

Evaluation of Relationship of Facial Landmarks with Midline of the Face Using Digital Analysis among the Population of Moradabad, North India

Dr. Aniket Mone¹, Dr. Swatantra Agarwal², Dr. Reena Mittal³, Dr. Shraddha Ambadkar⁴

¹Senior Lecturer, Department of Prosthodontics and Crown and Bridge, VYWS Dental College & Hospital, Amravati
amaniketmone[at]gmail.com

²Principal & Head, Department of Prosthodontics and Crown and Bridge, Kothiwal Dental College & Research Centre, Moradabad
drswatantra[at]yahoo.co.in

³Professor, Department of Prosthodontics and Crown and Bridge, Kothiwal dental College & Research Centre, Moradabad
reenamt2006[at]gmail.com

⁴Reader, Department of Prosthodontics and Crown and Bridge, VYWS Dental College & Hospital, Amravati
shraddhaambadkar111[at]gmail.com

Abstract: Background: The foundation of esthetics is achieving facial symmetry and understanding the facial midline which will help one better to grasp dentofacial esthetics. Currently, there is no standardized approach for determining the midline of the mouth or face in edentulous individuals. Many medical professionals opt for selecting a solitary, conspicuous anatomical landmark and extrapolating an imaginary line through it. As a result, clinicians lack any recognized standards for identifying the facial midline. Aim & Objectives: The study aims to digitally examine the relationship between chosen facial landmarks and the facial midline with the objective of formulating criteria for selecting anatomical landmarks specific to the Moradabad population in North India. Materials and method: Digital markings of four frequently used anatomic landmarks—the nose tip, dental midline, tip of the philtrum and nasion—were used on photographs of 100 individuals, ranging in age from 18 to 30. Digital frontal full facial photos of the subjects in smile were captured under preset conditions. Esthetic frame was constructed digitally on each image. Digitally, vertical lines were created that passed through each selected landmark. Using image analysis tools, a digital midline analysis was performed. A solitary observer conducted the entire midline analysis process, and both one-sample t-tests and paired t-tests were executed. Result: The findings revealed that all four landmarks differed individually and significantly ($P < 0.001$) from the commissural and the facial midline. Conclusion: Based on the limitation of the study, the following anatomic landmark hierarchy was found to be the closest to the facial midline: Nasion, Tip of the nose, Dental midline and the philtrum. Whereas, philtrum, the dental midline, tip of the nose and nasion were the anatomical landmarks in the order of closest proximity to the intercommissural midline.

Keywords: Facial midline, commissural midline, dental midline, esthetic frame, anatomical landmarks.

1. Introduction

The idiom "aesthetic" can indeed connote naturalness, attractiveness and a vibrant appearance. In dentistry, it often refers to the appearance of teeth and the overall smile. It has been also stated that aesthetic dentistry is "the art of the imperceptible".¹ Facial esthetics and desire of the patient to look better have become more important due to a rise in awareness in dentistry and increasing patient awareness outside of the field.²⁻⁵ In the past - symmetry, normality, and sexual dimorphism were thought to be the fundamental components of facial beauty. The midline, which is the dividing line utilized to achieve symmetry, also acts as the basic point of reference for all aesthetic deviations.⁶⁻¹⁰ Knowledge of midline allows for a better understanding of dentofacial aesthetics, which helps a patient obtain the best possible facial aesthetic appearance.⁷ Several dental practitioners often opt for a particular anatomical reference point and imagine a line passing through it, following established conventions and traditional beliefs. Without any established guidelines, the clinician is forced to estimate the midline using unreliable landmarks. The alignment of the maxillary and facial midlines holds greater significance in dental aesthetics compared to the alignment of the mandibular and facial midlines.¹ Certain authors have proposed situating the dental midline at the facial position where it exhibits the highest stability, while others have delineated the facial midline based on anthropometric considerations, defining it

