Original Article

Dynamic smile evaluation in different skeletal patterns

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ABSTRACT

Objective: To evaluate dynamic smile in different skeletal patterns and to correlate vertical smile parameters with the underlying causative factors.

Materials and Methods: A total of 150 participants ranging in age from 16–25 years were selected and divided into one of three groups—horizontal, average, and vertical skeletal pattern—using the following three cephalometric parameters: SN-MP, FMA, and Jarabak ratio. Videographic records of smile were obtained, and measurements were recorded and analyzed at rest, including upper lip length, and during smile, including maxillary incisal display, interlabial gap, intercommisural width, change in upper lip length, and smile arc. Differences among the three groups were subjected to two-way analysis of variance and *post hoc* and chi-square tests for smile arc. Correlations between vertical smile variables and vertical skeletal (N-ANS, N-Me) and dental cephalometric measurements (U1 to palatal plane) were also investigated.

Results: Vertical parameters were significantly increased in the vertical pattern when compared with the horizontal pattern, ie, upper lip length ($P < .01$), maxillary incisal display ($P < .001$), interlabial gap ($P < .001$), and change in upper lip length ($P < .001$), whereas intercommisural width was significantly decreased in vertical pattern when compared with the horizontal pattern ($P < .001$). Flat smile arc was seen more frequently in the horizontal pattern. Positive correlations were found between the N-Me, U1-PP, and change in upper lip length with vertical smile parameters.

Conclusions: Different skeletal patterns exhibit their characteristic smile features. Upper lip length is not responsible for increased incisal display during smile. Increased incisal display during smile is more closely associated with upper lip elevation than vertical skeletal and dental factors. (*Angle Orthod.* 2016;86:1019–1025)

KEY WORDS: Dynamic smile; Skeletal pattern; Vertical dimension

INTRODUCTION

Facial esthetics has been an objective of orthodontic treatment planning since the beginning of this specialty. For decades, the period of cephalometric dominance continued in which esthetics was defined primarily in terms of the profile as measured on a lateral cephalogram, and clinical examination was secondary. By the end of the 20th century, the soft tissue paradigm continued to expand and resulted in a paradigm shift in the field of orthodontics, placing greater emphasis on the clinical examination of soft tissue function and esthetics.[1]

Physical attractiveness is an important social issue in our culture, and the face is one of its key features. An attractive smile in modern society is often considered an asset in interviews, work settings, social interactions, and even the quest to attract a mate.[2] Improvement in facial esthetics is also a powerful motivation for seeking treatment[3]; therefore, orthodontic treatment should carefully consider a patient's facial appearance and particularly his or her smile.

Smile characteristics are determined by the interplay of static and dynamic relationships between the dentoskeletal and soft tissue components of the face.

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A perusal of the literature reveals that various vertical skeletal patterns present with their characteristic dentoskeletal and soft tissue features, but this is only the static aspect. No study has inquired about the dynamic aspect of the hard and soft tissue relationship, and whether different vertical facial patterns present with characteristic patterns of the smile. A few studies reported that smile characteristics change with changed vertical skeletal dimensions.[4–7] Peck et al.[4] observed that increased vertical maxillary height is a factor in causing gingival display. The present study was conducted to investigate whether smile characteristics differ in different skeletal patterns and to inquire about the contributing factors that govern the vertical smile parameters. The information thus obtained will help in directing the treatment toward the main contributing factors.

MATERIALS AND METHODS

This study was conducted with 150 participants selected among students, residents, and patients visiting the Department of Orthodontics. The participant selection criteria are described in Table 1. The study was approved by the Institutional Ethical Committee, and informed consent was obtained from all participants.

Standardized lateral head cephalograms were taken first to categorize the participants into different skeletal patterns using three cephalometric parameters: SN-MP, FMA, and Jarabak ratio (Table 2, Figure 1). This sample selection was in accordance with Bishara and Augspurger[8] and Zaher et al.,[9] who stated that a single cephalometric parameter is not sufficient to accurately identify a given facial type. Therefore, the division of participants into the groups was done on the basis of satisfying at least two of the three previously mentioned parameters. The groups were further divided into two subgroups according to sex, that is, males and females (Table 2) to study smiles separately in males and females.

