Original Article

Correlation of Skeletal and Dental Midlines in Patients with Bimaxillary Protrusion, The Concept of Medical Physics behind Setting Optimised Treatment Goals: A Digital Radiographic Study

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Abstract

Background: An aesthetic smile needs a balanced dental midline and symmetrical dentition. It is in this context that a discrepancy in the facial and dental midlines is considered to be one of the most common problems for orthodontists to correct. **Aim:** To compare the topographical location of the skeletal (maxillary and mandibular) midlines in comparison with the dental midline in patients with bimaxillary protrusion using digital orthopantomograms. **Patients and Methods:** 150 orthodontic patients aged 11-32 years with Angle's class I molar relation and class I skeletal base with bimaxillary protrusion were included. These participants were examined for their skeletal and dental midlines using digital orthopantomograms and the results obtained were subjected to statistical analysis. **Results:** Only 34 (22.67%) and 31 (20.67%) subjects revealed their skeletal (maxillary) midline and skeletal (mandibular) midline coinciding with the dental midline respectively. Again, only 60 (40.00%) subjects revealed their skeletal (maxillary) midline coinciding with the skeletal (mandibular) midline, while 30 (20.00%) subjects revealed deviation towards right and 60 (40.00%) subjects revealed deviation towards left when their skeletal (maxillary) midline was compared with the skeletal (mandibular) midline making midline shift towards left a more common phenomenon among the subjects included in the present study. **Conclusion:** The results obtained in the present study may play a significant role during orthodontic treatment planning and in correlating pre-to-post-treatment results following orthodontic corrections.

Keywords: Facial Asymmetry, Skeletal Midline, Dental Midline, Bimaxillary Protrusion, Orthopantomogram, Correlational Study

Introduction

Smile plays a major role in an individual. An aesthetic smile requires a balanced dental midline and symmetrical dentition. The dental midline is often taken as the focal point for an aesthetic smile.[1-4] Numerous studies have been conducted focusing on facial and dental midlines, wherein facial and dental midlines have been taken along the midsagittal plane, also known as the median plane, of the maxillary and mandibular arches. A discrepancy between facial midline and dental midline results in an unappealing smile. It is in this context that discrepancy in the facial and dental midlines is considered to be one of the common and persistent problems for orthodontists to correct.[5,6] In this regard, a recent study conducted by Zapata *et al*.,[7] developed the Finishing Analysis of Dental Outcome (FADO) guide to be used as a systematic approach for improving orthodontic treatment results.

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The FADO guide includes four distinct sections covering evaluation of mini-aesthetics (primarily covering evaluation of smile), evaluation of micro-aesthetics, occlusal and radiographic analysis as a tool to guide orthodontic treatment. To utilise the FADO guide, cast models, orthopantomograms, (also known as orthopantomographs) frontal and lateral smile photographs and intraoral frontal photographs are acquired during the pre-treatment analysis of the patient. Likewise, in another similar study conducted by Kürklü Arpacay *et al*.,[8] the authors recommended the usage of a distinct Dental Appearance Perception Scale developed in the form of a reliable and validated tool with potential to screen for the risk of body dysmorphic disorder and enhance treatment satisfaction among the patients.

Similarly, concerns have been raised among the patients regarding the bimaxillary appearance wherein patients with bimaxillary protrusion perceive themselves as being less attractive than those patients who have been treated for the condition.[9] Literature contains a plethora of numerical studies conducted on facial and dental midline deviations where extensive clinical examination was carried-out as well.[10-14] In the present radiographic study, orthopantomograms of the patients were used to compare the skeletal midlines with the dental midline. In a similar context, a study conducted by Jain *et al*.,[15] proposed considering a total of six significant midlines when planning orthodontic treatment: the skeletal midline, facial midline, maxillary and mandibular apical base, and the maxillary and mandibular dental midlines. In a systematic review, the same authors concluded that midline discrepancy is a major aetiological factor behind temporomandibular joint disorders, also recognised as TMDs.[16] A similar hypothesis was proposed in reviews conducted by Bardinet and Duhart[17] and Bardinet *et al*.,[18] in which the authors listed different forms of facial asymmetries- including mandibular lateral deviations, dental asymmetries without skeletal involvement and skeletal asymmetries as major predisposing risk factors for the development of TMDs, while suggesting various orthodontic and orthognathic approaches to resolve the condition. Furthermore, there is no specific consensus regarding the extent to which a deviation in the skeletal and dental midline is functionally and aesthetically acceptable in the patients. The aim of the present study was to compare the topographical location of skeletal (maxillary and mandibular) midlines with the dental midline in patients with bimaxillary protrusion using digital orthopantomograms.

