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THREE-DIMENSIONAL STEREOPHOTOGRAMMETRIC ASSESSMENT OF MALE–FEMALE FACIAL DIFFERENCES IN YOUNG ADULTS OF MAHARASHTRA

Dentofacial Orthopedics

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ABSTRACT

Context: Three-dimensional evaluation of facial soft tissue morphology has gained importance in orthodontic diagnosis and treatment planning, particularly for understanding sexual dimorphism within specific populations. **Aims**: To assess and compare three-dimensional facial soft tissue morphology between male and female young adults of Maharashtrian origin using stereophotogrammetry. **Settings and Design:** This was an observational cross-sectional study conducted at the Department of Orthodontics, Government Dental College and Hospital, Mumbai. **Methods and Material:** Three-dimensional facial images of 140 healthy Maharashtrian adults aged 19–30 years (70 males and 70 females) were captured using a mobile-based stereophotogrammetric system. Sex-specific average facial shells were generated, and surface-based best-fit superimposition was performed to evaluate linear surface deviations, color-coded deviation patterns, and regional morphological differences. **Statistical analysis used:** Descriptive statistics including mean absolute surface deviation, standard deviation, and maximum deviation values were used for quantitative analysis. **Results:** The mean absolute surface deviation between male and female average facial shells was 0.51 mm, with localized maximum deviations of up to 8.7 mm. Approximately 49.20% surface overlap was observed. Male facial morphology demonstrated greater transverse facial width, peri-ocular depth, wider alar base, and increased nasal projection, while female facial morphology showed greater malar prominence, fuller lips, and smoother facial contours. **Conclusions:** Distinct sexual dimorphism exists in three-dimensional facial soft tissue morphology among Maharashtrian young adults. Surface-based stereophotogrammetric analysis provides a comprehensive and clinically relevant approach for population- and sex-specific facial assessment.

KEYWORDS

Stereophotogrammetry; Facial soft tissues; Sexual dimorphism; Three-dimensional imaging; Facial morphology

INTRODUCTION

Facial soft tissue morphology is an important factor in determining facial harmony and is a major concern in orthodontic diagnosis, treatment planning, and assessment of esthetic outcomes. Modern orthodontics not only focuses on the accomplishment of functional occlusion but also on the optimization of facial balance, proportion, and overall facial appearance, since soft tissues represent a dynamic interface that overlies the skeletal and dental structures and has a profound effect on facial perception and attractiveness.[1-3]

Conventional two-dimensional diagnostic methods, such as lateral cephalometric analyses and facial photographs, are commonly employed for facial analysis; however, these modalities are prone to errors of projection, magnification, and the inability to accurately depict facial depth and surface topography.[4,5]

As patient awareness and expectations for facial esthetics continue to evolve, these issues become increasingly apparent. Three-dimensional imaging modalities can potentially address these issues by allowing for a complete analysis of facial morphology and more accurate surface topography analysis.[6,7]

Among the available three-dimensional imaging techniques, stereophotogrammetry is generally accepted as a non-invasive, ionizing radiation-free, rapid imaging technique with high resolution for facial surface imaging.[8] There are several validation studies available that show stereophotogrammetry to be a technique with acceptable accuracy, reliability, and reproducibility for facial anthropometry and morphologic analysis of soft tissues.[9-11]

Facial morphology is affected by genetic, environmental, and cultural factors and varies significantly among different ethnic and regional populations.[12,13] Therefore, the use of facial standards established from non-representative populations may result in incorrect diagnosis and inappropriate esthetic treatment objectives.[14] Although there is an increasing amount of literature on three-dimensional facial analysis, information on Indian populations, especially region-specific populations such as people of Maharashtrian origin, is scarce.[15]

Hence, the objective of the current study was to assess and compare the three-dimensional facial soft tissue morphology of young males and females of Maharashtrian origin using stereophotogrammetry, with specific emphasis on identifying sexual dimorphism.

Materials and Methods

Study Design and Ethical Approval

The observational cross-sectional study was carried out after obtaining approval from the Institutional Ethics Committee of Government Dental College and Hospital, Mumbai. (IEC No. 1190/2025) Written informed consent was obtained from all participants prior to inclusion in the study. The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines, and the relevant checklist was completed.[16]

Study Sample

The study sample consisted of 140 healthy young adults aged 19–30 years, including 70 males and 70 females. All participants were of Maharashtrian origin, with ancestry traceable for a minimum of three generations to ensure population homogeneity. Individuals with a history of craniofacial syndromes, facial trauma, previous orthodontic or orthognathic treatment, or clinically evident facial asymmetry were excluded.