Table 1. Participant Selection Criteria

Inclusion Criteria	Exclusion Criteria
North Indian participants aged between 16–25 years	Gross facial asymmetry
Participants with well-aligned arches	Visible periodontal disease, caries, excessive dental attrition
Overjet of 1–5 mm	History of trauma to the dentofacial region
No previous orthodontic treatment	Any missing or supernumerary teeth visible on smiling or prosthodontic or restorative work on any teeth visible on smiling
	Lip irregularities or history of lip surgery

Table 2. Distribution of Participants According to Facial Pattern and Sex (N = 150).

Facial Pattern and Sex	Horizontal Skeletal Pattern (n = 60)	Average Skeletal Pattern (n = 50)	Vertical Skeletal Pattern (n = 40)
SN-MP	<31°	31°–34°	>34°
FMA	<22°	22°–28°	>28°
Jarabak ratio[a]	>63%	59%–63%	<59%
Male	30	25	20
Female	30	25	20

[a] Jarabak ratio = S-Go_c/N-Me × 100 (Go_c, constructed gonion).

The videographic equipment and method for recording dynamic smiles were based on the guidelines established in previous studies.[10,11] The digital camcorder (Nikon D7100 DSLR camera with 18–105 mm lens; Nikon, Tokyo, Japan) was stabilized on a tripod stand and placed at the same distance of 3 feet from the participant (this ensured equal magnification for all participants). Two rulers with millimeter markings secured at right angles to each other on a stand were

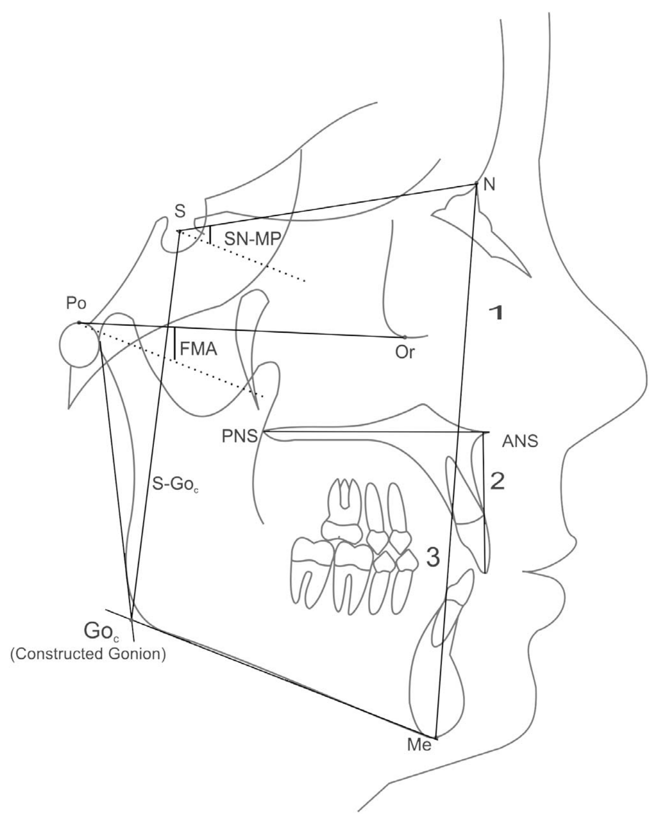

Figure 1. Parameters used to classify facial patterns, ie, SN-MP, FMA, and the Jarabak ratio (S-Goc/N-Me × 100; where Goc is the constructed gonion and N-Me is the vertical skeletal height of the face) in the following cephalometric variables used in the study: (1) vertical height of anterior maxilla, (2) U1 to palatal plane, (3) vertical skeletal height of face.

kept alongside the face of the participant, allowing direct measurement at life size. The natural head position was clinically achieved by asking each participant to look eye level into a mirror hung on the wall in front of the participant. The camera lens was adjusted at the level of apparent occlusal plane. The relaxed lip position was achieved by asking the participant to lick the lips and then swallow. The participants were then instructed to say ‘‘Subject number___my name is___cheese’’ followed by a smile. Recording began 1 second before the participant started speaking and ended after the smile. All video clips were taken by the first author.