Patients and Methods

This observational study included 150 orthodontic patients, aged 11-32 years with Angle's class I molar relation and a class I skeletal base with bimaxillary protrusion. Inclusion criteria for the study subjects were the presence of an Angle's class I molar relation and a class I skeletal base with bimaxillary protrusion, patients with no history of trauma, no gross facial asymmetries, no clinical signs of developmental disorder and no previous history of any kind of orthodontic or orthognathic intervention. Patients with Angle's class II or III molar relation, a class II or III skeletal base, dental crowding or spacing, missing tooth/teeth or prosthetic replacement were excluded. Participants (75 male, 75 female) were selected, their digital orthopantomograms were retrieved from the departmental. These radiographs were obtained using a standardised technique. The selected orthopantomograms were manually traced on lacquered polyester acetate tracing paper including the maxillary and mandibular central incisors. For the skeletal median plane, a horizontal line was drawn at the midpoint of the bite block and a perpendicular line was drawn from the Anterior Nasal Spine (ANS) to the Antegonion (Ag). The ANS represented the tip of the anterior nasal spine, while the Ag represented the deepest point on the antegonial notch which is the concavity on the lower border of the mandible just anterior to the angle of the mandible. Dental midline was taken from a perpendicular line drawn between the midpoint of the central incisors to the horizontal line for both the maxilla and the mandible (Figures 4 and 5). Each analysis was done by a single evaluator to avoid inter-observer bias, and the values obtained were statistically analysed to examine deviation of the dental midline from the skeletal median plane.

Ethical consideration

The objectives for the study were explained to the participants, and ethical approval was obtained from the Institutional Ethics and Review Board (approval no. SAIMS/IERB/01-96-2022). Written, informed consent was obtained from all the subjects before their inclusion in the study, and written permission was obtained from the institutional authorities to use the data exclusively for research and academic purposes.

Sample size estimation

Precision (Margin of error) =8%
Desired confidence level =95%
Sample size (n)=150

Formula used to calculate sample size:

$$n = \frac{Z^2 pq}{d^2}$$

Where, Z=Standard normal variate value (Z=1.96 at 5% error or, 95% confidence interval)
p=46.67%, q=100-p
d=Margin of error=8%

Statistical analysis used

Data were analyzed using Statistical Package for Social Sciences (SPSS) software, version 19.0 (IBM Corporation, Armonk, NY, USA). The chi-square (X^2) test was used to analyse the data obtained. The X^2 test was used to examine the relationship between two categorical variables.
Statistical significance was set at 0.05 levels, while probability values (p-values) less than 0.05 were considered statistically significant.

Results

Table 1 presents the gender and age distribution of the study subjects wherein an equal number of male and female subjects were included in the present study, while maximum number of subjects were found to be in the age group of 17-24 years (n=77, 51.33%). Again, the mean age of the study subjects included in the present study was calculated as 21.08±5.74 years. Table 2 and Figure 1 present the comparison of the skeletal (maxillary) midline shift in comparison to the dental midline on right and left sides among the study subjects wherein only 34 (22.67%) subjects revealed their skeletal (maxillary) midline coinciding with the dental midline, while 19 (25.33%) male and 27 (36.00%) female subjects revealed their skeletal (maxillary) midline shifted towards right; and 40 (53.33%) male and 30 (40.00%) female subjects revealed their skeletal (maxillary) midline shifted towards left when compared with the dental midline. Likewise, Table 3 and Figure 2 present the comparison of the skeletal (mandibular) midline shift in comparison to the dental midline on right and left sides among the study subjects wherein, again, only 31 (20.67%) subjects revealed their skeletal (mandibular) midline coinciding with the dental midline, while 27 (36.00%) male and 34 (45.33%) female subjects revealed their skeletal mandibular) midline shifted

