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ORIGINAL PAPER

Comparative assessment of 2D photogrammetry versus direct anthropometry in nasal measurements

Shehzeen Afaq [1], S.K. Jain [1], Nidhi Sharma [2], Sonika Sharma [1]

[1] Department of Anatomy, Teerthanker Mahaveer Medical College and Research Center, Moradabad, Uttar Pradesh, India
[2] Department of Anatomy, Kalyan Singh Medical College Bulandshahr, Uttar Pradesh, India

ABSTRACT

Introduction and aim. The nose significantly influences facial aesthetics, necessitating a comprehensive understanding of nasal anatomy and facial aesthetics standards for successful rhinoplasty. This study investigates the reliability and precision of two-dimensional photogrammetry compared to direct measurements for nasal anthropometry.

Material and methods. This cross-sectional study was carried out at Teerthanker Mahaveer Medical College and Research Center, Moradabad which included 640 volunteers from six zones of the Indian population. Direct anthropometry and 2D photogrammetry were the two methods used to evaluate each parameter. A caliper was employed for direct anthropometry, and software analysis of nasal characteristics was used for the indirect 2D technique.

Results. The result revealed significant gender-based differences in all nasal dimensions assessed by direct measurements, with the exception of the length of the nasal bridge. In contrast, 2D photogrammetry demonstrated no significant variation in anatomical nasal width and nasal bridge length across the genders. Of the eight nasal parameters analyzed, five parameters (nose height, morphological nose width, alar length, nasal tip protrusion, and nasal index) exhibited excellent reliability. Nasal bridge length and columellar length showed moderate reliability of 2D photogrammetry.

Conclusion. This research reveals gender-based differences in nasal dimensions, with males generally having larger dimensions. It suggests 2D photogrammetry as a reliable alternative to direct anthropometry for specific nasal measurements, offering practical benefits in clinical and aesthetic applications. However, it has limitations, such as moderate reliability in measuring nasal bridge length and Columellar length, underscoring the necessity for cautious interpretations for specific parameters. Further research is recommended to improve precision and applicability, while addressing limitations like sensitivity to imaging distortion and also incorporating the 3D technique to enhance the robustness of the methodology; the absence of 3D is a benchmark.

Keywords. facial analysis, nasal anthropometry, photogrammetry, rhinoplasty, two-dimensional anthropometry

Introduction

In the world of plastic surgery, creativity plays a pivotal role.[1] Plastic and reconstructive surgery thrives on a diverse range of technologies, pioneering techniques and meticulous planning to achieve spectacular results in facial anthropometry for enhancing patients aesthetics as well as their quality of life.[2] Rhinoplasty is still considered one of the most prevalent cosmetic surgical procedures throughout the world, with its favorable results reliant on careful preparation prior to surgery and intraoperative execution.[3]

2D photogrammetry has recently evolved as a non-invasive technique, particularly in the realm of facial anthropometry.[4] In the context of faces, this non-invasive method offers an efficient way to obtain multiple

Corresponding author: Shehzeen Afaq, e-mail: shehzeenafaq@gmail.com

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facial images from different angles and then, using specialized software (Digimizer and Crisalix) to reconstruct a 3D model, analyze various features such as symmetry, distances, angles, and proportions to extract specific measurements and data.[4] The 2D approach offers several substantial advantages in the healthcare and medical domains such as:[4]

- Increased patient comfort: This approach provides a non-invasive and pleasant means of retrieving data, which may enhance the entire experience without requiring patients to endure intrusive treatments.
- Reduced measurement variability: It can help reduce the variability in measurements compared to manual methods. Human error can lead to inconsistencies in manual methods, while proper calibration and execution of photogrammetry ensures more precise and consistent results.
- Digital record-keeping: Photogrammetry makes patient data easily accessible for future reference.

The accuracy of any method in the acquisition of anthropometric data is of prime importance to the researcher. Although, direct anthropometry is already established as a gold standard technique, it is also an established fact that it is a time consuming approach along with that it cannot be measured various angles of the face. So, for this reason we have to go for higher modalities like 2D and 3D analysis. But, the disadvantage of the newer techniques, as already stated by many studies, is that it is very expensive and can't be applied in all type of settings. On the other hand, 2D photography is still not widely explored in the literature as there has not yet been extensive research on the accuracy of 2D photography in relation to rhinoplasty.