Imaging System and Image Acquisition

Three-dimensional facial images were obtained using a mobile-based stereophotogrammetric system following a standardized image acquisition protocol.[6,7,11] Participants were seated upright with the head positioned in natural head position and were instructed to maintain a relaxed facial expression with lips at rest. Facial images were captured at the highest available resolution, encompassing the facial region from ear to ear and extending inferiorly to the chin. Image acquisition for each participant was completed within approximately 20 seconds to minimize motion-related artifacts.

Image Processing and Morphological Analysis

All facial scans were processed to generate sex-specific average facial shells for male and female groups. Surface-based best-fit superimposition was performed using Geomagic Control X software. Morphological differences between male and female facial forms were evaluated using surface-based analysis techniques described in previous validation studies.[9-11,19,20] The following analyses were conducted:

- Linear surface deviation analysis to quantify absolute distances between corresponding surface points
- Color-coded deviation mapping and histogram analysis to visualize the magnitude and direction of surface deviations
- Surface area and shape analysis to identify region-specific morphological differences across the facial surface

Clinical Demonstration

To demonstrate potential clinical utility, the facial scan of a randomly selected male participant presenting with facial disharmony was superimposed onto the male average facial shell. This comparison was performed for illustrative purposes only and was not included in quantitative or inferential analysis.

Statistical Analysis

Surface deviation measures were summarized using descriptive statistics, including mean absolute deviation, standard deviation, and maximum deviation values. Quantitative analysis was performed using analytical tools integrated within the three-dimensional imaging software. Inferential statistical comparisons were not performed, as the primary objective of the analysis was descriptive morphological comparison between male and female facial forms.

RESULTS

Average Facial Shells

Sex-specific three-dimensional average facial shells were generated for male and female Maharashtrian participants and were used as reference models for all comparative analyses (Figure 1). These composite facial shells represented mean facial morphology for each sex and reduced individual variability, enabling reliable surface-based group comparison.

Linear Surface Deviations

Surface deviation analysis between male and female average facial shells demonstrated a mean absolute surface deviation of 0.51 mm, with a standard deviation of 2.83 mm and a maximum deviation of 8.7 mm. Large areas of the facial surface showed minimal deviation between sexes; however, distinct localized regions exhibited greater surface differences. Approximately half of the facial surface demonstrated deviations exceeding commonly applied tolerance thresholds used in three-dimensional facial surface analysis. Quantitative surface deviation parameters and region-specific morphological characteristics are summarized in Table 1.

Color Histogram Analysis

Color histogram comparison revealed an overall surface overlap of 49.20% between male and female average facial shells (Figure 2). The remaining surface area exhibited direction-specific deviations, with both positive and negative values distributed across different facial regions. These deviations were regionally localized rather than uniformly distributed across the facial surface.

Surface Area and Shape Differences

Analysis of surface area and facial shape demonstrated clear regional morphological differences between male and female average facial shells (Figures 3–6). Male facial shells exhibited greater transverse facial width, increased periocular depth, wider alar base dimensions, and increased nasal projection relative to female facial shells. In contrast, female facial shells demonstrated greater malar prominence, increased lip fullness particularly in the upper lip region and smoother, more convex surface transitions across the midface and lower facial regions.

Clinical Demonstration

Superimposition of the facial scan of a randomly selected male participant onto the male average facial shell revealed notable surface deviations, particularly within the malar region and lower facial third (Figure 4). Reduced lateral malar projection and increased chin prominence were observed relative to the male average facial shell. This comparison was descriptive and illustrative in nature and was not included in quantitative or inferential analysis.

DISCUSSION

Principal Findings

The present study demonstrates clear sexual dimorphism in three-dimensional facial soft tissue morphology among Maharashtrian young adults when assessed using surface-based stereophotogrammetric analysis. Rather than relying on isolated linear measurements, the use of average facial shells and surface deviation mapping enables visualization of region-specific morphological differences between male and female facial forms. The observed partial surface overlap between male and female facial shells indicates a shared overall facial framework while simultaneously highlighting localized areas of clinically relevant variation.

