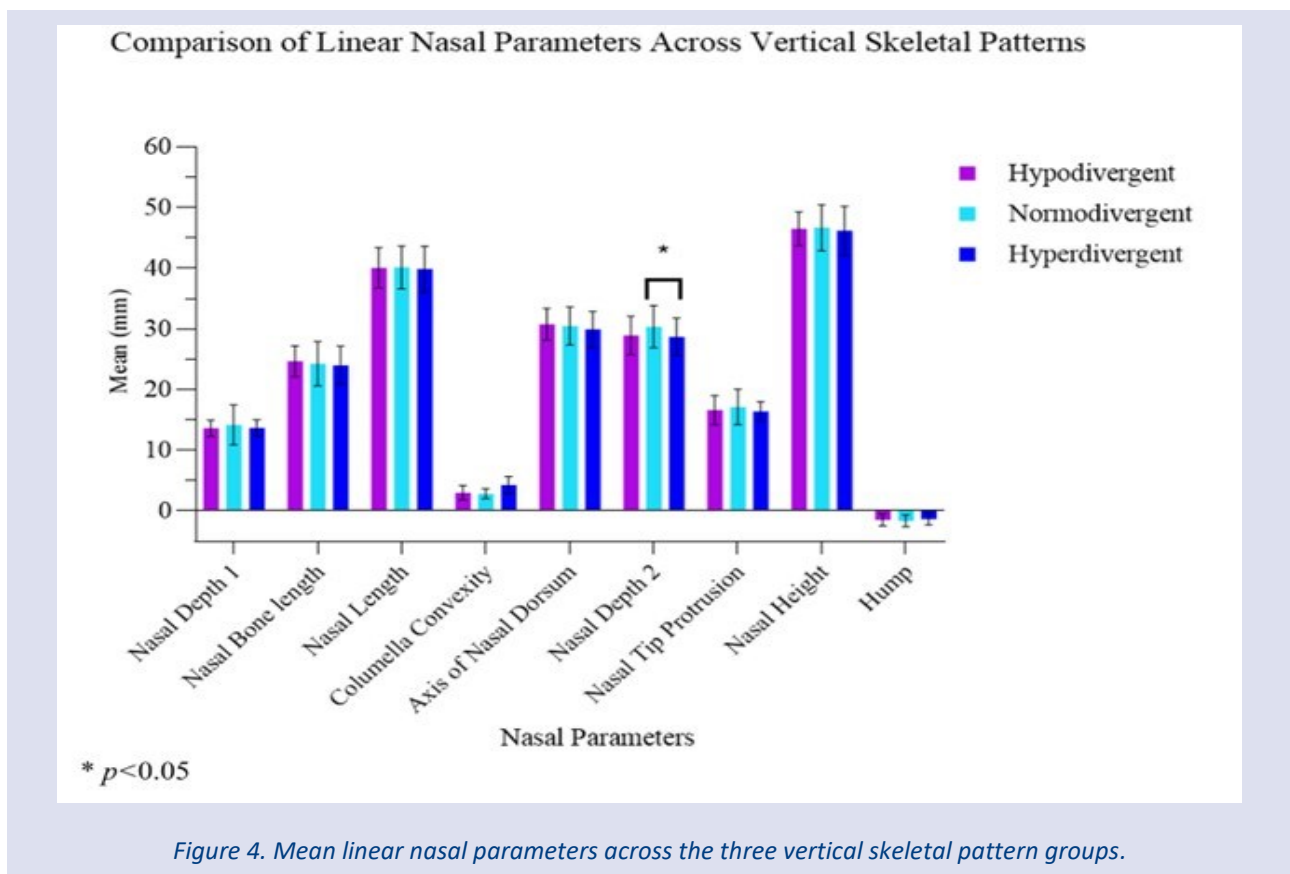


Figure 4. Mean linear nasal parameters across the three vertical skeletal pattern groups.