The digital video clips were imported into commercially available video editing software (Adobe Premiere Pro CC version 7.0.0; Adobe Systems Inc., San Jose, Calif), which provided individual frames that could be viewed (30 images per second). Each frame was then analyzed, and two frames were selected for each participant and saved in JPEG file format: the first frame represented each participant's lip at rest, and the second frame represented each participant's widest posed smile. The chosen frames of each participant were imported into Adobe Photoshop (Adobe Premiere Pro CC version 7.0.0) and cropped, leaving only a rectangular proportionate area of 6 $\times$ 4 inches that contained the perioral region, and scale and measurements were taken. For linear measurements in each photograph, the measurement scale was preset as follows and customized:

- Choose Image > Analysis > Set Measurement Scale > Custom (the ruler tool is automatically selected while setting the measurement scale).
- Drag the tool to draw a 10-mm line on the metallic scale visible in the photo and enter the logical length as 10 and logical units as millimeters (Figure 2).
- Click OK in the Measurement Scale dialog box to set the measurement scale on the document.
- Now the ruler tool is customized and will give real life-size measurements between any two selected points in millimeters.

Measurements were taken by drawing a line with the ruler tool, and measurements were recorded from the Measurement Log panel that appeared in the window. One measurement of upper lip length (ULL) was taken on each rest position photograph, and the following four measurements were taken on each smiling photograph: maxillary incisal display (MID), interlabial gap (ILG), change in upper lip length (ΔULL), outer intercomissural width (ICW; Table 3, Figure 3a,b). Smile arc was recorded as the one qualitative parameter, smile arc was also recorded (Table 3).

The following three cephalometric measurements were also noted: vertical height of anterior maxilla (N-ANS), vertical skeletal facial height (N-Me), and vertical dental height of the maxilla, (U1-PP; Table 3, Figure 1).

Statistics

Data were summarized as mean (standard deviation). Groups were compared by two-factor analysis of variance, and the significance of mean difference within (intra) and between (inter) groups was done by Tukey's *post hoc* test after ascertaining normality by the Shapiro-Wilk test and homogeneity of variance between groups by the Levene test. Categorical groups were compared by chi-square test. Correlations between the vertical smile variables and N-ANS, N-Me, U1 to PP, and ΔULL were also calculated. A two-tailed P value less than .05 ($P < .05$) was considered statistically significant. All analyses were performed on SPSS software (Windows version 17.0; SPSS Inc., Chicago, Ill).

RESULTS

Intraexaminer reliability coefficients ranged from 0.965 to 0.983. In terms of root mean square values, the random errors of estimation were less than 0.42 mm. No variables were significantly different between the test and retest measurements.

Comparisons between males and females are summarized in Table 4. Significant sexual dimorphism was observed in ULL, with males having longer lips than females.

Comparisons between the three groups within each gender revealed an increasing trend of values from horizontal to average to vertical pattern (Table 5). *Post hoc* tests reveal significantly higher values in the vertical pattern when compared with the horizontal pattern for vertical smile parameters, that is, ULL ($P <$ .01), MID ($P < .001$), ILG ($P < .001$), and ΔULL ($P <$ .001). The transverse smile measurement, that is, ICW, was significantly decreased in the vertical pattern when compared with the horizontal pattern ($P < .001$).

Pearson correlation analysis (Table 6) reveals a weak positive correlation between vertical skeletal parameters N-Me and U1 to PP and the vertical parameters of smile. Correlation coefficients are given in Table 6. ULL was also positively correlated ($r = 0.3$) with N-ANS, whereas other smile parameters were not correlated with N-ANS. ΔULL was positively correlated with ULL, MID, and ILG, with moderate strength of association with MID ($r = 0.59$).

A significant difference was found in the frequency distribution of smile arc among the three groups in both genders (Table 7). In the horizontal pattern, the flat smile arc was the most frequent observation (males 66.7%, females 60%).