Comparison with Previous Studies

The pattern of sexual dimorphism observed in the present study is consistent with findings reported in previous three-dimensional facial analyses across different populations. Prior stereophotogrammetric studies have documented greater transverse facial dimensions and increased nasal projection in males, alongside increased malar prominence and lip fullness in females, reflecting sex-related differences in craniofacial growth and soft tissue distribution.[13,21,22]

Studies conducted in European and North American populations have reported comparable region-specific variations, particularly within the periocular, malar, nasal, and labial regions, which are critical determinants of facial esthetics and gender perception.[14,23,24]

However, the magnitude and spatial distribution of these differences vary across populations, underscoring the influence of ethnic and population-specific factors on facial morphology.[12,15,25] The limited representation of Indian populations in existing three-dimensional facial literature has restricted the applicability of previously published facial standards. The present findings contribute population-specific comparative data that complement earlier reports from other ethnic cohorts without extrapolating non-representative facial norms.

Clinical Relevance

Accurate assessment of facial soft tissue morphology is fundamental to orthodontic and orthognathic diagnosis, where treatment outcomes are increasingly evaluated in terms of facial harmony rather than dental alignment alone. Two-dimensional diagnostic tools may underestimate complex surface variations, particularly in esthetically sensitive regions such as the midface, perioral area, and nasal region.[4,5] The surface-based three-dimensional approach used in the present study enables visualization of both the magnitude and direction of facial deviations, thereby supporting individualized and sex-aware facial assessment.

The illustrative patient comparison further demonstrates the clinical utility of three-dimensional facial templates, as deviations from population-based average facial shells were readily visualized. Such analysis may aid treatment planning in complex clinical scenarios, including orthognathic surgery, where precise evaluation of facial symmetry and proportionality is essential.[26]

Methodological Strengths

A major strength of this study lies in the application of surface-based three-dimensional analysis rather than landmark-dependent measurements, thereby reducing operator-dependent variability and enabling comprehensive evaluation of facial morphology. The generation of sex-specific average facial shells minimized individual variation and facilitated group-level comparison. Furthermore, the use of standardized image acquisition protocols and validated surface registration techniques enhanced the reproducibility and reliability of the findings.[9,17-19] The inclusion of a homogenous regional sample further strengthened internal validity by limiting confounding ethnic variability.

Limitations

Several limitations should be acknowledged. The cross-sectional design precludes assessment of age-related or longitudinal changes in facial morphology. The restricted age range limits generalization to other age groups, and the findings cannot be extrapolated to skeletal morphology, as hard tissue imaging was not included. Additionally, although mobile-based stereophotogrammetry provides clinically acceptable accuracy for group-level comparisons, it may not achieve the precision of high-end fixed stereophotogrammetric systems.[18,27] Future studies incorporating longitudinal designs, larger samples, multi-regional Indian populations, and combined hard–soft tissue analyses are warranted.

CONCLUSIONS

Three-dimensional surface-based analysis reveals distinct sexual dimorphism in facial soft tissue morphology among Maharashtrian young adults. Male facial morphology demonstrates greater transverse facial width and nasal projection, whereas female facial morphology shows increased malar prominence and lip fullness. These region-specific differences highlight the value of three-dimensional facial assessment in supporting population- and sex-aware orthodontic and orthognathic diagnosis and treatment planning.

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Nil.

Conflicts of Interest

The authors declare that they have no competing interests.

Ethical Approval

Ethical approval for the study was obtained from the Institutional Ethics Committee of Government Dental College and Hospital, Mumbai.

Table 1. Surface-based three-dimensional facial differences between male and female participants

Parameter	Male–Female Comparison
Mean absolute surface deviation (mm)	0.51
Standard deviation of surface deviation (mm)	2.83
Maximum surface deviation (mm)	8.70
Overall surface overlap (%)	49.20
Predominant male facial characteristics	Broader facial width; greater periocular depth; wider alar base; increased nasal projection
Predominant female facial characteristics	Greater malar prominence; fuller lips; smoother and more convex facial contours

Footnote: Surface deviation values represent absolute distances between corresponding points on male and female average facial shells.

Figure Legends

Figure 1. Average three-dimensional facial shells of Maharashtrian male and female participants.