Aim

To close this gap, this study will compare the accuracy and reliability of 2D photogrammetry against direct methods for determining nasal measurements for rhinoplasty. We want to explore the 2D approach for the facial analysis and its use in the era of technology which can be helpful to the society. It will be a convenient method for analysis in epidemiological studies and may be an alternative of direct and 3D analysis.

Material and methods

This descriptive cross-sectional study took place at the Department of Anatomy with in the Teerthanker Mahaveer Medical College and Research Center in Moradabad, Uttar Pradesh, India. This study, conducted from January 2023 to January 2024 involved 640 participants from six different Indian zones, with 320 males and 320 females, using a cross-sectional research formula (n=Z P (100-P)/E) to ensure a representative sample size. The assumptions used for the calculation of the sample size was confidence interval (95%), standard deviation (0.456), allowable error (0.05) and standard normal variate for a 95% confidence interval was 1.96. The study involved individuals from six distinct Indian zones: East, West, North, South, North-East, and Central. The study included healthy Indian subjects aged 18-25.[3] Those having a history of facial plastic surgery, intellectual disability, congenital craniofacial abnormality, significant damage, and mixed-ethnic background were excluded from the reserach.[3-6] The study was approved by the Institutional Ethical Committee (Ref. no. TMU/IEC/20-21/103) at Teerthanker Mahaveer Medical College and Research Center, with informed consent from each subject, following the 1975 Helsinki Declaration's ethical guidelines. Participant anonymity during photography was maintained through the following measures: informed consent, masking identifiable features, no personal identifiers (names and contact details), and restricted access (images were stored on password protected system), non-disclosure (images were exclusively used for research purpose. Eight nasal dimensions (nose height, anatomical nose width, morphological nose width, columella length, nasal bridge length, alar length, nasal tip protrusion and nasal index) were measured and calculated by two different approaches: direct and 2D indirect.

Direct method

We acquired written agreement before measurements, and allayed any lingering doubts by thoroughly explaining the measuring procedure to the participants. Participants were required to maintain neutral head posture (Frankfurt plane) and facial expressions while measuring anatomical landmarks using a surgical skin pencil and caliper, with average readings considered to be accurate (Fig. 1).[7]

Fig. 1. Direct anthropometry

2D indirect photogrammetry

A 24.2-megapixel DSLR (digital single-lens reflex) camera was utilized by the department's photography section to take pictures in well-lit conditions. We captured the photos with the head positioned in the Frank Furt plane and aligned with the reference scale. We scrutinized the images for flaws such as misorientation, distortion, or imaging artefacts. We saved the JPEG files and sent them to the Digimizer Image Analysis program (Version 5.7.5). This software is incredibly user-friendly and versatile for facial image analysis (Fig. 2 and 3).[8]

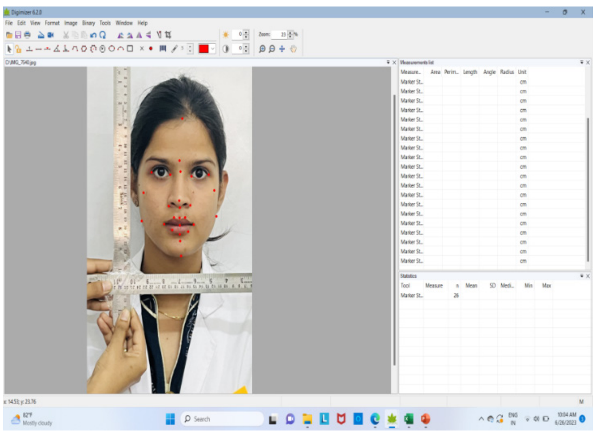

Fig. 2. Indirect anthropometry (frontal view)

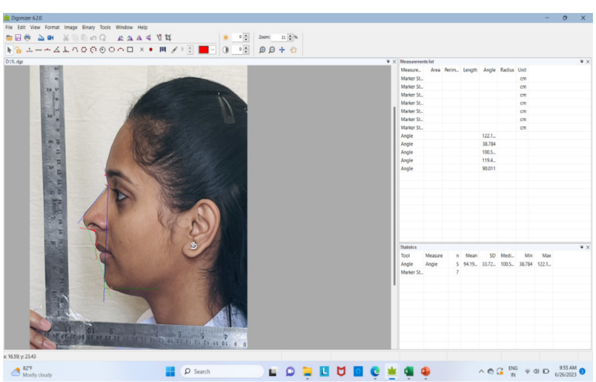

Fig. 3. Indirect anthropometry (lateral view)