as a line connecting three anatomical points: nasion, subnasale, and either gnathion or menton.¹¹⁻¹² In numerous prior investigations, researchers recommended utilizing intraoral reference points like the interincisal papilla to ascertain the dental midline. According to the data, the interincisal papilla was considered as the most appropriate reference point followed by the maxillary labial frenum and mid-palatal suture.¹³⁻¹⁴ Some people think that nasion and philtrum (often called Cupid's bow) are important markers for finding the facial midline. This midline of face, also known as the vertical axis of face, is established by drawing a line between these two points. Supporters contend that this alignment holds paramount importance for diverse design considerations, especially in esthetic and restorative treatment planning.¹⁵ In light of recent advancements in digital technologies, photogrammetry, developed as an alternative to traditional measurement methods which utilizes a combination of 3D and 2D techniques to gauge the distances between various chosen facial landmarks. This non-invasive and economical method offers a lasting record of facial features. Accessing this data later ensures consistency in long term studies that involve numerous researchers who may use different direct measuring techniques.¹⁶ In recent times, several authors have employed computer-assisted technology, introducing the concept of an esthetic frame in their studies which is a rectangular structure that accurately delineates the midline of the face. The aesthetic frame pertains to the facial region that includes

features of aesthetic importance, such as midlines, angles, and smile characteristics.^{1,2,7,9,17} Differences in anthropological indices have been observed across various populations and regions, with the Indian population standing out due to its vast diversity in races, mixed cultures, and ethnicity.¹⁸ Therefore, the purpose of the current study was to digitally assess the correlation between the midline of face, commissural midline & the chosen facial landmarks i.e., to establish practical guidelines for the selection of landmarks in order to accurately determine the facial midline in clinical settings, with a specific focus on individuals from the Moradabad population in North India. Null hypothesis in the present study asserts that there is no appreciable distinction between the commissural & facial midline and the chosen facial anatomic landmarks.

2. Aim and Objectives

Aim:

- To determine correlation between chosen facial landmarks & midline of face.

Objectives:

- To formulate an order of chosen facial landmarks based on their proximity to the midline of the face.
- To prioritize the selected facial landmarks based on their proximity to the commissure midline.
- To investigate the correlation between the midline of commissures and midline of the face

3. Materials and Methods

In this study, individuals who visited the Outpatient Department of Prosthodontics and Crown & Bridge at Kothiwal Dental College and Research Centre were examined and chosen. A total of 100 participants were selected based on eligibility criteria. The study received ethical approval from the Institutional Ethics and Review Board (IERB) and informed consent was obtained from all selected participants. The study included individuals aged 18-30, of both genders, residing in the Moradabad area. Those with a history of acquired or congenital conditions affecting facial appearance or form, facial asymmetry, a history of orthodontic treatment, the absence of upper front teeth, the presence of replacements or restorations for upper front teeth, teeth gaps or crowding issues, severe periodontal problems, or asymmetry in ophthalmic features were excluded. For marking the anatomical landmarks, full face digital images were captured in a relaxed smiling position, following the established photographic setup. A digital single-lens reflex (DSLR) camera equipped with a 70 mm focal length lens and a point flash was utilized to capture life-sized images with a 1:1 magnification ratio employing an aperture set at F4.5. Consistent lighting conditions were upheld across all photographs. A tripod ensured the camera's proper height and horizontal alignment thus minimizing any potential vibrations. Subjects were positioned against the cephalostat to stabilize the head and achieve a standardized image, with the head adjusted to align the Frankfurt-Horizontal (F-H) plane and camera lens parallel to the floor. The camera was positioned 1.5 meters (or 5 feet) from the subject's face, maintaining the visual axis parallel to the room floor at the patient's eye level. A single photograph was taken

for each individual and digitally analyzed. The images were directly transferred to the computer for analysis. (Fig. 1)



