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Anthropometric Analysis Supported by Digital Simulation in Turkish Rhinoplasty Patients

Rinoplasti İstemiyle Başvuran Türk Hastaların Dijital Simülasyon Destekli Nazal Antropometrik Ölçümleri

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ABSTRACT

Objective: Three-dimensional (3D) simulation analyses used to evaluate nasal morphology support the surgeon's visual assessment using digital measurements. This study aimed to perform a 3D simulation-supported anthropometric analysis of nasal structures in Turkish patients presenting for rhinoplasty, compare the obtained data with established aesthetic norms, and examine correlations between nasal anthropometric measurements.

Materials and Methods: A total of 315 patients (257 females, 58 males) aged 18–65 years who presented for primary rhinoplasty were included. Interpupillary distances were measured manually and integrated into the Crisalix (Crisalix SA, Switzerland) 3D simulation system. The nasofrontal angle, nasolabial angle, nasal bridge length, alar width, and nasal projection parameters were recorded and analyzed.

Results: The mean interpupillary distance was 6.23 ± 0.18 cm in males and 6.10 ± 0.26 cm in females. The mean anthropometric values were 151.44° ± 6.27° for the nasofrontal angle, 111.89° ± 10.97° for the nasolabial angle, 4.53 ± 0.33 cm for nasal bridge length, 5.80 ± 0.41 cm for alar width, and 2.88 ± 0.29 cm for nasal projection. Nasal bridge length, alar width, and nasal projection were higher in males than in females, whereas no significant difference was found in angular measurements. Strong positive correlations were observed between the parameters.

Conclusion: This study provides patient-centered three-dimensional anthropometric data for Turkish individuals seeking rhinoplasty. The use of 3D analysis systems may support traditional subjective and two-dimensional surgical assessments with objective digital measurements, thereby improving the predictability of preoperative planning and facilitating individualized, patient-centered approaches.

Keywords: 3-D Imaging, Anthropometry, Rhinoplasty

ÖZET

Amaç: Nazal morfolojiyi değerlendirmekte kullanılan 3 boyutlu (3D) simülasyon analizleri, cerrahın görsel değerlendirmesini dijital ölçümlerle desteklemektedir. Bu çalışmanın amacı, rinoplasti istemiyle başvuran Türk hastalarda burun yapısının 3D simülasyon destekli antropometrik analizini gerçekleştirmek ve elde edilen verileri literatürdeki estetik normlarla karşılaştırmak ve beraberinde nazal antropometrik ölçümlerin birbirleri ile olan korelasyonu incelemektir.

Gereç ve yöntem: Çalışmaya, 18-65 yaş aralığında, primer rinoplasti amacıyla başvuran 315 hasta (257 kadın, 58 erkek) dahil edildi. Hastaların interpupiller mesafeleri manuel ölçüldü ve Crisalix (Crisalix SA, İsviçre) 3D simülasyon sistemine entegre edildi. Simülasyon yazılımı aracılığıyla nazofrontal açı, nazolabial açı, burun köprüsü uzunluğu, alar genişlik ve nazal projeksiyon parametreleri kaydedilip incelendi.

Bulgular: Çalışmaya dahil edilen erkek hastalarda ortalama interpupiller mesafe 6.23 ± 0.18 cm, kadın hastalarda ise 6.10 ± 0.26 cm olarak ölçüldü. Genel ortalama antropometrik değerler: nazofrontal açı için 151.44° ± 6.27°, nazolabial açı için 111.89° ± 10.97°, burun köprüsü uzunluğu için 4.53 ± 0.33 cm, alar genişliği için 5.80 ± 0.41 cm ve nazal projeksiyon için 2.88 ± 0.29 cm olarak belirlendi. Erkeklerde burun köprüsü uzunluğu, alar genişliği ve nazal projeksiyon değerleri kadınlara göre daha yüksek bulundu; buna karşın açılar açısından anlamlı fark saptanmadı. Parametreler arasında güçlü pozitif korelasyonlar gözlendi.

Sonuç: Bu çalışma, rinoplasti istemiyle başvuran Türk hastalara ait hasta- merkezli üç boyutlu antropometrik veriler sunmaktadır. Üç boyutlu analiz sistemleri, cerrahın geleneksel olarak subjektif ve iki boyutlu değerlendirmelerini objektif dijital ölçümlerle destekleyerek preoperatif planlamanın daha öngörülebilir hale gelmesine ve hastaya özgü yaklaşımların geliştirilmesine katkı sağlayabilir.