### Comparison of Angular Nasal Parameters Across Vertical Skeletal Patterns

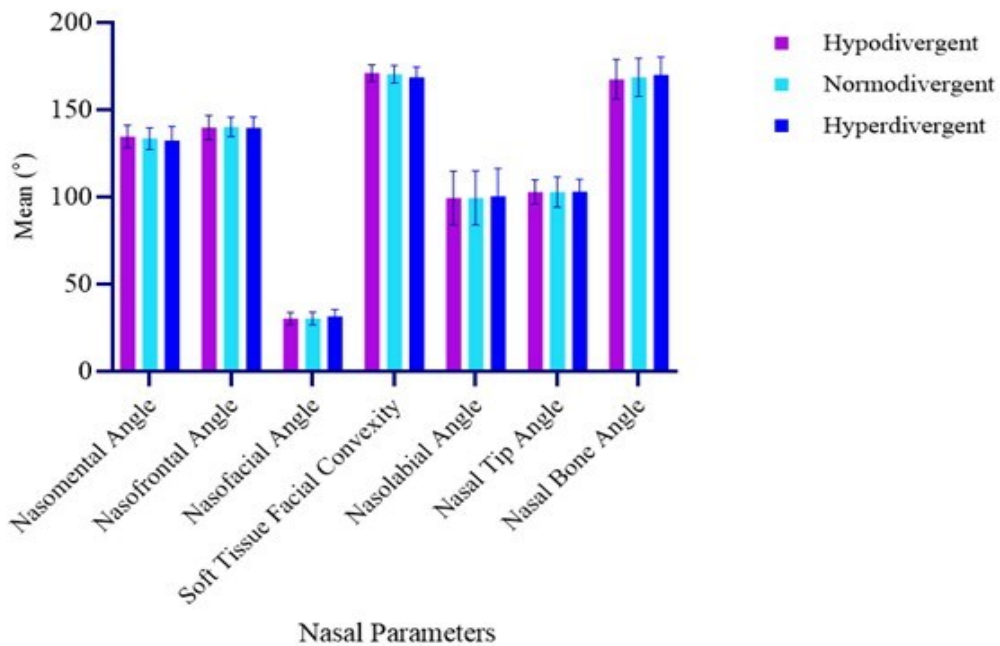


Figure 5. Mean angular nasal parameters across the three vertical skeletal pattern groups.

### Discussion

While sagittal skeletal relationships have been extensively investigated in relation to nasal morphology, the influence of vertical skeletal divergence on nasal dimensions remains inadequately explored, particularly within Southeast Asian, specifically Malaysian populations. Most available nasal cephalometric norms are derived from Caucasian samples and primarily focus on anteroposterior skeletal discrepancies, limiting their clinical applicability in populations with distinct craniofacial characteristics. Given the growing emphasis on facial aesthetics and the integral role of nasal morphology in orthodontic and orthognathic treatment planning, population-specific data examining nasal characteristics in relation to vertical skeletal patterns are essential. The present study was therefore designed to address this gap by establishing nasal cephalometric norms for Malaysian Malay females and evaluating differences across hypo-, normo-, and hyperdivergent skeletal patterns.

Interpretation of the nasal findings in this study necessitates evaluation of the skeletal characteristics of the study cohort. The sagittal skeletal relationship of the participants, assessed using the ANB angle, demonstrated a mean value of  $3.04^\circ \pm 1.08$ , which is comparable to the established Malay cephalometric norm of  $3.20^\circ \pm 1.20$  reported by Norman et al.<sup>13</sup> This confirms that the study cohort appropriately represents a skeletal Class I Malay population. In the vertical dimension, the mean MMPA of  $27.39^\circ \pm 1.84$  observed in this study was slightly higher than the  $27.00^\circ \pm 4.00$  reported in Caucasian populations, suggesting a tendency towards a more vertical facial

morphology among Malays.<sup>14</sup> This distinction further highlights the importance of population-specific skeletal and nasal reference values when evaluating facial aesthetics.