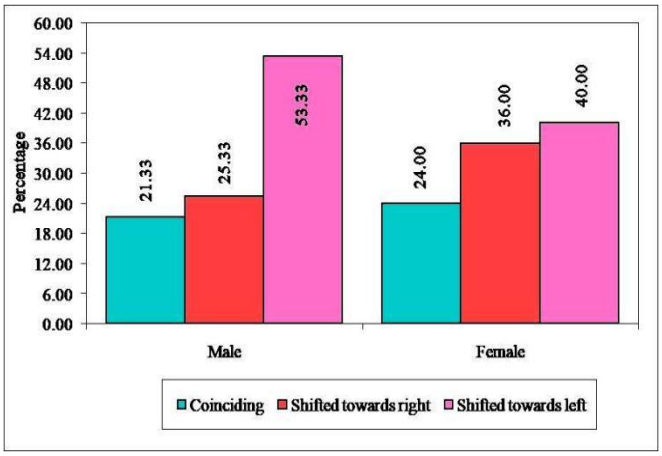


Figure 1: Comparison of skeletal (maxillary) midline shift in comparison to dental midline on right and left sides among the study subjects

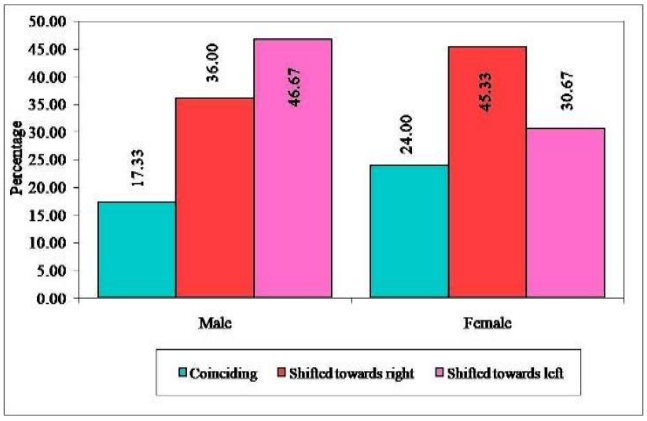


Figure 2: Comparison of skeletal (mandibular) midline shift in comparison to dental midline on right and left sides among the study subjects

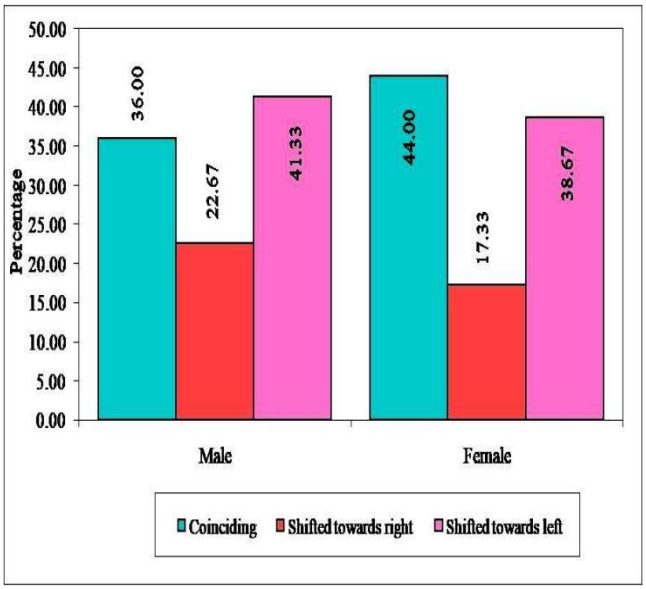


Figure 3: Comparison of skeletal (maxillary) midline shift in comparison to skeletal (mandibular) midline on right and left sides among the study subjects

Table 1: Gender and age distribution of the study sample

Variable(s)	Category	Number (n)	%
Gender	Male	75	50.00
	Female	75	50.00
	Total	150	100.00
Age group	11-16	31	20.67
(in years)	17-24	77	51.33
	25-32	20	13.33
Mean age	21.08±5.74		
(in years)			
	Total	150	100.00