Statistical analysis

We used SPSS version 25 for analysis (IBM, Armonk, NY, USA), evaluating data homogeneity using Shapiro-Wilk and Kolmogorov-Smirnov tests. A Normal distribution implies no variables deviating from the normalcy assumption. We assessed the descriptive statistics of facial parameters using mean and standard deviation, and an unpaired t-test for sexual dimorphism. We used Bland Altman (graphical presentation), regression analysis and intra-class correlation coefficient (ICC) statistical test to evaluate the reliability of the 2D method against the direct method.[4] For every statistical analysis, the threshold of significance for statistical purposes was established at $p<0.05$.

Bland Altman analysis (BAA)

This statistical approach is primarily used to assess the agreement between two different methods.[9] We plotted the difference of two methods on the Y-axis and average of two methods on the X-axis. After that we applied one-sample t-test on the basis of difference values of two methods and got the mean and standard deviation. After that plot generate three horizontal reference lines along the Y-axis. The middle line represent the mean values. Upper or lower limit comes when we add or subtract 1.96 in mean and multiply by the standard deviation.

In a BAA, two criteria need to be met to establish that two methods are comparable.

– The mean difference should be small and close to zero
– Standard deviation of this difference should be small

Regression

In the context of method comparison, the r-value indicates the strength and direction of the linear relationship between two methods, the p-value determines the significance of the comparison.[9] The level of significance, usually <0.05, at which the null hypothesis is rejected indicated by the p-value. It shows a significant differences between two approaches if it is less than or equal to this level, and no significant difference if it is larger than this level.

Intra-class correlation coefficient (ICC)

ICC measures the reliability of methods, with a range of 0–1 ICC coefficient.[4] If we get ICC values less than 0.4 with wider confidence interval (CI) that means poor reliability. Moderate reliability is indicated by ICC values between 0.4–0.75 with narrow CI; Excellent reliability of the method is shown by ICC values more than 0.75 with the narrowest CI.

Results

Table 1 shows the mean and SD of nasal parameters across both approaches. Males exhibited generally higher mean values whereas females showed greater alar length and nasal tip protrusion. Both methods showed slight variation which demonstrating the reliable approximations for most of the parameters according to their mean values.

Table 1. Descriptive statistics of nasal parameters for each gender by both approaches

Parameters	Measurements of nasal parameters (Mean±SD)			
	Male		Female	
	Direct method	Indirect method	Direct method	Indirect method
Nose height (cm)	4.5±0.43	4.16±0.37	4.1±0.54	4.06 ±0.55
Anatomical nose width (cm)	3.01±0.29	3.1±0.24	2.87±0.19	2.79±0.23
Morphological nose width (cm)	3.2±0.3	3.1±0.24	3±0.23	3.09±0.23
Columellar length (cm)	1.2±0.21	1.10±0.17	0.98±0.21	1±0.2
Nasal bridge length (cm)	4.06±0.4	3.6±0.38	4.07±0.38	4.12±0.39
Alar length (cm)	2.9±0.37	2.8±0.39	3.2±0.7	3.20±0.72
Nasal tip protrusion (cm)	0.7±0.08	0.69±0.11	0.79±0.17	0.79±0.18
Nasal index (cm)	79±11.3	76.05±8.8	69.9±10.2	70.59±10.8

Table 2. Depiction of the sexual dimorphism in nasal parameters by both approaches

Parameters	Direct method		2D-indirect method	
	T	p	T	p
Nose height	-2.7	<0.05	-3.3	<0.05
Anatomical nose width	2.5	<0.05	0.4	>0.05
Morphological nose width	4.27	<0.05	1.17	<0.05
Columellar length	2.35	<0.05	-0.58	<0.05
Nasal bridge length	-0.046	>0.05	-6.9	>0.05
Alar length	-3.02	<0.05	-3.3	<0.05
Nasal tip protrusion	-3.13	<0.05	0.28	<0.05
Nasal index	4.6	<0.05	3.01	<0.05

Table 2 reveals significant gender-based differences in all nasal dimensions assessed via direct measurements, with the exception of nasal bridge length. In contrast, 2D photogrammetry demonstrated no significant variation in anatomical nasal width and nasal bridge length across the genders.