Anahtar Kelimeler: 3 Boyutlu Görüntüleme, Antropometri, Rinoplasti

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INTRODUCTION

Anthropometric analyses play a critical role in the evaluation of nasal morphology by supporting the surgeon's visual assessment with objective measurements. However, literature shows that variations in measurement parameters and methodological inconsistencies across studies have limited the standardization of nasal anthropometric evaluation (1–3).

In recent years, three-dimensional (3D) simulation systems have become increasingly integrated into rhinoplasty practice, particularly for preoperative planning and patient communication. These technologies enable detailed visualization and precise quantitative analysis of nasal structures, overcoming several limitations associated with traditional two-dimensional assessment methods (4–7).

Despite the growing body of anthropometric research in rhinoplasty, most existing studies primarily focus on defining ideal or normative nasal measurements derived from aesthetic standards or general population data. In contrast, relatively limited attention has been given to patient-centered nasal anthropometric characteristics that reflect the surgical expectations of individuals actively seeking rhinoplasty, particularly when assessed using three-dimensional simulation platforms (7). Furthermore, large cohort data evaluating rhinoplasty candidates within specific populations remain scarce.

This study aimed to analyze the nasal anthropometric characteristics of Turkish individuals presenting for primary rhinoplasty using three-dimensional simulation technology and to compare these patient-centered measurements with aesthetic reference values reported in the literature, with a focus on preoperative nasal morphology and its proportional relationships rather than normative population standards.

Accordingly, we hypothesized that three-dimensional simulation–derived preoperative nasal anthropometric measurements in Turkish individuals seeking rhinoplasty would demonstrate clinically relevant proportional relationships between nasal parameters and descriptive differences from commonly cited aesthetic reference values, and this information could be provived patients to support individualized preoperative planning and patient counseling.

MATERIALS AND METHODS

Study Design

This retrospective, multicenter study analyzed preoperative data from 315 patients who presented for primary rhinoplasty between June 2021 and June 2025. All 3D simulations and anthropometric measurements were performed by a senior surgeon.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional ethics committee (approval no: E.83321821-805.02.03-748). Written informed consent was obtained from all participants for the use of their clinical data, photographs, and anthropometric measurements. No external funding was received.

Patient Selection

A consecutive sampling method was used, including all eligible patients aged 18–65 years who presented for primary rhinoplasty. The criteria of inclusion ere that patients had to have complete preoperative photographic and measurement data (including standardized frontal, oblique, lateral, and basal views, as well as a manually measured interpupillary distance).

Patients were excluded if they had a history of nasal or facial surgery, facial trauma, craniofacial anomalies, or systemic diseases known to affect facial morphology.

3D Anthropometric Analysis

All 3D simulations and anthropometric measurements were performed using the Crisalix 3D simulation platform (Crisalix SA, Switzerland), which was routinely used at the participating centers during the study period. All measurements were performed by the same experienced surgeon to ensure consistency.

Standardized preoperative facial photographs were obtained using a digital camera (Canon EOS 5D Mark II, Canon Inc., Tokyo, Japan) at a fixed distance, under

standardized lighting conditions, and from consistent angles.

The manually measured interpupillary distance, obtained using a ruler, together with the standardized photographic data, was entered into the simulation system to generate a 3D model for each patient. All measurements were performed using standardized protocols within the simulation system. The system was then used to calculate the nasofrontal angle (formed between the nasal root and the forehead), the nasolabial angle (formed between the nasal base and the upper lip), the nasal bridge length (distance from the glabella to the pronasale), the alar width (distance between the alae), and the nasal projection (anterior displacement of the nasal tip relative to the facial plane) (Figures 1, 2).