Figure 1: Stabilization head with cephalostat

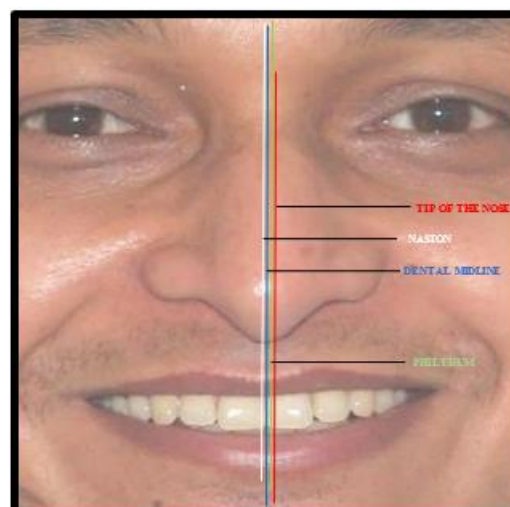


Figure 2: Vertical Lines constructed over chosen anatomical landmarks



Figure 3: Esthetic frame and facial midline & Establishment of commissural midline

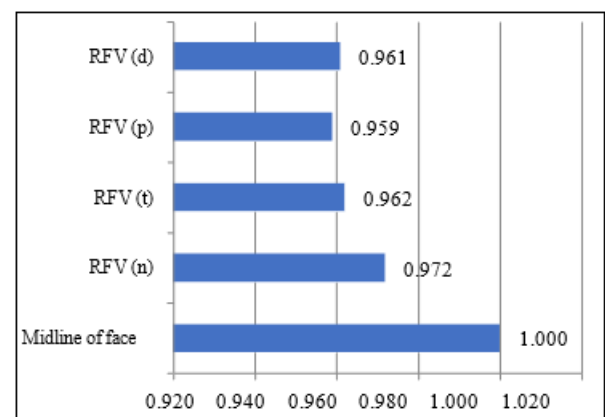
The anatomical landmarks used in the study were as follows – Nasion, Tip of the nose, Philtrum of the lip, Dental midline. Digital markings were applied to specific points on the patient's photographs using Adobe Photoshop CS imaging software. (Fig. 2) These points included the nasion, tip of the nose, philtrum of the lip & dental midline (A vertical line

passing through the apex of the incisal embrasure between the two maxillary central incisors and aligned parallel to the vertical lines of the frame). Afterward, these markings were examined to establish their correlation with the facial midline, following the guidance provided by the esthetic frame. To ascertain the facial midline, the innovative "Esthetic frame" was digitally superimposed onto the photographs (Fig. 3). This frame is defined as an area on an individual's face where aesthetic features like midlines, angles, and smile characteristics are noticeable and objectively measurable. Its upper border is delineated by a line drawn from the exocanthion of one eye to the exocanthion of the other eye. The two lateral borders consist of lines drawn perpendicular to each other from the exocanthion of each eye. The lower border is a line parallel to the upper border, extending from the inferior border of the lip. The facial midline is determined by dividing the distance between the two lateral borders of the frame. Likewise, to locate the commissural midline, a pair of vertical lines were drawn at the corners of the mouth during a smiling posture. Another vertical line bisecting the distance between the previously drawn lines at the corners of the mouth defines the commissural midline (Fig. 3). To evaluate the correlation between anatomical landmarks and their respective midlines, Relative Facial Midline Value (RFV) and Relative Commissural Midline Value (RCV) were employed as pragmatic tools for photographic analysis. Subsequently using imaging software, four vertical lines were digitally placed on the subject's photograph passing through the anatomically marked points. The lines were color coded as follows – Nasion (white), Tip of the nose (Red), Philtrum (Green), Dental midline (Blue). The Relative Facial Midline Value (RFV) was described as the proportional closeness of an anatomical landmark to the facial midline. The constant "F" represented the distance between the lateral border of the esthetic frame and the specified facial midline. Variables were designated for different distances: "n" for the distance to the nasion and the lateral border of the esthetic frame, "p" for the distance to the philtrum and the lateral border of the esthetic frame, "t" for the distance to the tip of the nose and the lateral border of the esthetic frame, and "d" for the distance from the dental midline to the lateral border of the frame. The RFV for the nasion (RFVn) was derived by dividing "n" by "F" (n/F). Similarly, RFVs were computed for all other anatomical landmarks using the same formula, such as RFVp (p/F), RFVt (t/F), and RFVd (d/F). The Relative Commissural Midline Value (RCV) was defined as the proportional distance of an anatomical landmark from the commissural midline. A constant "C" represented the distance between the right or left cheilion and the commissural midline. Variables were assigned for different distances: "nx" for the distance from the right or left cheilion to the nasion, "px" for the distance to the philtrum, "tx" for the distance to the tip of the nose, and "dx" for the distance from the right or left cheilion to the dental midline. The RCV for the nasion (RCVn) was calculated by dividing "nx" by "C" (nx/C). Similarly, RCVs were computed for all other anatomical landmarks using the same formula, such as RCVp (px/C), RCVt (tx/C), and RCVd (dx/C). The term "Cx" was specified as the estimated distance between the lateral border of the esthetic frame and the midlines of the commissures. Consequently, the ratio Cx/F represented the connection between the midline of the