Table 2: Comparison of skeletal (maxillary) midline shift in comparison to dental midline on right and left sides among the study subjects

Gender	n	Coinciding	%	Shifted towards right	%	Shifted towards left	%
Male	75	16	21.33	19	25.33	40	53.33
Female	75	18	24.00	27	36.00	30	40.00
Total	150	34	22.67	46	30.67	70	46.67
Chi-square (X^2) value=2.9375*; p*-value=0.2302							

Table 3: Comparison of skeletal (mandibular) midline shift in comparison to dental midline on right and left sides among the study subjects

Gender	n	Coinciding	%	Shifted towards right	%	Shifted towards left	%
Male	75	13	17.33	27	36.00	35	46.67
Female	75	18	24.00	34	45.33	23	30.67
Total	150	31	20.67	61	40.67	58	38.67
Chi-square (X^2) value=4.0925; *p*-value=0.1292							

Table 4: Comparison of skeletal (maxillary) midline shift in comparison to skeletal (mandibular) midline on right and left sides among the study subjects

Gender	n	Coinciding	%	Shifted towards right	%	Shifted towards left	%
Male	75	27	36.00	17	22.67	31	41.33
Female	75	33	44.00	13	17.33	29	38.67
Total	150	60	40.00	30	20.00	60	40.00
Chi-square (X^2) value=1.2000; *p*-value=0.5488							

towards right while 35 (46.67%) of the male and 23 (30.67%) of the female subjects demonstrated a shift towards the left when compared with the dental midline.

Table 4 and Figure 3 present the comparison of the skeletal (maxillary) midline shift in comparison to the skeletal (mandibular) midline on right and left sides among the study subjects wherein 60 (40.00%) of the subjects revealed their skeletal (maxillary) midline coinciding with the skeletal (mandibular) midline, 30 (20.00%) of the subjects revealed deviation of their skeletal (maxillary) midline towards the right and 60 (40.00%) of the subjects revealed deviation towards the left in comparison with the skeletal (mandibular) midline. On further analysis, deviation of the skeletal (maxillary) midline either towards the right or left when compared to the skeletal (mandibular) midline was found to be more prevalent in the male subjects with 17 (22.67%) of the male subjects revealing deviation of their skeletal (maxillary) midline towards the right and 31 (41.33%) of male subjects revealing deviation of their skeletal (maxillary) midline towards the left when compared to the skeletal (mandibular) midline.

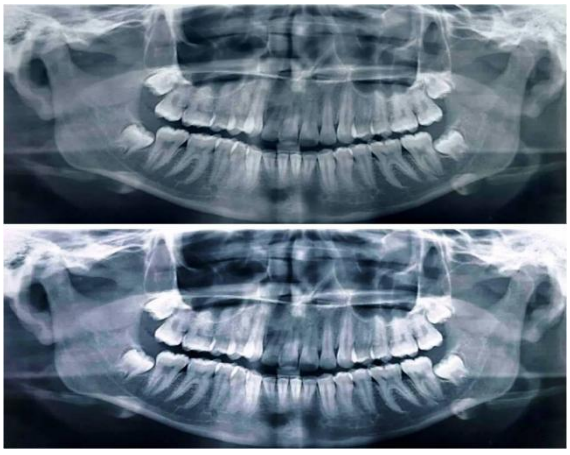


Figure 4: a) Upper- Basic and b) Lower- With enhanced contrast: Digital orthopantomogram revealing dental midline shift in comparison to skeletal midline in a patient

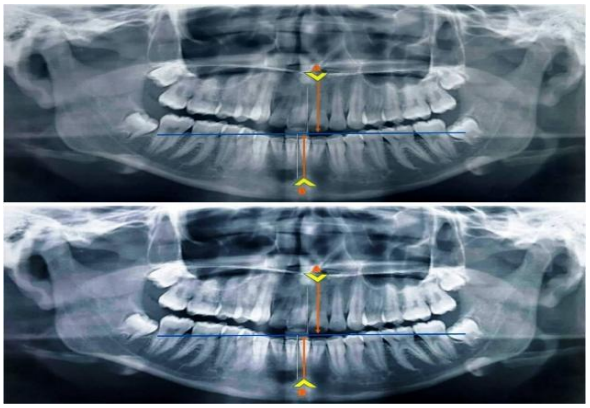


Figure 5: a) Upper- Basic and b) Lower- With enhanced contrast: Digital orthopantomogram revealing dental midline shift in comparison to skeletal midline in the same patient with Point A representing Anterior Nasal Spine (ANS), Point B representing Antegonion (Ag), and with orange line representing skeletal midline, White line representing dental midline and blue line representing the median plane

