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Original Research Article

Comparative Evaluation of Dynamic Smile and Gingival Contour in Different Malocclusion

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Abstract: This observational study evaluated dynamic smile characteristics and anterior gingival contour in 60 subjects divided into three groups of 20 each: Angle's Class I, Class II Division 1, and Class II Division 2 malocclusions. Standardized videographic records were used to capture rest and widest posed smile frames, from which upper lip length, change in upper lip length, maxillary incisal display, interlabial gap, outer intercommissural width, and gingival contour were measured using image-analysis software. Data were analyzed with ANOVA and Tukey's post hoc test ($p \leq 0.05$). Upper lip length, change in upper lip length, outer intercommissural width, and gingival contour showed statistically significant intergroup differences, whereas maxillary incisal display and interlabial gap did not. Class I subjects exhibited the longest upper lip, greatest change in upper lip length during smiling, widest outer intercommissural width, and the most favorable gingival contour, while Class II Division 1 subjects presented shorter upper lips and narrower smiles. These findings suggest that Class I malocclusion is associated with more favorable dynamic soft tissue and gingival aesthetics, underscoring the need to consider malocclusion-specific smile characteristics in orthodontic diagnosis and treatment planning to optimize aesthetic outcomes.

Keywords: Dynamic smile analysis, Smile aesthetics, Gingival contour, Gingival zenith, Maxillary incisal display, Interlabial gap, Upper lip length, Intercommissural width, Videographic evaluation, Soft tissue analysis, Orthodontic diagnosis, Esthetic treatment planning.

INTRODUCTION

The aesthetics of a smile has become increasingly important in the practice of modern dentistry and is synonymous with a natural and harmonious appearance. An attractive and pleasing smile clearly enhances the acceptance of an individual in the society by improving the initial impression in interpersonal relationships. Facial aesthetics has been an objective of orthodontic treatment planning since the beginning of this specialty. 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 aesthetics1. Improvement in facial aesthetics is also a powerful motivation for seeking treatment; therefore, orthodontic treatment should carefully consider a patient's facial appearance and particularly his or her smile.

A true smile is a complex gesture; it initiates with a lateral movement of the corners of the mouth 2. At the beginning, lips tend to remain in contact, except for people who have a short upper lip. The characteristics of the smile are determined by the interaction of the static and dynamic relationships between the dento-skeletal and soft tissue components of the face. The smile starts with contractions of muscle bundles originating from nasolabial fold and upper lip levator muscles, whose fibres are inserted to upper lip. Medial muscle bundles pull the upper lip upward on anterior teeth level and lateral muscle bundles pull the upper lip upward on posterior teeth level. The lip then meets resistance at the fold because of the heavy cheek fat due to which the folds deepen. The levators, notably the zygomatic major and the levator superior, rise the lip, fold and cheek to a higher level. In the final stage of smile, contraction of periocular muscles caused a winking of the eyes. Furthermore, everyone has an anatomical and functional muscular variability of nasolabial fold and this could change the individual capacity to show gum during smile3.

As the smile expands and approaches laughter the lips separate, mouth angles curve upwards and superior teeth are exposed to view. As the angles of the mouth extend and the lips separate, the mesial half of the maxillary first molars and the mandibular second pre molar may be exposed, while the front upper lip lifts up reaching the superior incisive collar4.

Aesthetics are the main reasons for the patients to visit an orthodontist. The parameters usually used to establish orthodontic diagnosis undervalued the aesthetic objectives and considered them hard to modify and treat. The main objective of treatment plan has been ideal occlusion, treating the molar and canine relationship as a priority. It was true for many other characteristics (overjet reduction, crowding resolution or space closing), however some of the aesthetic characteristics, such as gum exposure, could be made worse followed by the treatment keeping only the ideal occlusion in account5.