Figure 4 shows the graphical representation of the male nasal parameters, for the good limit of agreement, most of the data points clustered around the mean and falling under the upper and lower limits of the scatter plot. All the parameters showing the good limit of agreement because all the parameters followed the two criteria of the BAA: The mean difference is small and close to zero and the standard deviation of this difference is also small.

Figure 5 shows a graphical representation of the female nasal parameters. For a good limit of agreement, most of the data points clustered around the mean and falling under the upper and lower limits of the scatter plot. All the parameters showing the good limit of agreement because all the parameters followed the two criteria of the BAA: The mean difference is small and close to zero and standard deviation of this difference is also small.

Table 3. Regression analysis for methods accuracy in both gender

Nasal parameters	Male				Female			
	R	R^2	F	p	R	R^2	F	p
Nose height	0.24	0.059	3.61	0.062	0.26	0.046	3.64	0.064
Anatomical nose width	0.25	0.064	3.95	0.05	0.29	0.078	3.2	0.4
Morphological nose width	0.43	0.188	2.36	0.13	0.38	0.178	3.16	0.13
Columellar length	0.198	0.039	13.39	0.001	0.19	0.029	14.39	0.007
Nasal bridge length	0.054	0.003	0.172	0.68	0.064	0.001	0.182	0.59
Alar length	0.051	0.003	1.49	0.701	0.059	0.006	1.5	0.601
Nasal tip protrusion	0.28	0.08	5.15	0.27	0.35	0.09	5.0	0.17
Nasal index	0.41	0.16	11.7	0.001	0.40	0.15	12.9	0.009

Table 4 shows the linear regression for the nasal parameters, in terms of R-value, R-square value, f-value and p-value. Columellar length and nasal index are the two parameters that are showing the $p<0.05$, which expects that there could be differences between the measurements of two methods.

Table 4. Intra-class correlation coefficient values for accuracy of 2D method against direct method in both genders

Parameters	Male		Female	
	ICC coefficient	95% CI (Lower to upper bound)	ICC coefficient	95% CI (Lower to upper bound)
Nose height	0.99	0.98–0.99	0.97	0.92–0.98
Anatomical nose width	0.85	0.81–0.92	0.94	0.92–0.96
Morphological nose width	0.91	0.86–0.96	0.93	0.82–0.97
Columellar length	0.69	0.56–0.89	0.66	0.62–0.96
Nasal bridge length	0.69	0.62–0.86	0.63	0.58–0.95
Alar length	0.99	0.98–0.99	0.96	0.82–0.88
Nasal tip protrusion	0.97	0.93–0.99	0.96	0.96–0.99
Nasal index	0.97	0.95–0.98	0.96	0.94–0.97

Table 4 presents the Intra-class correlation coefficient in both genders. Only the columellar length and nasal bridge length were represented the ICC values below the 0.75 with narrow confidence interval. While the rest of the parameters represented the ICC values >0.75 with narrowest CI.

Discussion

A descriptive cross-sectional study was conducted among 640 normal healthy subjects from six demographic zones of the Indian population for the screening of nasal parameters. As everyone knows, India has a diverse population of many ethnicities and cultures, thus we included representatives from each of the six zones. Rhinoplasty is a type of face surgery where the intention is to preserve or restore nasal function and support while achieving aesthetic harmony with the adjacent facial characteristics.[10] By one's personality and lifestyle, the nose has varying degrees of significance in terms of facial aesthetics.[10] Face analysis is the initial stage in planning a surgical procedure and is essential to the formulation of an appropriate treatment strategy for operations involving cosmetic or reconstructive surgical procedures.[11]

So for this is the largest research study, to the best of our knowledge, which includes subjects from various zones of India and measurements taken by two methods to check the accuracy and reliability of 2D indirect photogrammetry against the direct anthropometry.

In the present study we found mean nasal length in males was 4.5±0.43 and 4.16±0.37 cm by direct and indirect method respectively. The mean nasal length in females was 4.1±0.54 and 4.06 ±0.55 cm by both methods. Parab et al. conducted a research on nasal parameters of the Indian population by the indirect method and they found mean values of nasal length in males 4.43±0.45 cm and in females 4.13±0.45 cm.[3] Patil et al. conducted an anthropometric study on a south Indian population and reported 5.8 cm mean value in males and 5.6 cm of nasal length in females.[12] After comparison, we measured slightly lower values of nasal length.