Discussion

Facial asymmetry is a common phenomenon in human subjects; however, significant facial asymmetry is a cause for concern due to both functional and aesthetic sequelae.[19-21] Furthermore, the aetiology of facial asymmetry ranges from congenital disorders to acquired diseases, as well as traumatic and developmental causes and deformities.[19-21] The assessment of facial asymmetry essentially consists of three important parameters; a careful and meticulous patient history, thorough physical examination and medical imaging. In this regard, medical imaging including recent three-dimensional (3-D) innovations using ionising and non-ionising radiation, such as cone-beam computed tomography (cone beam CT) analysis, 3-D landmark-based analysis, stereophotogrammetry and mirror-original alignment analysis are helpful not only in establishing an objective diagnosis based on precise measurement of facial asymmetry but also in setting optimised treatment goals during the treatment planning stages.[22-27] These discrepancies in the facial symmetry, play a quintessential role in the aesthetic assessment of an individual having long-term physical, mental and psychological impacts.[28-30] Accurate assessment and quantification of facial asymmetry, therefore, remain the most significant aspects of establishing an accurate diagnosis, planning treatment and evaluating post-surgical changes. [31-33] By integrating various technological advancements, treatment goals can be tailored to each individual patient to enhance precision and applicability in clinical practice, as well as to achieve predictable treatment outcomes at macro-aesthetic, mini-aesthetic and micro-aesthetic levels by orthodontists, prosthodontists, restorative specialists and oral and maxillofacial surgeons.[34-36]

The present study aimed to evaluate the coincidence or, deviation of the skeletal (maxillary and mandibular) midlines in comparison with the dental midline in patients with bimaxillary protrusion using digital orthopantomograms. The findings indicate that only 22.67% and 20.67% of the participants revealed their skeletal (maxillary) and skeletal (mandibular) midlines coinciding with the dental midline respectively. Furthermore, 40.00% of participants revealed their skeletal (maxillary) midline coinciding with the skeletal (mandibular) midline, while 20.00% exhibited a deviation towards the right and 40.00% towards the left when the skeletal (maxillary) midline was compared with the skeletal (mandibular) midline. These results indicate that a midline shift towards the left is a more common phenomenon among the study cohort. Similar conclusions were drawn in the study conducted by Beyer and Lindauer[10] which estimated the mean threshold for an acceptable deviation of dental midline to be 2.2±1.5 mm.

The authors observed significant differences in the deviation threshold for each individual patient ($p<0.05$) with the orthodontists and general dentists being less tolerant of midline deviations than the patients themselves ($p<0.001$). Likewise, both the orthodontists and laypeople easily recognised facial midline discrepancies and perceived the concerned patients as less attractive as the size of the dental-to-facial midline discrepancy increased in a study conducted by Johnston *et al*.[11] It was also observed that the probability of a layperson recording a less favorable attractiveness score with a discrepancy of 2 mm or greater was as high as 56% in the aforementioned study.

Similarly, Cardash *et al*.,[12] stated that midline deviations of less than 2 mm were generally unnoticeable by the clinicians and patients, although, the detection rate increased significantly with larger discrepancies in the studied cohort. In a study conducted by Janson *et al*.,[13] to evaluate the impact of orthodontic treatment, specifically midline position, buccal corridor and smile arc on patient aesthetics, the authors concluded that well-planned orthodontic treatments wherein extractions were indicated for orthodontic reasons; additionally, dental midline deviations of up to 2.2 mm were found acceptable by both orthodontists and laypeople. Furthermore, the authors, concluded, based on the observations made in their study, that axial midline angulation of up to 10°, as well as the sizes of the buccal corridor and smile arc, did not appear to have a significant impact on perceived aesthetics in the studied cohort. In another similar study conducted by Silva *et al*.,[37] to evaluate layperson perception of facial and dental asymmetries, the authors concluded that the visual perception thresholds for a symmetrical face model (SFM) were in the order of a maximum of 2 mm for dental midline shifts, 4 mm for nasal deviation, 5° for dental midline Cant and 3° for the frontal incisal plane Cant. Again, chin deviations of less than 6 mm were, in general, not perceived by the studied cohort.