commissures and the midline of the face. The application of RFV and RCV aimed to establish a consistent correlation between an anatomical landmark and the respective midline under consideration. This method ensured that all landmarks within the esthetic frame shared a common denominator, eliminating the necessity to resize images to match individual face sizes. The determination of whether to select the right or left lateral border of the esthetic frame, as well as the commissures, was based on deviations in anatomical landmarks. Therefore, the shortest distance to the lateral boundary of the frame was uniformly chosen. As a result, both RFV and RCV were consistently values less than or equal to 1. If a line drawn along one anatomical landmark coincided with any other landmark, the same RFV and RCV value were recorded for both.

4. Result

Three sets of 1-sample t tests were conducted. One set of 4 t tests was conducted to test the null hypothesis that the mean ratios of the 4 specified anatomic measures did not differ from 1.00 (whether they all lined up with the facial midline). The analysis indicated that the difference between the mean ratio of each anatomic landmark and the midline of the face was statistically significant ($P < 0.05$). The nasion was the closest, followed by the tip of nose, dental midline and philtrum in relation to the facial midline.

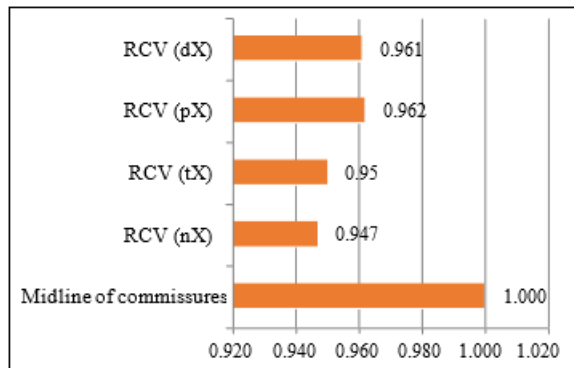


Graph 1: Hierarchical relationship i.r.t various RFVs

Table 1: Comparison of various mean relative facial values with standard ratio 1

	N	Mean RCV	Std. Deviation	Mean difference with standard ratio 1	T value	P value
RCV (nX)	100	0.947	0.0345	-0.0527	-15.267	0.00**
RCV (tX)	100	0.95	0.0424	-0.0503	-11.873	0.00**
RCV (pX)	100	0.962	0.0316	-0.0382	-12.075	0.00**
RCV (dX)	100	0.961	0.031	-0.039	-12.596	0.00**

Whereas it was found to be different for the commissural midline i.e., Philtrum, dental midline, tip of the nose and nasion. On applying independent t –test, it was also observed that the difference between the relative commissural value with the standard ratio 1 i.e., the facial midline was statistically significant i.e., $p < 0.05$.