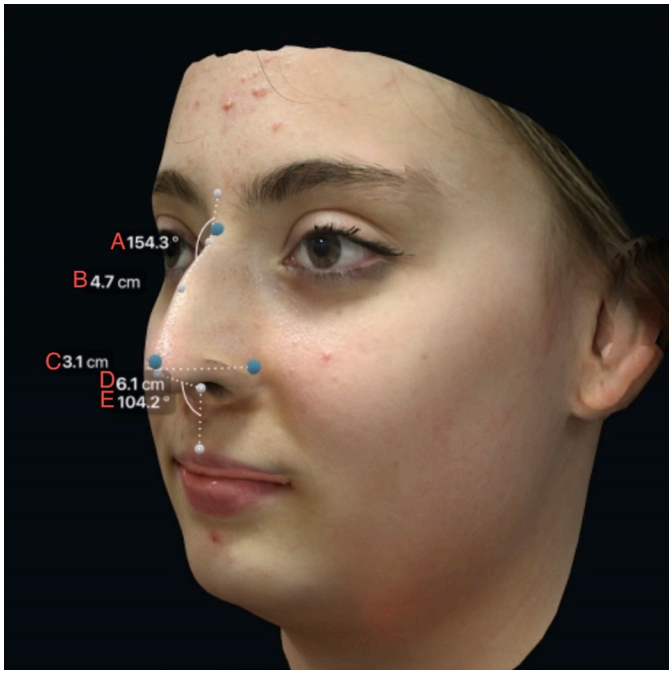

Figure 1. Standardized digital anthropometric assessment obtained using the Crisalix 3D simulation system (Crisalix SA, Switzerland) in a female patient. A: Nasofrontal angle; B: Nasal bridge length; C: Nasal projection; D: Alar width; E: Nasolabial angle. Written informed consent for scientific publication was obtained from the patient.

Aesthetic Reference Values

The aesthetic reference values used for comparison were derived from previously published anthropometric and rhinoplasty planning studies commonly applied in nasal aesthetic analyses. These values were used as descriptive contextual benchmarks rather than as population-matched control data. Therefore, comparisons with aesthetic reference values were interpreted descriptively, and no inferential statistical testing was performed for these literature-based comparisons (3,5,8,9).

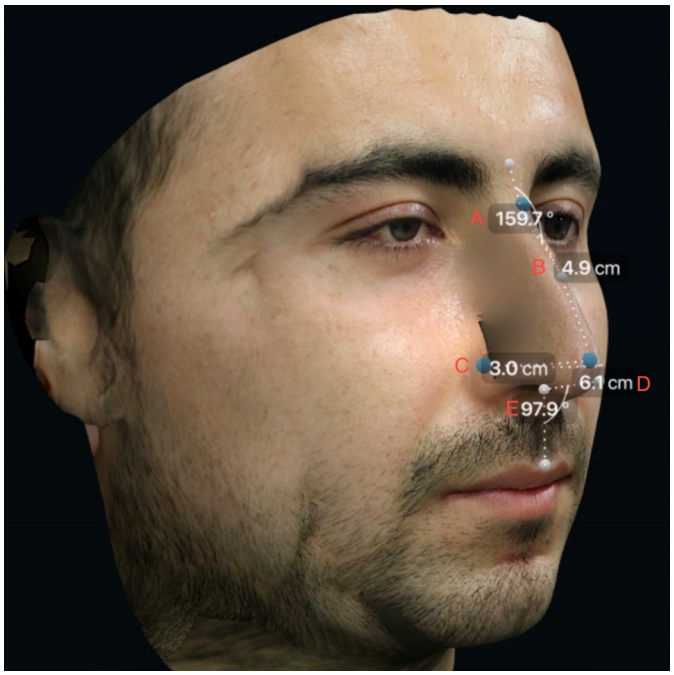

Figure 2. Standardized digital anthropometric assessment obtained using the Crisalix 3D simulation system (Crisalix SA, Switzerland) in a male patient. A: Nasofrontal angle; B: Nasal bridge length; C: Nasal projection; D: Alar width; E: Nasolabial angle. Written informed consent for scientific publication was obtained from the patient.

Statistical Analysis

Statistical analyses were performed to evaluate the relationships among nasal anthropometric parameters and to assess gender-based differences. Data are presented as mean ± standard deviation. Data distribution and normality were assessed using the Shapiro–Wilk test. For normally distributed variables, independent samples t-tests were planned, whereas non-normally distributed variables were analyzed using the Mann–Whitney U test. Variance homogeneity was evaluated using the Levene's test, and Welch's correction was applied when appropriate.