In another similar study conducted by the same authors using a new asymmetrical face model (AFM), a dental midline shift of up to 1 mm to the left was found to have no significant impact, while a shift to the right had a negative impact on the perception of facial attractiveness. This led the authors to conclude that not only do facial asymmetries, such as the nose and chin deviations, have a significant impact on the perception of dental midline shift, but the direction of this shift is also a major factor in the perception of aesthetics in the sample studied.[38] In two other notable studies conducted by the same authors, they highlighted the significance of axial midline angulation and the transverse occlusal plane using the asymmetrical face model (AFM), stating that even a minor axial dental midline angulation of 3.5° with an occlusal plane cant of 2° were easily perceived by the patients irrespective of the direction of the cant. However, it was found more favourable for axial midline angulation to point in the same direction as nose and chin deviations to make it less perceivable, although, the direction of nose and chin deviations were observed to be irrelevant in determining the occlusal plane Cant. The authors, therefore, concluded that dental midline should be as vertically straight as possible, while the occlusal plane should be as parallel as possible to the interpupillary line in the presence of an asymmetric face.[39,40]

Contradictory findings were obtained in another study conducted by Ferreira *et al*.[41] wherein the authors concluded that dental midline shift of up to 1 mm were generally noticeable, and had a significant negative impact on the perception of aesthetics by the laypeople included in their study. In contrast, strikingly higher threshold values for dental midline deviation (2.92±1.10 mm) were observed in the study conducted by Williams *et al*.,[42] the authors also concluded that facial type and gender of the included cohort had a significant impact on the threshold values deemed acceptable.

The findings of the present study, which indicated that 22.67% and 20.67% of the participants skeletal (maxillary) and skeletal (mandibular) midlines coincided with the dental midline, respectively are in agreement with the findings of the study conducted by Khan and Kazmi.[43] However, in a sample of Pakistani population, the authors observed significantly higher values of up to 47.9% and 46.1% respectively for the facial midline coinciding with the maxillary and mandibular midlines. Furthermore, the findings of the present study, which indicated that only 40.00% of the participants revealed their skeletal (maxillary) midline coinciding with the skeletal (mandibular) midline with 20.00% of the participants revealing a deviation towards the right and 40.00% towards the left when their skeletal (maxillary) midline was compared with skeletal (mandibular) midline. Observing midline shift towards the left is a more common phenomenon among the study cohort, and are also in agreement with the results obtained in the study conducted by Khan and Kazmi,[43] wherein the authors observed that maxilla-mandible midlines coincided in 64.1% of the sample studied, while a deviation towards the left was found to be a more common observation than a shift towards right.

Likewise, similar observations were made in a study conducted by Salman *et al*.,[44] evaluating dental midline shift among 7-15 years old children in Babylon/Iraq. A midline shift was observed in 55.66% of the studied sample; this was found to be more common among the females (31.3%) and subjects over 12 years in age (20%) and in the mandible than maxilla. Furthermore, subjects with Angle's class I malocclusion were found to reveal a significantly higher prevalence of dental midline shift (34%) compared to those with either Angle's class II (13%) or Angle's class III (9%) malocclusion (p=0.028).