Tjan et al classified smiles into three types according to teeth and gingival tissue display during smiling (Fig 1). In his study, the essential factors were the lip–tooth–gingiva relationship, tooth characteristics and the surrounding gingival morphology. These factors are also the anatomical foundation of aesthetic dentistry and the key factors for treatment planning6.

High maxillary lip line	>100%	29%	
Standard maxillary lip line	75%-100%	56%	
Low maxillary lip line	<75%	15%	

Fig 1.1: Tjan's classification of smile[6]

The upper and lower lips frame the display zone of the smile. Within this framework, the components of the smile are the teeth and the gingival scaffold. The soft-tissue determinants of the display zone are lip line, intercommissural width, interlabial gap, smile index (width/height), and gingival architecture[7].

As a general guideline, the lip line (amount of vertical tooth exposure) is optimal when the upper lip reaches the gingival margin, displaying the total cervicoincisal length of the maxillary central incisors, along with the interproximal gingivae[8]. A high lip line exposes all of the clinical crowns plus a contiguous band of gingival tissue, whereas a low lip line displays less than 75% of the maxillary anterior teeth. Because female lip lines are an average 1.5mm higher than male lip lines, 1-2mm of gingival display at maximum smile could be considered normal for females[9].

The average lip length at rest, as measured from subnasale to the most inferior portion of the upper lip at the midline, is about 23 mm in males and 20 mm in females (Table 1). What is significant, however, is the relationship of the upper lip to the maxillary incisors and to the commissures of the mouth[10]. Lip length should be roughly equal to the commissure height, which is the vertical distance between the commissure and a horizontal line from subnasale.

Table 1.1: Mean upper lip lengths from various studies (mm)[8]

AUTHORS	MALE (mm)	FEMALE (mm)
Burstone	23.8	20.1
Farkas et al	21.8	19.6
Powell, Humphreys	23.8	20.1
Wolford	22	20
Peck et al	23.4	21.2
Arnett, Bergman	19-22	19-22

The intercommissural distance of a smile refers to the distance between the corners of the mouth (commissures) when the lips are in a smiling position. It's a key measurement in smile analysis, used to evaluate and quantify various aspects of a smile's appearance, such as the smile's width and the balance of facial features. Dickens et al. found an increase in commissural height by 1.3 mm in males and by 1.1 mm in females from 16 to greater than 40 years[11].

The contour of the gingival tissue surrounding the teeth also plays an important role in providing an optimal aesthetic appearance in the maxillary anterior sextant and affects the harmonious appearance of a smile. Consequently, any dental procedure performed in this zone is an aesthetic challenge because of its visibility. The physiological gingival architecture has been described as one that consists of knife-edged gingival margins tightly adapted to the teeth, interdental grooves and cone-shaped interdental papilla. Such parabolic architecture is critically outlined by the zenith, which is defined as the most apical point of the gingival marginal scallop[12].

Three categories of the gingival contour are classified:

a. Straight gingival line type (the central incisor and canine zenith at the same level)
b. Upward gingival line type (the canine zenith point is apically to the central incisor)

Downward gingival line type (the canine zenith point is coronal to the central incisor)

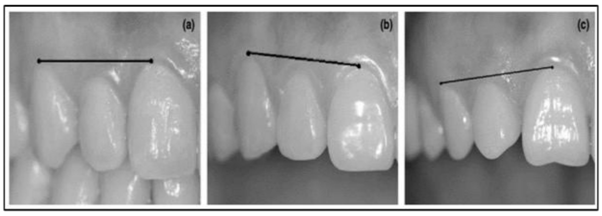

Fig 1.2: Categories of the gingival contour[12]

Extensive studies have been performed on Caucasian subjects to establish the mechanism, characteristics and factors influencing a smile; in contrast, there is very little such data for Asian populations[13]. Numerous studies of smile aesthetics have used still photos. Photos, however, do not capture the dynamics of a smile, an element that can contribute to overall smile aesthetics. No study has inquired about the dynamic aspect of the hard and soft tissue relationship, gingival contour, and different malocclusion present with characteristic patterns of the smile[14].