Correlations between anthropometric parameters were analyzed using Pearson or Spearman correlation coefficients, depending on data distribution. All statistical analyses were conducted using IBM SPSS

Table 1. Descriptive and comparative anthropometric measurements of the study population

Parameter	Overall mean ± SD	Male mean ± SD	Female mean ± SD	Shapiro–Wilk P (Male)	Shapiro–Wilk P (Female)	*Gender comparison P value
Interpupillary distance, cm	6.12 ± 0.29	6.23 ± 0.18	6.10 ± 0.26	<0.001	<0.001	<0.001
Nasofrontal angle, °	151.44 ± 6.27	150.13 ± 9.96	151.73 ± 5.06	<0.001	0.010	>0.05
Nasolabial angle, °	111.89 ± 10.97	112.37 ± 15.72	111.79 ± 9.62	<0.001	<0.001	>0.05
Nasal bridge length, cm	4.53 ± 0.33	4.76 ± 0.38	4.48 ± 0.30	0.739	<0.001	<0.001
Alar width, cm	5.80 ± 0.41	6.10 ± 0.45	5.73 ± 0.37	0.554	0.027	<0.001
Nasal projection, cm	2.88 ± 0.29	3.03 ± 0.34	2.85 ± 0.27	0.102	<0.001	<0.001

SD, standard deviation.

*Gender comparisons were performed using the Mann–Whitney U test.

Statistics version 26.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $p < 0.05$.

RESULTS

The mean age of the patients was 35.3 ± 6.1 years. The mean interpupillary distance was measured 6.23 ± 0.18 cm in males and 6.10 ± 0.26 cm in females (Table 1).

Mean Anthropometric Parameters

Based on the 3D simulation data, the mean nasofrontal angle was 151.44° ± 6.27°, and the mean nasolabial angle was 111.89° ± 10.97°. The average nasal bridge length was 4.53 ± 0.33 cm, the mean alar width was 5.80 ± 0.41 cm, and the mean nasal projection was 2.88 ± 0.29 cm (Table 1).

Gender Comparison

Significant gender-based differences were observed in several parameters. Male patients exhibited a longer nasal bridge (4.76 ± 0.38 cm) and greater nasal projection (3.03 ± 0.34 cm) compared with female patients (4.48 ± 0.30 cm and 2.85 ± 0.27 cm, respectively; $p < 0.05$). Alar width was also greater in males (6.10 ± 0.45 cm) than in females (5.73 ± 0.37 cm) (Table 1).

No statistically significant gender differences were identified for the nasofrontal angle (150.13° ± 9.96° in males vs. 151.73° ± 5.06° in females) or the nasolabial angle ($p > 0.05$).

Correlation Analysis

Correlation analysis revealed strong positive relationships between nasal bridge length and alar width ($r = 0.86$), and between nasal bridge length and nasal projection ($r = 0.84$). A particularly strong positive correlation was observed between the alar width and nasal projection ($r = 0.96$).

Gender-based subgroup analyses demonstrated similar correlation patterns. In female patients, strong positive correlations were observed between nasal bridge length and alar width ($r = 0.83–0.86$) and between the alar width and nasal projection ($r = 0.95–0.97$). In male patients, the corresponding correlations were $r = 0.86$ for nasal bridge length and alar width, and $r = 0.83$ for alar width and nasal projection.

Weak negative correlations were identified between the nasofrontal angle and nasolabial angle in both males ($r = –0.20$) and females ($r = –0.13$). Post-hoc power analysis (G*Power 3.1), based on an independent samples t-test model and observed effect sizes (Cohen's d), demonstrated statistical power exceeding 80% for all primary anthropometric variables and greater than 95% for most comparisons.

DISCUSSION

Positioned centrally on the face, the nose plays a critical role in facial harmony and strongly influences overall aesthetic perception. Consequently, rhinoplasty remains one of the most frequently requested aesthetic procedures and can have a profound impact on physical appearance, self-esteem, social interactions, and overall psychosocial well-being (10,11).

Accurate preoperative assessment of nasal proportions and their relationship with surrounding facial structures is a fundamental component of

successful rhinoplasty planning. Anthropometric measurements provide objective reference points that complement a surgeon's visual evaluation. Traditionally, these assessments have relied on two-dimensional (2D) photography, which is inherently limited by its inability to adequately represent depth, as well as by variations in lighting and perspective (1,2). Advances in three-dimensional (3D) imaging and simulation technologies have largely addressed these limitations by enabling more precise quantitative measurements and improved visualization of nasal morphology (4,6). In addition to enhancing surgical planning, these systems also allow patients to develop more realistic expectations prior to surgery.