Nasal structure can be quantified by different types of measuring tools, either two dimensions<sup>15</sup> or three dimensions radiographically,<sup>16</sup> clinically,<sup>17</sup> and photography.<sup>18</sup> In radiographic assessment, lateral cephalometry is widely used since it is readily available as pre-orthodontic assessment,<sup>19</sup> and the ability to measure both soft and hard tissue structures. In cephalometric analysis, nasal parameters are measured through linear and angular attributes. Angular measurements typically reflect the degree of nasal protrusion and play a crucial role in determining facial harmony, while linear measurements serve as key indicators of nasal size, providing data on nasal dimensions. External nasal dimensions can be defined by total length — measured as nasal length and nasal height — and total width, defined by nasal depth 1 and nasal depth 2. Internal nasal dimensions are typically represented by the nasal bone length. Additionally, nasal dorsum axis and nasal tip protrusion determine the overall shape and profile of the nose, whereas columella convexity reflects soft tissue prominence at the nasal base, influencing the lower nasal contour.

In the current study, a retrospective data was analyzed to establish the cephalometric normal values of 16 nasal parameters and to compare these parameters across different vertical skeletal relations among Malay female subjects with a Class I skeletal pattern. Subjects were selected based on the inclusion criteria to ensure sample

homogeneity as previous studies have indicated that nasal morphology varies with age,<sup>20</sup> gender,<sup>21</sup> and ethnicity.<sup>22</sup> Subjects aged 18 to 30 years old were selected, as this age range represents a period of minimal nasal morphological changes, with nasal growth typically ceasing following puberty.<sup>7</sup>

The mean nasal length and height for Class I normodivergent Malay females were  $40.13 \pm 3.53$  mm and  $46.67 \pm 3.79$  mm, respectively, both shorter than those of Saudi females<sup>15</sup> and Egyptian females.<sup>23</sup> Similarly, nasal width, represented by nasal depth 1 and nasal depth 2, was lower than in Caucasian females.<sup>7</sup> For internal nasal dimension, the nasal bone length in Malay females was also shorter compared to both Saudi females<sup>24</sup> and Caucasian females.<sup>7</sup> These differences in nasal dimensions can be attributed to variations in nasal morphology across ethnic groups. Aljabaa<sup>15</sup> suggested that the larger nasal dimensions observed in Saudi women are attributed to a more prominent nasal dorsum and increased nasal length. Similarly, Egyptian females exhibit a more protruded nose with an elongated dorsum, features often associated with Mediterranean phenotypes.<sup>23</sup> Meanwhile, Caucasians generally exhibit a more prominent and wider nose with a longer nasal bone, a trait that may be influenced by climatic adaptation. Europe's cold and dry climate presents greater environmental challenges compared to the humid conditions in Asia. Noback et al.<sup>25</sup> reported that Europeans typically have longer, narrower nose with prominent nasal bridge and pointed nasal tip, whereas Asians tend to have shorter, broader noses with a less pronounced nasal bridge. These morphological differences have been associated with adaptive mechanisms for air conditioning and humidification in response to regional climate variations. The findings emphasise the variation in nasal morphology across different ethnic groups, reflecting the influence of evolutionary adaptations to different climate conditions.

Interestingly, our study revealed that the Malay population has minimal to no nasal hump across all vertical skeletal groups. This finding concurs with a study by Jang and Moon,<sup>26</sup> who reported a higher prevalence of nasal hump in Western populations compared to Asian populations. Similarly, Rodrigues Dias et al.<sup>27</sup> also found that nasal hump was most prevalent among Portuguese patients compared to South Korean counterparts. Additionally, the average columella convexity in Malay females was recorded at  $2.81 \pm 0.82$  mm, which was shorter than that of Caucasian females, reported at  $3.45 \pm 1.15$  mm.<sup>7</sup> These findings suggest that Malay female noses are generally less prominent compared to those of Caucasians.

Angular nasal measurements reflect not only the shape but also the projection and orientation of the nose relative to surrounding facial structures. The shape of the nose can be described based on dorsal protrusion, which determines whether the nose appears projected or flat, and nasal tip rotation, which influences whether the tip appears pointed or droopy. Different angular measurements capture various aspects of nasal projection and tip orientation. The nasofacial angle specifically reflects protrusion of the nose alone, whereas nasofrontal and nasomental angles depict

the nasal protrusion in relation to the frontal bone and mandible, respectively. The nasal tip angle describes tip rotation independently, while nasolabial angle represents the rotation of the nasal tip in relation to the upper lip. Meanwhile, the nasal bone angle represents the inclination of the nasal bone and contributes to the overall shape of the nasal bridge.