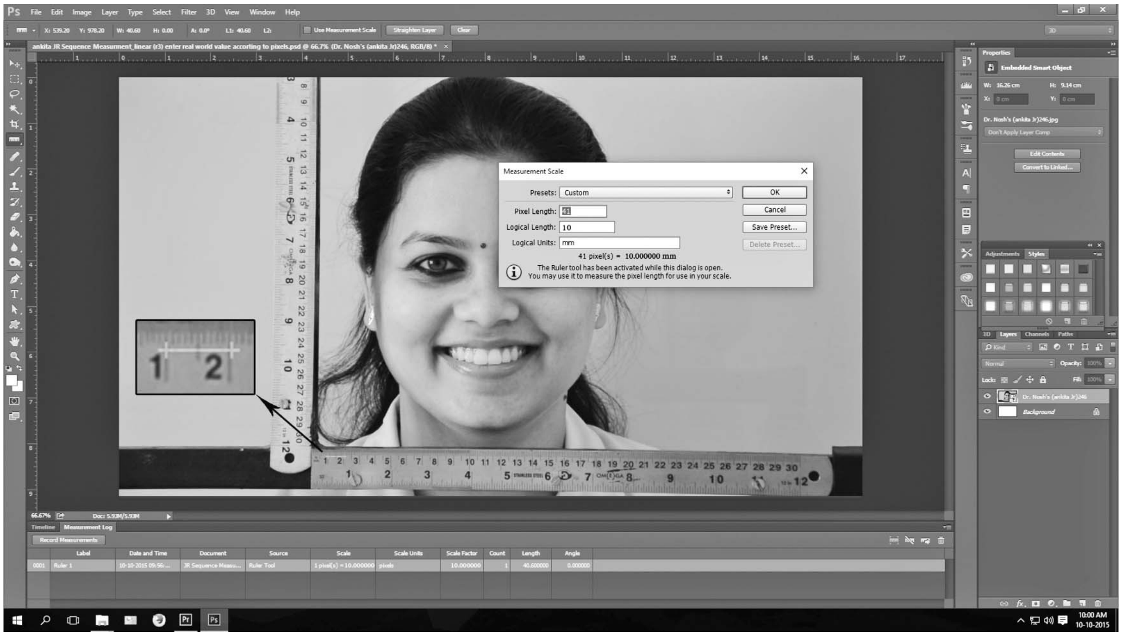

Figure 2. Analysis of smile using Adobe software (Adobe Systems Inc., San Jose, Calif).

DISCUSSION

Smile is a representation of the dynamic relationship of perioral soft tissue with underlying skeletal and dental components. Many studies have reported age-related variations[14,15] as well as sexual dimorphism[16] in smile characteristics. To eliminate the effect of these factors, we evaluated the smile dynamics of individuals aged 16–25 years and separately as males and females. An unequal sample size was accepted because of the decreased prevalence of vertical skeletal patterns.

All of the vertical smile parameters (ie, MID, ILG, ΔULL) were significantly higher in the vertical pattern when compared with the horizontal pattern. The transverse smile measurement, (ie, ICW) showed the opposite trend. ICW was significantly higher in the horizontal pattern when compared with the vertical pattern. Therefore, it can be speculated that smile dynamics also vary according to the skeletal pattern of the face, with a vertical pattern having an increased vertical dimension of smile, incisal display, and ILG and a decreased transverse smile dimension, and vice versa with the horizontal pattern. Similar observations were made by Grover et al.[5] In the present study, it was also revealed that the vertical pattern exhibits significantly higher upper lip elevation during smile.

It is already well established that different skeletal patterns have characteristic dentoskeletal features, and the results of the present study reveal that different skeletal patterns present with different patterns of smile as well.