Graph 1: Hierarchical relationship i.r.t various RCVs

Table 2: Comparison of various mean relative commissural values with standard ratio 1

	N	Mean RCV	Std. Deviation	Mean difference with standard ratio 1	T value	P value
RFV (n)	100	0.972	0.0192	-0.0276	-14.350	0.00**
RFV (t)	100	0.962	0.0276	-0.0379	-13.710	0.00**
RFV (p)	100	0.959	0.0291	-0.0406	-13.941	0.00**
RFV (d)	100	0.961	0.0293	-0.0394	-13.433	0.00**

5. Discussion

Esthetic dentistry represents a delicate blend of creative abilities and scientific concepts. The midline serves as a fundamental reference for all esthetic considerations, given its crucial role in facial and dental aesthetics.¹⁹ A vital aspect of facial beauty and esthetics is the symmetry of the dental and facial midlines, with dental midline deviations influencing the esthetic perception of young individuals, particularly in relation to gender. Consequently, a comprehensive understanding of the midline contributes to a more nuanced comprehension of both facial and dental esthetics. When it comes to smile design, esthetic treatment strategies begin with the midline of the face. Further enhancing aesthetic appeal is the alignment of the maxillary midline with the facial midline.¹ Therefore, it is imperative for dentists to possess the capability to accurately determine a patient's correct midline.²

Facial landmarks play a crucial role in assessing discrepancies between facial and dental midlines. Over time, different facial reference points, such as the midpoint of the interpupillary line, nasion, nose tip, philtrum and chin, have been employed to establish these midlines.^{1,2,7-9,18,20,21} Typically, a traditional technique establishes the facial midline by connecting points at the glabella or nasion, subnasale, and pogonion using dental floss. However, this method may yield inaccurate results due to difficulties in precisely identifying points and the parallax required for visualizing them. Furthermore, the three points might not line up in situations where there is mandibular asymmetry. Hence, the decision process may be made more difficult by the sites' far from the dental midline placement.²

A limited tolerance for differences in dental midlines from the facial midline limits the clinical trials that have been documented in the literature. This leave clinicians without predictable guidelines, and many resort for determining the

midline based on unverified landmarks. Examining the relationship between facial and dental midlines through the application of an esthetic frame helps identify deviations from ideal symmetry, providing valuable guidance for treatment strategies. Midline discrepancies transcend age and gender, leading to the digital assessment of the facial midline in this study, drawing upon the esthetic frame framework introduced by Bidra et al.⁷, Kurian et al.², and Moshkelgosha et al.¹⁷ The concept of the esthetic frame, introduced in this study, entails a rectangular boundary designed to objectively delineate the facial midline. This frame acts as a region on the human face where critical features such as midlines, tilts, and smile characteristics can be observed and assessed with precision. Numerous authors recommend capturing images with the subject's head positioned naturally. However, it's essential to be mindful before photographing to avoid head rotation, especially in the vertical axis. Importantly, research has demonstrated that subjects with head rotation along the vertical axis often exhibit a notable displacement of the midline, frequently in the opposite direction of the rotation. This observation has been highlighted by various sources in the literature.^{7,9,17,22} Therefore, in the current study, a cephalostat was employed to maintain the patient's head in a precisely defined and stable position throughout the photographic session, aiming to eliminate the potential for human error in detecting rotation. Although cephalostats are mainly utilized in imaging and anthropometric measurements investigations, they offer utility in standardizing clinical light photographs as well. When grids and cephalostats are used on individuals who do not exhibit overt facial asymmetry, consistent and repeatable photos can be obtained from a variety of subjects. This remains true, acknowledging the presence of a certain degree of asymmetry in individuals who do not exhibit apparent craniofacial deformities.²

Photography has served as an additional tool in anthropological concerns, a notion endorsed by Sheldon (1940), who proposed that precise anthropological measurements can be derived from standardized photographs. Tanner and Weiner emphasized a number of advantages provided by photogrammetry over direct measurements in their investigation of this technique. Images provide a definitive record of the subject and enabling the researcher to take as many as measurements needed at their convenience.²³ Besides 2D photographs, some authors contend that the clinical evaluation of anatomical landmarks and midlines is a practical approach for identifying facial and dental midlines as well as quantifying discrepancies.¹ With the rising popularity of digital cameras and computer technology, morphometric measurements have emerged as a simple tool to operate and economically viable way to precisely evaluate changes in soft tissue. The simplicity, non-invasiveness, and efficiency of this procedure make it a valuable approach, especially when images are captured in a consistent environment. While some authors suggest that 3D analysis can be utilized for assessing facial and dental midlines, the current limitations of existing 3D analysis devices, such as their high cost and space requirements, render them impractical for routine clinical use.²² Consequently, from a clinical perspective, understanding the hierarchy or optimal selection of landmarks becomes crucial for clinicians in determining

midlines for individual patients.