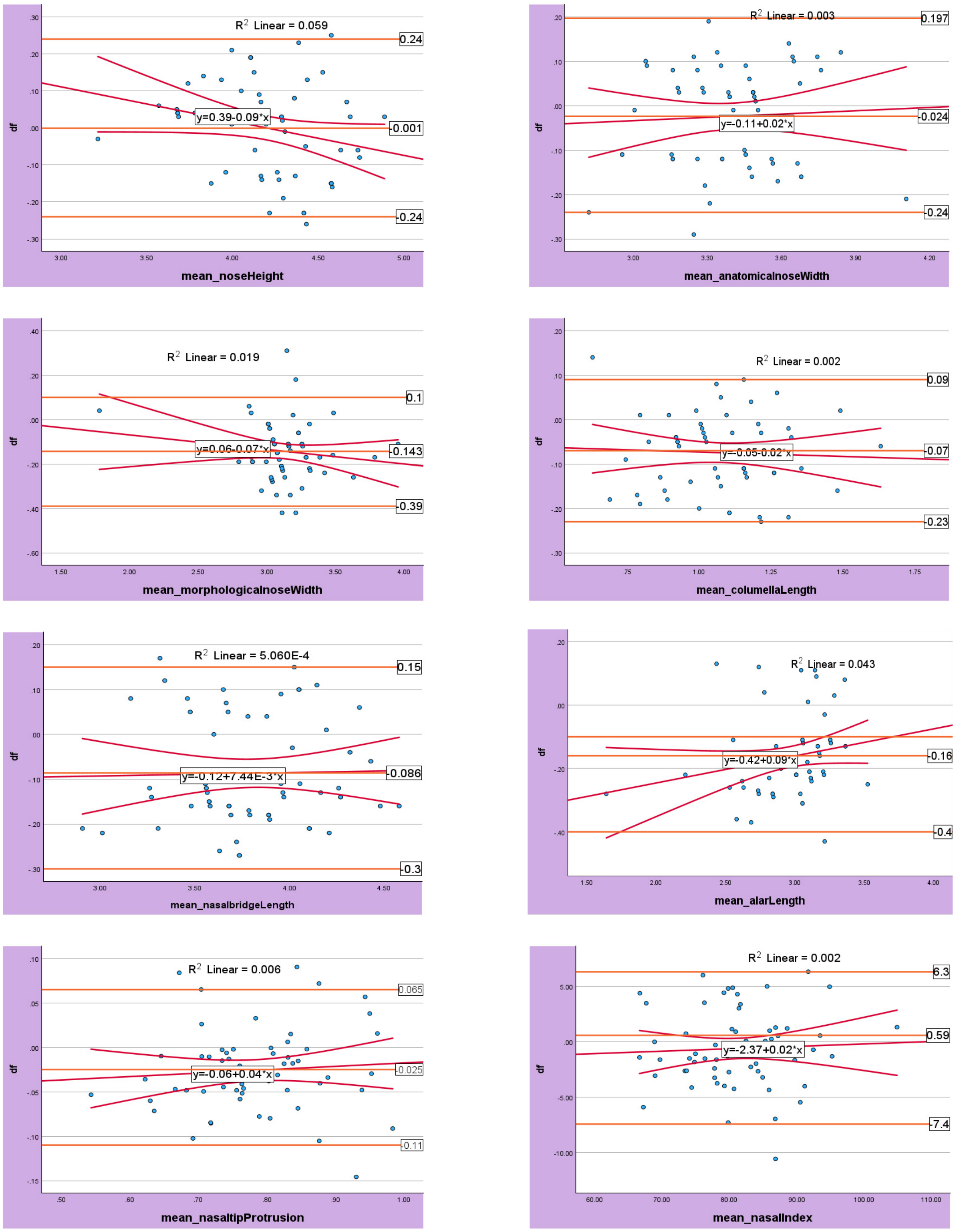

Fig. 4. Bland Altman graphical representation for males

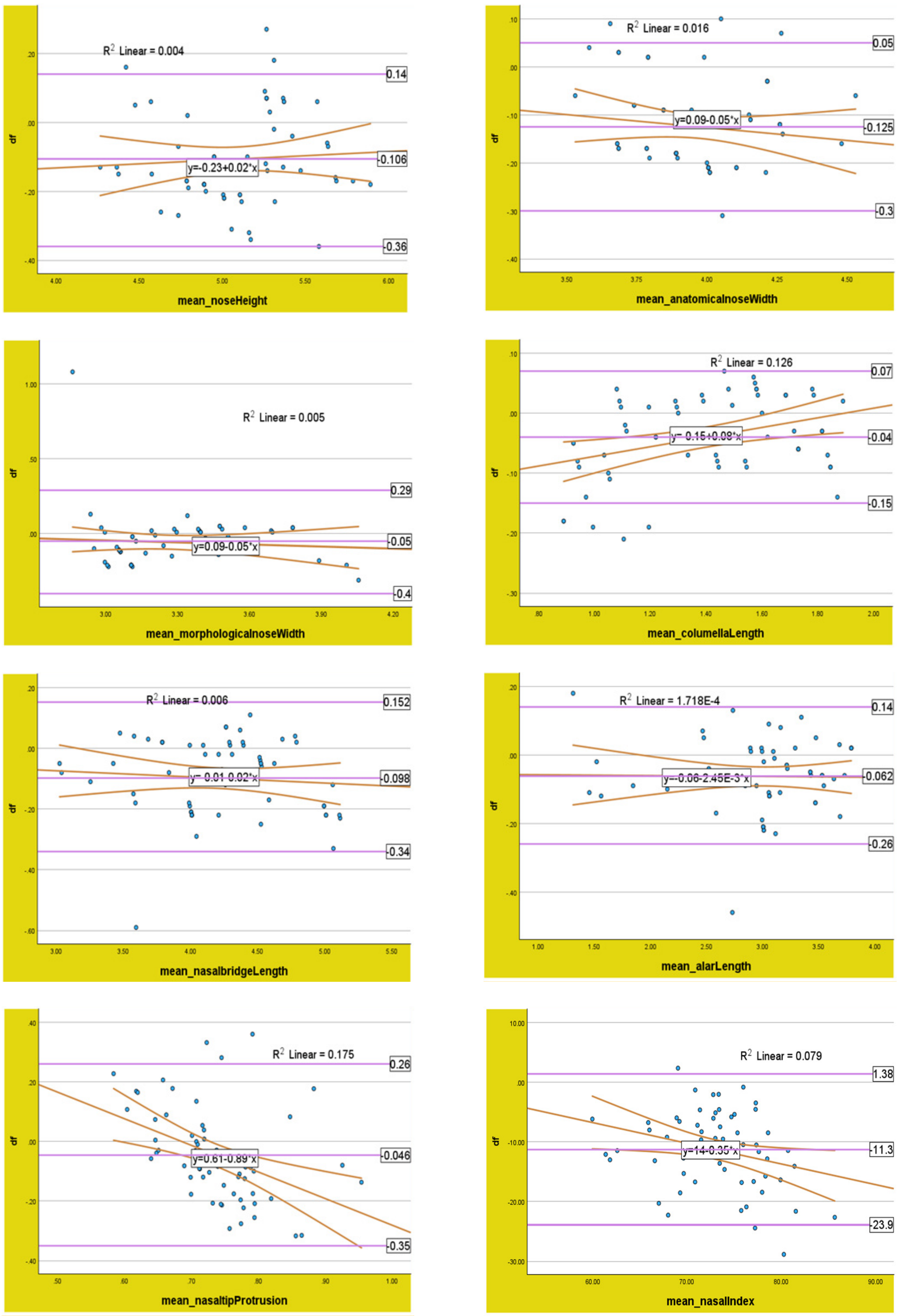

Fig. 5. Bland Altman Graphical Representation for females

In the current study, nose width in males was 3.2±0.3 and 3.1±0.24 cm, and in females it was 3±0.23 and 3.09±0.23 cm, by both the methods. Parab et al. showed the mean nasal width in males was 3.79±0.29 and in females 3.57±0.41.[3] Findings of our study coincide with the findings of the Parab et al study. According to our study, collumellar length in males was 1.2±0.21 and 1.10±0.17 cm, and in females 0.98±0.21 and 1±0.2 cm by both the approaches. Mehta et al. performed a study on the Indian population of different zones and they found 0.94±0.2 cm mean values of Columellar length in both sexes of the Indian population.[10] Our study coincides with the mean values of their study.

In this current study, nasal bridge length in males was 4.06±0.4 and 3.6±0.38 cm, and in females 4.07±0.38 and 4.12±0.39 cm. Mehta et al. found the 4.39±0.5 cm mean values of both genders.[10] We got slightly lower values of nasal bridge length as compared to the Mehta et al. study.