Therefore, this study was done to evaluate the relationship between different malocclusion (Class I, Class II division 1, and Class II division 2) and dynamic component of a smile using videographic records of subjects; measuring and analysing the components of smile such as maxillary incisal display, interlabial gap, upper lip length and change in upper lip length, outer intercomissural width along with gingival contour.

Aim of the Study

- To evaluate the dynamic aspect of soft tissues during smile along with the gingival contour in different malocclusion.

Objective of the Study

- To evaluate dynamic aspect of soft tissue during smile in Angle's Class I, Class II div 1, and Class II div 2 malocclusions.
- To evaluate the gingival contour of anterior teeth in Angle's Class I, Class II div 1, and Class II div 2 malocclusions.
- To compare the dynamic aspect of soft tissue during smile and gingival contour among Angle's Class I, Class II div 1, and Class II div 2 malocclusions.

Null Hypothesis

- There is no significant difference in the dynamic aspect of soft tissue during smile and gingival contour among different malocclusion.

MATERIALS AND METHODOLOGY

Sample Selection

The study was conducted with 60 patients undergoing orthodontic treatment in the Department of Orthodontics and Dentofacial Orthopaedics of Inderprastha Dental College and Hospital.

The subjects have been divided into 3 groups according to different Angle's malocclusion:

- Group A- Class I malocclusion
- Group B- Class II, division 1 malocclusion
- Group C- Class II, division 2 malocclusion

Inclusion Criteria

- No history of previous orthodontic treatment
- Grossly symmetrical face
- Angle's Class I, Class II div 1, and Class II div 2 malocclusions
- Age group- 15 years to 40 years
- Presence of stippling

Exclusion Criteria

- Facial asymmetry
- Localized gingivitis or periodontitis
- Tooth wear index score 2-4
- History of trauma to the dentofacial region
- 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
- Subjects having Angle's Class III malocclusion

Armamentarium

- Canon EOS 1500D 24.1MP DSLR camera
- Tripod stand for Canon EOS 1500D 24.1MP DSLR camera
- Adobe Premiere Pro CC version 7.0.0
- Mouth mirror
- William's probe

Fig 2.1: Canon EOS 1500D 24.1MP DSLR camera with tripod stand

A trained team of healthcare professionals conducted physical examinations to assess posture, spinal alignment, and range of motion. Participants were also evaluated for body mass index (BMI) and other anthropometric measurements.

DATA COLLECTION PROCEDURE

Method

Clinical evaluation was done to check the molar relationship and position of the anterior teeth with the help of mouth mirror. The frontal, buccal right, and buccal left intra-oral photographs was taken with Canon EOS 1500D 24.1MP DSLR camera using cheek retractor for the subject's record of the malocclusion. The categorization of the subjects into different Angle's malocclusion was done as:

Group A- Class I malocclusion- The mesiobuccal cusp of the mandibular first molar occludes in the embrasure area between the maxillary second premolar and first molar. The mesiobuccal cusp of the maxillary first molar is aligned directly over the buccal groove of the mandibular first molar. The mesiolingual cusp of the maxillary first molar is situated in the central fossa area of the mandibular first molar.

Group B- Class II, division 1 malocclusion- The mesiobuccal cusp of the mandibular first molar occludes in the central fossa area of the maxillary first molar. The mesiobuccal cusp of the mandibular first molar is aligned with the buccal groove of the maxillary first molar. The distolingual cusp of the maxillary first molar occludes in the central fossa area of the mandibular first molar. The maxillary anterior teeth are protruded and a large overjet is present.

- Group C- Class II, division 2 malocclusion- *The molar relationships are Class II where the maxillary central incisors are retroclined. The maxillary lateral incisor teeth may be proclined or normally inclined and a deep overbite exists.*

The digital camera (Canon EOS 1500D 24.1MP DSLR) was stabilized on a tripod stand switched to video mode and placed at the distance of 3 feet from the subject (this ensured equal magnification for all subject). Two rulers with millimetre markings secured at right angles to each other on a stand will be kept alongside the face of the subject, allowing direct measurement at life size[26].