Standard rhinoplasty planning is often guided by idealized anthropometric measurements. For example, the preferred nasofrontal angle sits commonly within a range of 115°–130° (12). The ideal nasolabial angle (the angle that represents nasal tip rotation) is generally considered ideal between 95–110° in females and 90–95° in males (3,11). According to traditional aesthetic norms, the alar base width is commonly evaluated in relation to the intercanthal distance rather than the interpupillary distance. In the present study, the interpupillary distance was manually measured and used for three-dimensional model calibration; however, the intercanthal distance was not specifically assessed. Therefore, a direct comparison with this particular aesthetic canon was not performed. Instead, alar width was interpreted descriptively and in relation to other nasal linear parameters within the three-dimensional model (10,12).

Nasal projection is typically defined as approximately 60% of nasal length, contributing to a balanced facial profile (2,8). Nasal bridge length is usually evaluated in proportion to overall facial height and, together with projection and alar width, plays a key role in determining perceived nasal length and harmony (1,5).

In the present study, all anthropometric measurements were obtained preoperatively from individuals actively seeking rhinoplasty. When compared with commonly cited aesthetic reference values, these patients demonstrated a higher nasofrontal angle, a nasolabial angle near or above the upper end of traditional reference ranges, relatively increased alar width, and greater nasal projection (3,5,8,9). The nasal bridge length in our cohort (4.53 cm) was comparable to that reported by Santos et al. (4.61 cm) (11) but greater than that reported by Altinkaya (4.44 cm) (9). Collectively, these findings indicate that individuals seeking rhinoplasty commonly present with a flatter nasofrontal profile, a wider alar base, and greater nasal projection compared with traditionally defined aesthetic ideals (12). Nevertheless, these findings should be interpreted in the context of individual factors such as ethnicity, gender, and age, underscoring the importance of personalized surgical planning.

Gender-based analyses demonstrated that males exhibited significantly greater nasal bridge length, alar width, and nasal projection than females, findings that are consistent with known differences in facial skeletal structure and soft tissue characteristics (12,13). In contrast, no significant gender differences were observed in the nasofrontal or nasolabial angles, suggesting that aesthetic angular relationships may be perceived similarly across genders.

Correlation analyses provided additional insights into the interdependence between nasal parameters. Strong positive correlations were observed between nasal bridge length and alar width, nasal bridge length and nasal projection, and, most notably, between alar width and nasal projection. These relationships were consistently observed in both male and female subgroups, indicating that these structural parameters are closely linked within the three-dimensional nasal framework. Conversely, the weak negative correlations between the nasofrontal and nasolabial angles suggest that these angular measurements may vary independently, these findings support their separate consideration during surgical planning (4,7). These proportional relationships may assist surgeons in individualized preoperative planning, as increased nasal projection, wider alar base measurements, or altered angular relationships may influence decisions regarding tip rotation, projection control, alar base modification, or the potential need for supportive

grafting techniques to achieve balanced nasal proportions (14).

The use of three-dimensional simulation technology represents a major strength of this study. Beyond objective measurements, three-dimensional simulation systems may also contribute to individualized surgical planning and patient–surgeon communication by facilitating visualization of anticipated postoperative outcomes and alignment of aesthetic expectations, as previously emphasized in the literature (7). Compared with conventional 2D photography, 3D systems provide a more comprehensive visualization of facial anatomy and enable the assessment of spatial relationships that cannot be fully captured in two dimensions (15). Zogheib et al. (16) demonstrated that 3D facial scanning offers improved depiction of linear facial proportions, comparable accuracy for angular measurements, and higher observer confidence compared with 2D photography. Similarly, Yamamichi et al. (7) highlighted the utility of cloud-based 3D simulation systems, such as Crisalix, in enhancing patient–surgeon communication and aligning simulated outcomes with patient expectations. Compared with previous studies, the present investigation benefits from a relatively larger sample size and multicenter data, strengthening the reliability and clinical relevance of its findings.