The mean values of alar length in males was 2.9±0.37 and 2.8±0.39 and in females 3.2±0.7 and 3.20±0.72 cm by both the approaches, respectively. Bhandari et al. conducted research on alar length in a New Delhi population and they report a mean of 3.48±0.21 cm in males and 3.14±0.25 in females.[13] After comparison, we got lower values of males and slightly higher values in females.

The mean values of nasal tip protrusion in males was 0.7±0.08 and 0.69±0.11 and in females 0.79±0.17 and 0.79±0.18 cm by both the approaches, respectively. The nasal tip protrusion was found to be 2.07±0.27 in males and 1.94±0.26 in females in research conducted by Parab et al. on an Indian population.[3] After comparison, we found much lower values of nasal tip protrusion.

The nasal index in males was 79±11.3 and 76.05±8.8 and in females 69.9±10.2 and 70.59±10.8. Mehta et al. found 73.27 in males and 72.35 in females.[10] Patil et al. conducted research on a south Indian population and found the values of nasal index in males was 84.91 and in females 67.75.[14] Chabra et al. conducted research on the north Indian population and they reported values of 77.39 in males and 72.28 in females.[15] After comparison, we found similar values. Our values of nasal index lies between 70–84.9, which comes under the category of mesorrhine.[20]

On the other hand, this research also assessed the reliability and accuracy of 2D indirect method against the direct method which is considered the gold standard.

The mean values for males and females of the nose height were -0.001 and -0.1, respectively. Scatter plot of both sexes showed that most of the data points fell under the limit of agreement. The regression analysis of the nose height showed the R-value 0.24 in males and 0.26 in females with the $p>0.05$, with expectation that there could be no difference between the measurements of methods. Nose height in both sexes have more than 0.75 ICC values with narrowest CI. Lim et al. conducted study for the reliability assessment of 2D photogrammetry with a BAA and ICC statistical approach.[4] According to their research, BAA scatter plots represented the agreement between approaches, and their ICC values were 0.99 and CIs limit 0.98-0.99. The same results were found by the current research.

The mean values for males and females of the ANW were -0.024 and -0.12, respectively. Mean values represented the agreement between the approaches. The R-value was 0.25 and 0.29 in males and females, respectively, and their p value was 0.05, which indicates no difference between measurements. The ICC values for males of 0.85 and 0.94 for females had the narrowest CI. Negi et al. conducted research to check the relation between direct anthropometry and indirect anthropometry by using BAA and regression analysis, and they report strong agreement between the approaches.[5] The present study showed the same result.

The mean values for males and females of the MNW were -0.143 and -0.05, respectively. R-value for the MNW was 0.43 in males and 0.38 in females with an insignificant p-value, which suggests no difference between the method measurements. On the other hand, ICC values for the both sexes were 0.91 and 0.93 respectively. Lim et al. reported 0.92 ICC with narrowest CI for the nose width; they suggest an excellent reliability of the method.[4] Similar results were provided by the current research.

The mean values for males and females of the columellar length were -0.07 and -0.04, respectively. R-value showed by the CL parameter was 0.198 in males and 0.19 in females with significant p value, which indicates differences between the methods. Their ICC values for males 0.69 and 0.66 for females with a wide CI. Farkas et al. verified the accuracy of photogrammetry by using 104 facial parameters. After analysis, they stated that columellar length was quite reliable but there was technique measurement differences.[16] Similar results are shown by the present study.

The mean values for males and females of the nasal bridge length were -0.098 and -0.086, respectively. Nasal bridge length represented the R-value 0.54 in males and 0.064 in females with >0.05 p-value. Their ICC values for males 0.69 and 0.63 for females with a wider CI. Aksu et al. used BAA and ICC methods, and they concluded that NBL demonstrated consistency along the reference plane of the measurements.[17] Our study only showed the moderate reliability according to the ICC, and level of agreement.

The mean values for males and females of the alar length were -0.16 and 0.06, respectively. Alar length represented an R-value 0.51 in males and 0.059 in females with >0.05 p-value. Their ICC values for males 0.99 and 0.96 for females with a narrow CI. Farkas et al.

also suggested a strong agreement and reliability of the alar length.[16] After comparison, we also found the same results.