The primary goal of this study was to examine and compare the association between facial anatomical landmarks, the facial midline and the intercommissural midline in dentate individuals from the Moradabad population in North India. The selected anatomical landmarks, namely nasion, nose tip, philtrum and dental midline, are commonly used in clinical practice. Conducting this study within the local population aims to provide specific guidelines for midline determination tailored to this population, particularly useful in esthetic rehabilitation. The dental midline was evident when the subjects were positioned in the smiling posture that is typical for aesthetic examination.¹⁷ To improve precision in identifying landmarks, point digitization was utilized, involving the digital marking of each anatomical landmark on the image. The use of designing software for outlining lines and framing the image aimed to reduce inherent human errors in measurements. In this investigation, midline of face was established using the esthetic frame concept outlined by Bidra et al.⁷. The esthetic frame was devised to assess concerns associated with an aesthetically displeasing smile. Throughout the photography session, a cephalostat was utilized to ensure that the patient's head remained in a consistent position, thereby enhancing the accuracy of the study's result. The null hypothesis, asserting that there would be no disparity between the chosen facial anatomical landmarks and the midlines of the face and commissures was ruled out, since a significant variation in the distances of the chosen landmarks from both the facial and commissural midlines showed up in the current study. In this study, Nasion was identified as a specific anatomical landmark when examining the hierarchical arrangement of facial midlines. Studies carried out by Moshkelgosha et al.¹⁷, Farahani et al.⁹ and Mantri et al.²⁴ observed that the nearest anatomical landmark to the midline of the face was the nasion. While it occupies a favorable position in the middle fifth of the face, its relationship with the midline of the face has not been extensively studied.¹¹ However, Kurian et al.² and Bidra et al.⁷ argued that, despite Nasion ranking as the closest landmark to the facial midline, its practicality in determining the midline of the mouth was questionable. They noted that Nasion, while distant from the dental midline may not be easily determined and analyzed, making it a less reliable clinical indicator for assessing each of the midlines. In subjects with no history of orthodontic treatment, the tip of the philtrum was positioned second in the hierarchical order, while the dental midline was ranked third for both the midline of the face and the midline of the commissures. This result highlights the credibility of the tip of the philtrum as a dependable landmark for determining the midlines of the face and mouth. It was supported by the studies conducted by Regmi S et al.²⁵, Moskelgosha et al.¹⁷, Bidra et al.⁷ and Farahani et al.⁹, which revealed that the tip of the philtrum was found 2nd in close proximity with the midline of the face, whereas, Kurian et al.² found that the philtrum was the closest one to the midline of the face with respect to other chosen landmarks.

Regrettably, the study protocol did not incorporate an examination of the axial angulations of the dental midline. Nonetheless, the findings imply the existence of a symmetrical pattern in nature concerning the positioning of the dental midline relative to the face. Study conducted by

Regmi et al.²⁵ found that dental midline was in close proximity with either of the midline i.e., facial midline and commissural midline whereas Singh A et al.¹ stated that dental midline was in close proximity of all the landmarks with respect to facial midline only. According to Moskelgosha et al.¹⁷, dental midline is not considered a reliable anatomical landmark for determining the midline of face. Comparable results have also been documented by Bidra et al.⁷