Figure 2. Color histogram comparison showing surface deviations between male and female average facial shells.

Figure 3. Extraoral and Intraoral photographs of Randomly selected patient

Figure 4. Superimposition of a randomly selected patient's facial scan onto the male average facial shell.Male average facial shell demonstrating broader facial width and increased nasal projection.

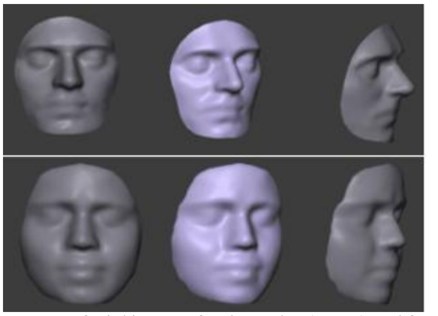


Figure 1 Average facial images for the males (row 1) and females (row 2)

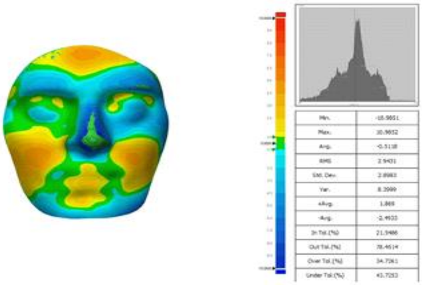
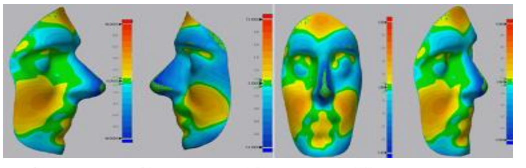


Figure 2 - Color map and histogram plot developed to compare superimposed average facial shells of males and females.



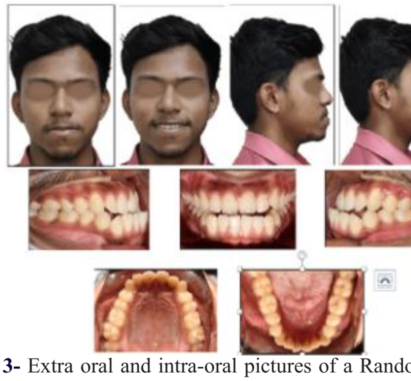


Figure 3- Extra oral and intra-oral pictures of a Randomly selected patient with a significant facial deformity

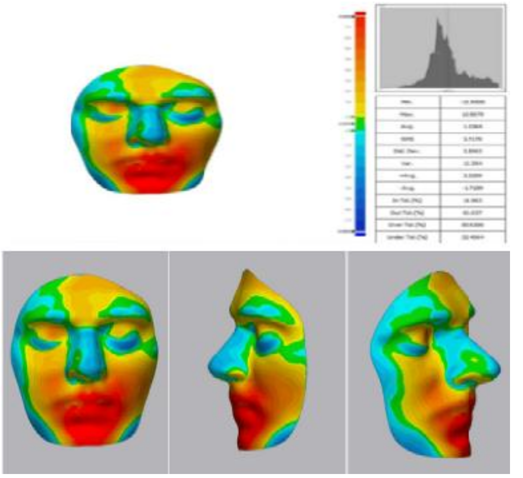


Figure 4 - Colour histogram differences between the Random selected Patient versus Maharashtrian young Adult Male Average.

Key Messages:

Three-dimensional facial analysis reveals clear, region-specific sexual dimorphism in Maharashtrian young adults, supporting sex-aware orthodontic and orthognathic diagnosis and treatment planning.