The mean values for males and females of the nasal tip protrusion were -0.046 and -0.025, respectively. Nasal tip protrusion represented the R-value 0.28 in males and 0.35 in females with >0.05 p-value. Their ICC values for male 0.97 and 0.96 for females had a narrow CI. The nasal tip protrusion had an ICC of 0.81 with 95% confidence intervals ranging from 0.72 to 0.88 according to the Lim et al. study.[4] We also report higher values of ICC with a narrow CI, that represented strong reliability.

The mean values for males and females of the nasal index were 0.59 and -1, respectively. Nasal index represented the R-value 0.41 in males and 0.4 in females with <0.05 p-value. Their ICC values for male 0.97 and 0.96 for females with a narrow CI. The mean values of nasal index BAA scatter plot showed strong association between the approaches while the significant p-value of the regression indicates differences between the measurements of the methods. On the other hand, values of ICC and CIs suggest strong reliability of the 2D method.

Our research introduces novelty by employing three methods to assess the reliability of the 2D method: Bland-Altman, regression and ICC analysis. Both agreement and reliability parameters are pivotal in evaluating the quality of the method employed, and our study uniquely combines these three statistical parameters, which are not taken in consideration in previous studies.

The two-dimensional photogrammetric method has been widely applied in research both nationally and internationally, as documented in references 18 and 19. However, there is limited research and certain constraints in studies that compare 2D photogrammetry with direct measurement. Furthermore, current research exhibits conflicting findings on this matter. Some researchers showed that, for numerous facial dimensions, 2D photogrammetry is less precise compared to direct and 3D measurement methods, while the other two studies concluded that 2D photogrammetry aligns closely with direct measurement.[20,21]

In the present study, eight parameters were examined, all the parameters showed mean value towards the zero and minimal SD for the BAA statistical approach. All the scatter plot represented the good agreement between the methods. According to the regression analysis, most of the measurement showed insignificant values (p>0.05), which indicates that there is no difference between measurements of two methods. It's worth noting that a method's reliability is only beneficial if it also demonstrates good agreement, and conversely, good agreement is not useful if the method lacks reliability.

That is why another method used for the reliability assessment- the ICC coefficient. Most of the parameters showed excellent reliability except the columellar length and nasal bridge length. Therefore according to our research, only six out of the eight nasal dimensions can be reliably and accurately measured using 2D photogrammetry. These parameters warrant further research due to technical challenges such as image distortion, resolution of image, head orientation, magnification discrepancies, parallax effects, lighting inconsistencies and measurements difficulty from the lateral aspects. The recognition of the above aspects will help us to interpret the findings in an intricate manner. Researchers will go to more detail on this subject in future articles, stressing the measures used to accuracy while recognizing that other studies using bigger data sets and stratified sampling are required to validate the generality of the result. Future research also incorporating the three-dimensional technique to enhance the robustness of the methodology, the absence of 3D is a benchmark.

We recognize certain limitations in our study. Firstly, both the approaches were conducted by a single observer and secondly, research is limited by exclusion of 3D photogrammetry, a method known for its enhanced accuracy in facial dimension measurement. Finally, future research endeavors should aim to integrate various measurement approaches, including direct, 2D indirect, and 3D technologies.

Conclusion

This study concludes gender-based differences in nasal dimensions, with males generally having larger dimensions. This study highlight the need for tailored approaches in cosmetic procedures to ensure aesthetically sensitive appropriate outcomes. The findings of this study indicate that 2D Photogrammetry emerges as a dependable alternative to the direct method. It offers cost-effectiveness, non-invasiveness, time efficiency, reduced operator dependence, and avoids direct patient contact. It suggests 2D photogrammetry as a reliable method for specific nasal measurements, offering practical benefits in clinical and aesthetic applications.

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Declarations

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Author contributions

Conceptualization, S.K.J. and N.S.; Methodology, S.A.; Software, S.A.; Validation, S.A., N.S. and S.S.; Formal Analysis, S.A.; Investigation, S.A; Resources, S.A.; Data Curation, S.A.; Writing – Original Draft Preparation, S.A.; Writing – Review & Editing, S.A; Visualization, N.S.; Supervision, S.K.J.; Project Administration, S.K.J.

Conflicts of interest
The author(s) declare no competing interests.

Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval
The study was approved by the Institutional Ethical Committee (Ref. no. TMU/IEC/20-21/103) at Teerthanker Mahaveer Medical College and Research Centre.

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