The second aspect of this study dealt with the search for the associated factors contributing to the differing patterns of smile. Upper lip length at rest (ULL) was highest in the vertical pattern and least in the horizontal pattern. Significant differences in ULL were found between the vertical and the horizontal patterns. In the present study, ULL was found to be positively correlated

Table 3. Measurements Used in the Study

Measurements on rest position photograph (Figure 3a)
1. Upper lip length at rest (ULL)[12]: distance measured between subnasale and stomion superius

Measurements on smile photograph (Figure 3b)
1. Maxillary incisal display (MID)[12]: distance measured from stomion superius to maxillary incisor edge
2. Interlabial gap (ILG)[12]: distance measured from stomion superius to stomion inferius
3. Outer intercommissural width (ICW)[12]: distance measured between right and left outer commisures
4. Change in upper lip length from rest to smile (ΔULL)[12]: difference in upper lip length during rest and during smile taken as percentage ratio of upper lip length at rest. It represents the lip elevation during smile.
5. Smile arc[13]:
   a. Flat (maxillary incisal edges, canine and premolar cusp tips had no curvature relative the lower lip line)
   b. Parallel (maxillary incisal edges, canine and premolar cusp tips, from mesial to distal, followed the curvature of the lower lip)
   c. Reverse (incisal edges, canine and premolar cusp tips had a reverse curve relative the lower lip line).

Cephalometric measurements (Figure 1)
1. N-ANS: skeletal height of anterior maxilla
2. N-Me: vertical skeletal height of face
3. U1 to palatal plane (U1-PP): perpendicular distance from maxillary incisal edge to palatal plane

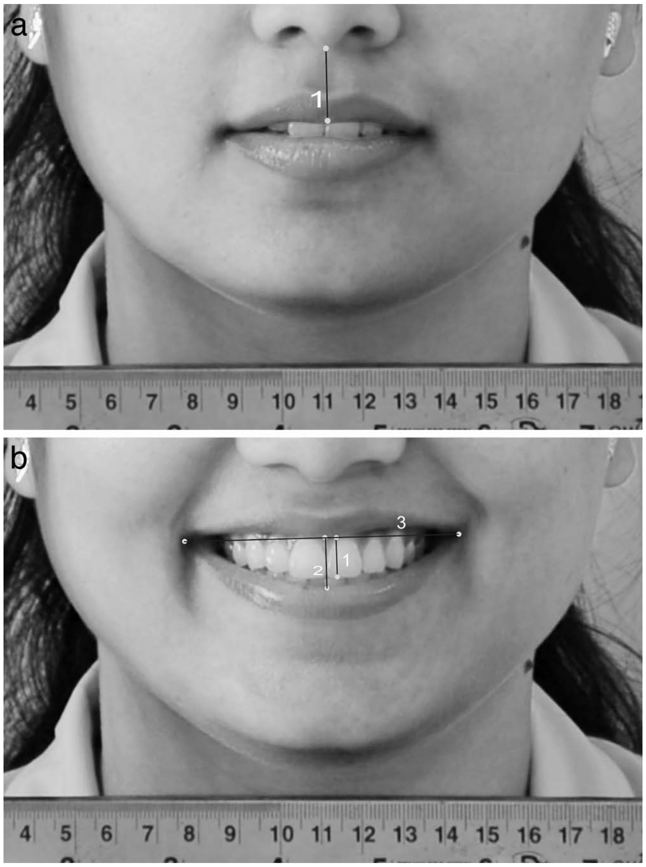

Figure 3. (a) Measurement taken at rest: upper lip length at rest. (b) Measurements taken at smile photograph: (1) maxillary incisal display, (2) interlabial gap, (3) outer intercommissural width.

with vertical skeletal and dental height. The results of our study were comparable with the findings of Blanchette et al.[17], Lai et al.[18], and Feres et al.,[19] who reported in their cephalometric studies that dolichofacial individuals have longer lips, whereas brachyfacials have shorter lips. They stated that in dolichofacial individuals, soft tissue follows the underlying skeletal development and tries to compensate for lip seal difficulties because these individuals are more prone than others to develop lip incompetence. ULL is one of the important factors that determine the amount of maxillary incisor and gingival exposure during speech and smiling.[20,21] Short ULL has been considered a suspect in producing gingival smile line, and controversial data exist in the literature regarding this. Although Peck et al.[4] found no difference in ULL between the gingival smile group and reference groups, Miron et al.[22] observed short ULL in participants with a high smile line. In the present study, it was revealed that ULL at rest was not responsible for increased incisal exposure during smile.