The second phase of the research aimed to evaluate the closeness and hierarchical arrangement of anatomical landmarks to the commissural midline (center of the mouth). According to the study, the philtrum was positioned at the top of the hierarchy, indicating that it serves as a more dependable indicator for establishing the oral midline. Similar studies conducted by Moshkelgosha et al.¹⁷, Mantri et al.²⁴, John M et al.²⁶, Kurian et al.² and Singh A et al.¹ showed that philtrum was found to be the nearest anatomical landmark of all with respect to the commissural midline. In the hierarchical order for both the midline of the face and commissural midline, the dental midline held the second position, with the nasal tip ranked 3rd. Similar findings were found in studies conducted by Moskelgosha et al.¹⁷, Mantri et al.²⁴, Farahani et al.⁹, John et al.²⁶, Singh A et al.¹, where the dental midline was positioned second in the hierarchical order, closely associated with the commissural midline. Conversely, a study conducted by Bidra et al.⁷ found that the dental midline was the closest landmark in relation to the commissural midline. In the hierarchical order for both the commissural midline and the facial midline, the nasal tip was identified as the 3rd landmark in relation to the other anatomical landmarks. This observation is consistent with findings from studies conducted by Moskelgosha et al.¹⁷, Bidra AS et al.⁷, Farahani et al.⁹ and Singh A et al.¹, where the nasal tip was ranked 3rd in the hierarchy concerning the commissural midline. Nevertheless, it is important to mention that Moskelgosha et al.¹⁷, in their investigation, emphasized that the nasal tip exhibited the most significant deviation concerning the facial midline. As a result, they did not recommend using this landmark for locating either of the midlines. In the current study, nasion was determined to be the farthest among all the landmarks concerning the commissural midline. Comparable findings were also reported in investigations done by Moskelgosha et al.¹⁷, Bidra et al.⁷ and Farahani et al.⁹

The third segment of the study concentrated on investigating the correlation between the facial midline and the midline of the commissures (Cx/F). The outcomes unveiled a noteworthy variance in the association of the commissural midline with the facial midline. Therefore, the conclusions drawn from this research indicate that the commissural midline might not serve as a dependable anatomical reference point for delineating the midline of the face. Similar observations were reported in another study by Mantri et al.²⁴

However, the commissural midline was found to be the closest of all the other landmarks in the studies conducted by Singh A et al.¹, Kurian N et al.², John M et al.²⁶, Bidra et al.⁷, Regmi S et al.²⁵ and Kurian N et al.², suggesting that it can be taken into consideration for establishing the midline of the face.

In this study, the use of Relative Facial Midline Value (RFV) and Relative Commissural Midline Value (RCV) as ratios served as operational tools to assess the relationship between anatomical landmarks and the midline of the face, establishing a hierarchy. The adoption of ratios, as opposed to linear measurements, is a notable advantage of the study. Knowing the hierarchy or the optimal selection of anatomical landmarks for determining the midline in a specific patient is more crucial for clinicians than determining linear deviations in a given population. While the method employed in this study allows for accurate analysis of linear deviations, ratios are preferred because they facilitate easier comparison with results from similar studies in different populations.

The average ratios for specific landmarks varied depending on which midline was being analyzed, which could present a theoretical limitation because ratios alone cannot clarify whether the difference observed is because of the denominator or numerator term. Nevertheless, this discrepancy did not affect how landmarks were ranked in terms of importance. The study, conducted by a single observer using a convenience sampling approach, maintained a distribution approximating normality. Stringently applied exclusion criteria aimed to minimize confounding factors. Even with thorough marking methods, it is difficult to completely eradicate inherent human faults in delineating anatomical landmarks. Challenges were observed in marking nasion soft tissue and nasal tip, particularly due to nasal anatomy, among clinical landmarks, underscoring the necessity for caution in interpreting these findings. While offering fundamental insights into the hierarchical relationship of different facial anatomical landmarks with midlines, the study recognizes the necessity for further research on a larger sample size spanning a broader geographical area to confirm the hierarchy of selected facial landmarks for delineating the midline of the face.

6. Conclusion

Based on the constraints of the study, the following conclusions were drawn:

- 1) A notable distinction was evident in the average ratios of the chosen anatomical landmarks in comparison to the facial midline and commissural midline.
- 2) The ranking of anatomical landmarks closest to facial midline followed this hierarchy: Nasion, Nose tip, Dental Midline and Philtrum.
- 3) The hierarchical order of anatomical landmarks closest to the commissures of the face consisted of Philtrum, Dental midline, Nose tip & nasion.

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