REFERENCES

1. Bailey LJ, Proffit WR, White RP. Assessment of patients for orthognathic surgery. Semin Orthod 1999; 5:113-120.
2. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Am J Orthod Dentofacial Orthop 1993; 103:299-312.
3. Nanda R, Ghosh J. Facial soft tissue considerations in orthodontic diagnosis. Semin Orthod 1995; 1:115-123.
4. McNamara JA. A method of cephalometric evaluation. Am J Orthod 1984; 86:449-469.
5. Hajeer MY, Millett DT, Ayoub AF, Siebert JP. Applications of three-dimensional imaging in orthodontics: Part I. J Orthod 2004; 31:62-70.
6. Kau CH, Richmond S, Incrapera A, English J, Xia JJ. Three-dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery. Int J Med Robot 2007; 3:97-110.
7. Richmond S, Zhurov A, Playle R, Marshall D, Rosin PL. The use of three-dimensional facial imaging in orthodontics. Br Dent J 2004; 197:595-600.
8. Heike CL, Upson K, Stuhaug E, Weinberg SM. Stereophotogrammetry for facial anthropometry in craniofacial disorders: A review. Cleft Palate Craniofac J 2010; 47:603-611.
9. Weinberg SM, Naidoo S, Govier DP, Martin RA, Kane AA, Marazita ML. Anthropometric precision and accuracy of digital three-dimensional photogrammetry. Cleft Palate Craniofac J 2006; 43:735-742.
10. Aldridge K, Boyadjiev SA, Capone GT, DeLeon VB, Richtsmeier JT. Precision and error of three-dimensional phenotypic measures acquired from photogrammetry. Am J Med Genet A 2005; 138A:247-253.
11. Ayoub AF, Garrahy A, Hood C, White J, Bock M, Siebert JP. Validation of a three-dimensional imaging system for facial measurement. Int J Oral Maxillofac Surg 2003; 32:390-394.
12. Farkas LG, Katic MJ, Forrest CR. International anthropometric study of facial morphology in various ethnic groups. Cleft Palate Craniofac J 2005; 42:349-356.
13. Ferrario VF, Sforza C, Dellavia C, Tartaglia GM. Sexual dimorphism in facial shape assessed by three-dimensional morphometry. J Anat 2003; 203:593-600.
14. Sforza C, Grandi G, Binelli M, Tommasi DG, Rosati R, Ferrario VF. Age- and sex-related changes in facial three-dimensional morphology. Forensic Sci Int 2009; 185:110.e1-110.e7.
15. Gupta A, Kharbanda OP, Sardana HK, Balachandran R. Facial soft tissue analysis of a North Indian population using three-dimensional imaging. J Indian Orthod Soc 2015; 49:131-138.
16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. PLoS Med 2007; 4:e296.
17. Ma L, Xu T, Lin J. Validation of a three-dimensional facial scanning system based on structured light techniques. Comput Methods Programs Biomed 2009; 94:290-298.
18. Tzou CHJ, Artner NM, Pona I, et al. Comparison of three-dimensional surface-imaging systems. J Plast Reconstr Aesthet Surg 2014; 67:489-497.
19. Plooij JM, Swennen GRJ, Rangel FA, et al. Evaluation of reproducibility and reliability of three-dimensional soft tissue analysis using stereophotogrammetry. Int J Oral Maxillofac Surg 2009; 38:267-273.
20. Toma AM, Zhurov AI, Playle R, Marshall D, Rosin PL, Richmond S. The assessment of facial variation using three-dimensional imaging. Eur J Orthod 2012; 34:655-664.
21. Codari M, Pucciarelli V, Stangoni C, Beltramini GA, Sforza C. Sexual dimorphism of facial soft tissues assessed by stereophotogrammetry. Angle Orthod 2016; 86:626-633.
22. Seager C, Quaranta A, Mahmoudzadeh M, Marti B, Dubois L. Sexual dimorphism of facial soft tissues using three-dimensional photogrammetry. J Clin Orthod 2021; 55:210-218.
23. Gor T, Kau CH, English JD, Lee RP, Ovsenik M, Richmond S. Three-dimensional comparison of facial morphologies in populations from the United States, Slovenia, and Wales. J Orthod 2010; 37:93-99.
24. Talbert L, Kau CH, Christou T, Vlachos C, Souccar N. A three-dimensional analysis of Caucasian and African American facial morphologies. J Orthod 2014; 41:19-29.
25. Sforza C, Menezes M, Ferrario VF. Soft-tissue facial morphology in different populations assessed by three-dimensional imaging. J Oral Maxillofac Surg 2010; 68:2099-2106.
26. Swennen GRJ, Mollemans W, Schutyser F. Three-dimensional treatment planning of orthognathic surgery. J Oral Maxillofac Surg 2009; 67:2150-2162.
27. Liu C, Zhang Y, Jiang X. Accuracy of three-dimensional facial imaging systems: A systematic review. J Craniofac Surg 2019; 30:2397-2403.