Ethnic variations in nasal morphology, particularly in angular parameters, have been well-documented in previous studies. Wen et al.<sup>28</sup> reported that Asian females generally exhibit reduced nasal projection compared to Caucasian females, a finding further corroborated by Jankowska et al.<sup>7</sup> Consistent with these observations, current study demonstrates that normodivergent Malay females exhibit a more acute nasofacial angle, a larger nasal bone angle, and more obtuse nasomental, nasofrontal and nasal tip angles compared to Caucasians. Similarly, Gu et al.<sup>29</sup> found that Asian population has a smaller nasolabial angle, suggesting less nasal tip rotation, in contrast to Caucasians who typically display a more upturned nasal tip. Additionally, the wider nasal bone angle observed in normodivergent Malay women further contributes to a flatter nasal dorsum. Taken together, these findings suggest that normodivergent Malay women exhibit a nasal profile that is less prominent, with a flatter nasal bridge, and a more downward-rotated nasal tip, reinforcing the distinct nasal morphological characteristics within this population.

Nasal depth, defined as the anteroposterior width of the nose, varies based on skeletal positioning, with nasal depth 2 (measured from the alar) consistently greater than nasal depth 1 (measured from the facial surface) due to the more posterior position of the alar curvature (Ac) relative to the vertical plane formed by the soft tissue nasion and subnasale.<sup>7</sup> This study confirms that nasal depth 2 is significantly greater in normodivergent individuals than in hyperdivergent individuals. This difference is largely influenced by maxillary morphology, as hyperdivergent individuals exhibit a shorter, more posteriorly positioned maxilla, altering nasal base orientation and reducing anterior projection, subsequently decreasing nasal depth 2 measurement.<sup>30</sup> Additionally, soft tissue characteristics further contribute to these variations, as hyperdivergent individuals typically have thinner midfacial soft tissues,<sup>31</sup> resulting in a less pronounced nasal contour compared to normodivergent individuals, who typically possess a fuller soft tissue profile.<sup>32</sup> These findings reinforce the role of skeletal and soft tissue interdependence in shaping nasal morphology and emphasize the necessity of population-specific cephalometric nasal norms.

A limitation of this study is the inclusion of only female subjects, which restricts direct generalisation of the findings to male populations. This design choice was intentional to minimise sex-related biological variability and to establish homogeneous nasal cephalometric reference values for Malaysian Malay females. Accordingly, the findings should be interpreted within the context of female patients, while future studies incorporating male subjects are warranted to enable sex-based comparisons and broader generalisability. Additional limitations include the time-

consuming nature of manual tracing and its focus on nasal morphology rather than functional aspects such as nasal airflow dynamics and airway patency. Despite this, multiple studies have demonstrated that differences in landmark identification and measurements between manual and digital tracing methods are minimal and not clinically significant, with both approaches showing comparable reliability and reproducibility.<sup>33,34</sup> Future studies could address these limitations by utilizing AI-driven cephalometric analysis for greater efficiency. Furthermore, acoustic rhinometry assessment could be integrated with AI-driven cephalometric analysis to enhance the evaluation of nasal function.<sup>35</sup> Despite these limitations, this study provides a comparative analysis of nasal morphology across different vertical skeletal dimensions among Malay women, reducing overreliance on Caucasian reference values and contributing valuable normative data for clinical applications in rhinoplasty, forensic anthropology, and population-based morphometric studies.

### Conclusions

The cephalometric reference values for nasal parameters in skeletal normodivergent Malaysian Malay adult females were established, demonstrating a nasal profile that is less prominent, with a flatter nasal bridge and a more downward-rotated nasal tip in this population. Additionally, nasal depth 2 was found to be significantly longer in normodivergent individuals compared to hyperdivergent individuals, suggesting that vertical skeletal patterns can influence this specific nasal variable.

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### Conflicts of Interest Statement

No conflicts of interest.

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