Although several studies have previously reported anthropometric measurements of Turkish nasal morphology, most have relied on conventional two-dimensional measurement techniques. To our knowledge, studies investigating the preoperative nasal anthropometric features of rhinoplasty-seeking Turkish patients using three-dimensional simulation systems are limited. The primary strength of the present study lies in its use of digital three-dimensional simulation technology to evaluate patient-centered nasal characteristics, specifically in individuals seeking rhinoplasty. Beyond contributing to the understanding of nasal morphology in this population, the data presented may also provide a valuable three-dimensional reference framework for future investigations of facial asymmetry, which has traditionally been evaluated using two-dimensional photographic methods (8).

Despite its strengths, this study has several limitations. First, the study population consisted exclusively of Turkish individuals seeking primary rhinoplasty; therefore, the findings should not be interpreted as representative of the general Turkish population. Rather, the results reflect patient-centered preoperative nasal characteristics observed in candidates for rhinoplasty. In addition, the retrospective design and the absence of a non-surgical control group limited our ability to distinguish rhinoplasty-seeking nasal morphology from population-level nasal anthropometric characteristics.

Another important limitation is the absence of postoperative anthropometric evaluation, long-term follow-up data, and patient-reported outcome measures. Therefore, the present findings should be interpreted as preoperative morphological data rather than as evidence of surgical outcomes, postoperative changes, or simulation accuracy. Nevertheless, these data may provide a useful reference framework for future studies comparing preoperative and postoperative nasal morphology using 3D simulation systems. Such investigations may further clarify the relationship between anthropometric measurements, surgical modifications, clinical outcomes, and patient satisfaction. Previous studies have suggested that greater congruence between preoperative three-dimensional simulation and postoperative outcomes may be associated with higher patient satisfaction and improved alignment of aesthetic expectations (7). Accordingly, future studies integrating objective anthropometric measurements with patient-reported satisfaction outcomes may provide a more comprehensive evaluation of rhinoplasty results.

Individual variations in soft tissue thickness, skin elasticity, nasal structural support, and age-related tissue characteristics may also influence anthropometric measurements and agreement between simulated and actual postoperative outcomes. As noted by Yamamichi et al. (7), discrepancies between simulated and actual outcomes may arise from soft tissue properties and

limitations in nasal structural support. Future studies incorporating subgroup analyses according to skin thickness, age, sex, and soft tissue characteristics may provide more refined and clinically applicable interpretations.

Another methodological limitation is the reliance on a single three-dimensional simulation platform. Differences in reconstruction algorithms, calibration methods, landmark definitions, and measurement protocols across various 3D systems may influence absolute measurement values and limit direct comparability with studies using other platforms. In addition, all linear measurements in the present study were derived from a calibrated three-dimensional model using manually measured interpupillary distance. Therefore, shared scaling effects cannot be excluded and may have contributed to the strong correlations observed between the linear nasal parameters, particularly between the alar width and nasal projection. Future studies using normalized ratios, repeated calibration procedures, and multivariable models adjusted for interpupillary distance, sex, and age may provide a more robust assessment of these proportional relationships.

Although all measurements were performed by the same experienced surgeon to maintain consistency and reduce interobserver variability, intraobserver and interobserver reliability analyses were not performed. This should be considered when interpreting the reproducibility of the measurements. Finally, the direct comparison of nasolabial angle values was limited by the scarcity of previously published data obtained using comparable three-dimensional simulation systems, as most available reference ranges were derived from two-dimensional measurements and represented idealized surgical targets rather than descriptive preoperative benchmarks. Future prospective studies incorporating multiple 3D imaging platforms, non-surgical control groups, repeated measurements, postoperative follow-up, and patient-reported outcome measures may enhance the generalizability, reproducibility, and clinical applicability of three-dimensional nasal anthropometric data.

CONCLUSION

By providing three-dimensional simulation-based anthropometric measurements from a large cohort of Turkish individuals seeking rhinoplasty, this study presents patient-centered data reflecting preoperative nasal morphology. These findings may serve as a valuable reference framework for individualized rhinoplasty planning, patient counseling, and the management of aesthetic expectations.

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Patient Consent: Written patient/participant consent has been obtained from the participants included in the study.

Declaration Regarding the Use of AI-Assisted Technologies: During the preparation of this manuscript, an artificial intelligence–based language tool was used exclusively to assist with English language editing (grammar, spelling, and clarity). The tool was not used to generate scientific content, interpret data, or draw conclusions. The authors reviewed and edited the manuscript and take full responsibility for the content.

Data Availability: The data supporting the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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