Maxillary incisor display during smile is affected by hard tissue factors, such as vertical maxillary height and dental height, and soft tissue factors, such as lip

Table 4. Means and Standard Deviations (SD) of Variables and Comparisons of Means Between Males and Females (*P* Value) Within the Three Groups by Tukey's *Post Hoc* Test

Measurement[a]	Group	Male, Mean (SD)	Female, Mean (SD)	*P* Value
ULL	Horizontal	21.10 (2.35)	18.26 (1.95)	<.001***
	Average	22.00 (2.00)	19.27 (2.25)	<.001***
	Vertical	23.36 (2.23)	20.44 (1.96)	<.001***
MID	Horizontal	7.93 (1.98)	8.01 (1.62)	.87
	Average	9.32 (1.51)	9.49 (1.11)	.999
	Vertical	11.45 (1.90)	11.03 (1.48)	.966
ILG	Horizontal	9.67 (2.22)	9.96 (1.99)	.992
	Average	11.76 (2.24)	10.74 (1.76)	.454
	Vertical	14.15 (1.49)	12.81 (1.89)	.263
ΔULL	Horizontal	22.21 (6.01)	24.26 (7.08)	.912
	Average	34.74 (9.46)	29.30 (8.71)	.135
	Vertical	42.31 (6.56)	42.51 (8.83)	1
ICW	Horizontal	60.12 (3.53)	59.63 (4.86)	.997
	Average	58.43 (3.66)	56.38 (3.99)	.444
	Vertical	55.14 (3.96)	51.10 (3.25)	.015*

[a] ULL, upper lip length; MID, maxillary incisal display; ILG, interlabial gap; ΔULL, change in upper lip length; ICW, outer intercomissural width.

* $P < .05$, just significant; *** $P < .001$, highly significant.

length and lip elevation.[22] In the present study, ULL at rest was recorded to be more evident in individuals with a vertical skeletal pattern than in the short or average face groups. A weak positive correlation was found between MID during smile and N-Me and U1 to PP, whereas a moderate positive correlation was found with ΔULL. Therefore, it can be implied that increased incisal display during smile is a result of a combination of increased skeletal as well as increased maxillary dental height but more closely associated with the increased elevation of the upper lip in individuals with a vertical skeletal pattern, and vice versa for individuals with a horizontal skeletal pattern. However, McNamara et al.[7] reported that the vertical display on smile of the maxillary right central incisor could not be correlated with the skeletal vertical dimension, as measured from N-Me and ANS-Me.

The ILG on smiling is one of the determinants that affects the smile index,[23] and it depicts the vertical limit of the smile zone. A positive correlation was observed with N-Me, U1 to PP, and ΔULL, so it was inferred that the ILG is governed by contributions from both skeletal and dental height as well as soft tissue factors, such as ULL elevation.

Change in ULL (%) was maximal for the vertical pattern followed by average and minimum for the horizontal pattern. Change in ULL is primarily a function of activity of upper lip musculature. It appears that individuals with a vertical skeletal pattern have more muscular capacity to raise the upper lip than do individuals with horizontal or average patterns. A positive correlation was found between ULL at rest

Table 5. Comparisons Between the Three Groups Within Males and Females (*P* Value) by Tukey's *Post Hoc* Test

	Comparison *P* Value		
Measurement[a]	Horizontal Pattern vs Average Pattern	Horizontal Pattern vs Vertical Pattern	Average Pattern vs Vertical Pattern
ULL			
Male	.389	.003**	.471
Female	.493	.005**	.450
MID			
Male	.001**	<.001***	<.001***
Female	.010*	<.001***	.021*
ILG			
Male	.001**	<.001***	.001**
Female	.692	<.001***	.007**
ΔULL			
Male	<.001***	<.001***	.015*
Female	.161	<.001***	<.001***
ICW			
Male	.371	<.001***	.096
Female	.896	<.001***	.016*

[a] ULL, upper lip length; MID, maxillary incisal display; ILG, interlabial gap; ΔULL, change in upper lip length; ICW, outer intercomissural width; ns, not significant.