Another remarkable observation made in the mentioned study was that 63.47% of the studied sample had a midline shift of 2 mm or more which was considered aesthetically unacceptable. In another study conducted by Mahdi *et al*.,[45] using a sample of young Iraqi adults, drew similar conclusions observing dental midline shift in almost 26% of the sample which was in close accordance with the findings of the present study. This was found to be more common among the female subjects (60.5%) and in the mandible than the maxilla and in subjects with Angle's class I malocclusion than in those with either Angle's class II or Angle's class III malocclusion, supporting the findings of Salman *et al*.[44] Similarly, Chahuara-Ramírez *et al*.,[46] also evaluated the coincidence of facial and maxillary dental midlines in a sample of Peruvian population and observed that an ideal and perfect coincidence of the facial and maxillary dental midlines was present in only 23.3% of the subjects, in agreement with the findings of the present study; conversely, an acceptable shift of up to 2 mm was observed in 95.7% of individuals. Likewise, a dental midline shift of up to 2 mm was considered acceptable for the female models, while up to 3 mm was acceptable for male models in the study conducted by Sayahpour *et al*.,[47] dental midline shift of up to 3 mm were also found to be acceptable in a study by Hodali and Massad.[48]

In line with the recent concept of facial flow line (FFL), which states that minor dental midline shifts in the direction of FFL can mask compromised aesthetics in an individual, Tahir *et al*.,[49] evaluated the range of dental midline deviation in terms of the FFL and observed that a range of up to 2-4 mm of midline deviations towards FFL can be well-tolerated by the subjects, though, deviations of higher order certainly needed intervention to optimise aesthetics. Similarly, maxillary dental midline shifts of up to 2 mm were considered acceptable by the orthodontists, general dentists, and in most cases, by the aesthetically trained, plastic and reconstructive surgeons, while this threshold of acceptability increased to 4 mm for laypersons in the study conducted by Kuruhan *et al*.[50] The authors further stated that mandibular asymmetries were considered to be aesthetically more acceptable than maxillary asymmetries, and deviations in the same direction was observed to be aesthetically more acceptable than deviations in the opposite direction. In accordance with the aforementioned studies, midline deviations of up to 3 mm were not only found to be aesthetically more

acceptable, but surprisingly, more attractive than ideal. However, intervention was strongly recommended for deviations exceeding 4 mm. Consequently, Korkut *et al*.,[51] concluded that generating symmetrical crown-width proportions of anterior teeth was more significant for achieving high aesthetics than midline discrepancies. Nevertheless, based on the findings of numerous studies, it can be concluded that midline discrepancies are a common phenomenon, though an exaggerated difference in midline positioning in the patients may pose a significant challenge.[52-54] It is in this pretext that the components of soft tissues as well as skeletal and dental hard tissues contributing towards facial asymmetry call for a thorough evaluation, both anatomically (static) and functionally (dynamic)-during the treatment planning stages to understand the subtleties of the interaction of each with corresponding facial elements and how well they can be managed through a unified multidisciplinary approach.[55-59] In this context, additional surgical procedures may be often be required to adjust the volume of hard or soft tissue components to achieve better symmetry and harmony with the rest of the face for the desired aesthetics.[60-72]

Limitations

One major limitation of the present study is the relatively small sample size; a larger sample would have helped in validate the findings and identify true patterns within the population. Furthermore, the study used digital orthopantomograms to compare the topographical location of skeletal (maxillary and mandibular) midlines with the dental midline in patients with bimaxillary protrusion. Using more advanced, imaging modalities such as cone-beam computed tomography (CBCT), would have provided a three-dimensional (3-D), distortion-free view of the craniofacial structures, allowing a more exact, quantitative evaluation of the skeletal and dental midline structures in all three planes thereby increasing precision.

Conclusion

The findings showed that only 22.67% and 20.67% of the subjects revealed their skeletal (maxillary) and skeletal (mandibular) midlines respectively coinciding with the dental midline. Also, only 40.00% of the subjects revealed their skeletal (maxillary) midline coinciding with the skeletal (mandibular) midline, 20.00% of subjects revealed a deviation towards the right and 40.00% of subjects revealed deviation towards the left when their skeletal (maxillary) midline was compared with the skeletal (mandibular) midline making leftward midline shift a more common phenomenon among the studied subjects. The results of the present study may play a significant role during orthodontic treatment planning and in correlating pre-to-post-treatment results obtained with orthodontic corrections. Multicentric studies involving larger sample sizes and adequate representation of populations from different geographic locations, races and ethnicities may help in optimising orthodontic treatment goals and the establishment of standards devised for specific populations in the future.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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