** $P < .01$, moderately significant; *** $P < .001$, highly significant.

Table 7. Frequency Distribution of the Smile Arc

Smile Arc	Horizontal Pattern, % (n = 30)	Average Pattern, % (n = 25)	Vertical Pattern, % (n = 20)	χ^2 Value	*P* Value
Males					
Flat	66.7	48.0	20.0	14.96	.005**
Parallel	33.3	44.0	80.0		
Reverse	0.0	8.0	0.0		
Females					
Flat	60.0	28.0	30.0	11.82	.019*
Parallel	33.3	72.0	70.0		
Reverse	6.7	0.0	0.0		

* $P < .05$, just significant; ** $P < .01$, moderately significant.

and ΔULL, which implies that the longer the upper lip, the more it elevates during smile. The same observation was also made by Miron et al.,[22] who found a positive correlation between the lip length and lip elevation.

Determination of the smile arc is highly dependent on the head posture as the head moves and the conversational distance.[13] Every effort was made to keep each participant's apparent occlusal plane parallel with the camera. A statistically significant difference was found between the frequency distribution of the smile arc of the three groups in both males and females. A flat smile arc was more frequently observed in the horizontal pattern with males (66.7%) and females (60%; Table 7). Previous studies have reported flat smile arcs as less acceptable or having lower esthetic scores when compared with consonant smile arcs.[24,25] In the present study, the observed high frequency of flat smile arcs in the horizontal skeletal pattern group may be attributed to inherent brachyfacial growth patterns that may lead to flat smile arcs. Patients with this skeletal pattern might theoretically have a tendency for the anterior maxilla to lack the clockwise tilt needed for an ideal smile arc.[25] Ackerman and Ackerman[26] stated that two factors that contribute to the appearance of the smile arc are the archform and sagittal cant of the maxillary occlusal plane. An individual's archform and particularly the configuration of the anterior segment will greatly influence the degree of curvature of the smile arc. The broader the archform, the less the curvature will be of the anterior segment and the greater the likelihood of a flat smile arc, which may explain the greater frequency of flat smile arcs seen in our study. Increasing the cant of the maxillary occlusal plane to Frankfort horizontal in the natural head position will increase the maxillary anterior tooth display and improve the consonance of the smile arc. Studies have reported a greater frequency of smile arc flattening in orthodontically treated patients.[23] Therefore, the treatment plans for different facial types should be different, with special precautions taken during incisor intrusion in the horizontal skeletal pattern because these patients are prone to smile arc flattening. Adequate measures should be employed for creating parallel smile arcs, such as careful planning of incisor intrusion, individualized bracket positioning, and controlling the cant of the occlusal plane by the appropriate use of extraoral forces.

Table 6. Correlations Between the Vertical Smile Variables and the Cephalometric Variables

		Correlation Coefficient (*r*)			
Measurement[a]	Mean (SD)	ULL	MID	ILG	ΔULL
N-ANS	53.4 mm (3.40)	0.301244	0.076243	0.121277	0.098292
N-Me	119.59 mm (6.06)	0.403499	0.290157	0.316439	0.226048
U1-PP	27.64 mm (3.05)	0.28164	0.289385	0.284528	0.263954
ΔULL	31.32% (11.0)	0.269461	0.599493	0.485744	1

[a] N-ANS, vertical height of anterior maxilla; N-Me, vertical skeletal facial height; U1-PP, U1 to palatal plane; ΔULL, change in upper lip length; SD, standard deviation.

Weak correlation level ($\pm$ 0.1 $\leq r <$ $\pm$ 0.5); moderate correlation level ($\pm$ 0.5 $\leq r <$ $\pm$ 0.8); strong correlation level ($\pm$ 0.8 $\leq r <$ $\pm$ 1).

CONCLUSION

- Different skeletal patterns exhibit characteristic smile dynamics. Vertical skeletal patterns were found to have more upper lip elevation.
- The short upper lip length at rest (ULL) is not responsible for increased incisal display.
- Increased incisal display during smile is more closely associated with upper lip elevation than vertical skeletal and dental factors.
- Flat smile arc distribution is more common in the horizontal skeletal pattern, whereas the parallel smile arc was more common in individuals with a vertical skeletal pattern. Therefore, extra care should be taken while treatment planning in horizontal patterns.

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