The natural head position was clinically achieved by asking each subject to look eye level on the wall in front of the subject. The camera lens was adjusted at the level of apparent occlusal plane. The relaxed lip position was achieved by asking the subject to lick the lips and then swallow. The subject was then instructed to say ''Subject number___my name is___cheese'' followed by a smile. Recording began 1 second before the subject started speaking and ended after the smile[35].

The digital video clips were imported into commercially available video editing software (Adobe Premiere Pro CC version 7.0.0), which provides individual frames that could be viewed (30 images per second). Each frame was then analysed, and two frames was selected for each subject and saved in JPEG file format: the first frame represented each subject's lip at rest, and the second frame represented each subject's widest posed smile[1]. The set of frames were for the widest posed smile were shown to a panel consisting of- an orthodontist, a prosthodontist, a periodontist, a general dentist, and a layman person for the meticulous selection of the frame[42]. The chosen frames of each subject were imported into Adobe Photoshop and then it was cropped, leaving only a rectangular proportionate area of 6*4 inches that contained the perioral region, and measurements was taken.

For linear measurements in each photograph, the measurement scale presented as follows:

- Image was selected → Analysis → Setting of Measurement Scale → Custom (the ruler tool was selected while setting the measurement scale).
- The tool was dragged to draw a 10-mm line on the metallic scale that was visible in the photo and the logical length was entered as 10 and logical units as millimetres.
- The option 'OK' was clicked in the Measurement Scale dialog box to set the measurement scale on the document.
- The ruler tool was customized which gave real life-size measurements between any two selected points in millimetres.

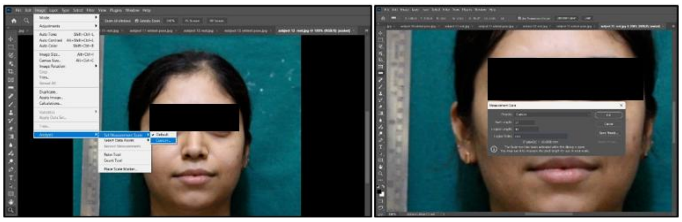

Fig 2.2: Figure showing the measurement scale dialog box to set the measurement scale from pixels to logical length (millimetres)

For smile evaluation, measurements were taken by drawing a line with the ruler tool, and was recorded from the Measurement Log panel that appeared in the window. One measurement of **upper lip length was taken on each rest position frame**, and the following four measurements were taken on each smiling photograph[1]:

1. **maxillary incisal display**
2. **interlabial gap**
3. **change in upper lip length**
4. **outer intercomissural width**

Fig 2.3: Upper lip length on rest position frame

Fig 2.4: Change in upper lip length on widest smile frame

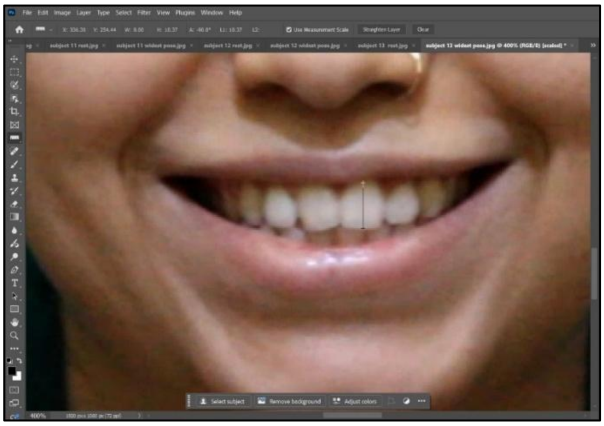

Fig 2.5: Maxillary incisal display on widest smile frame

Fig 2.6: Interlabial gap on widest smile frame

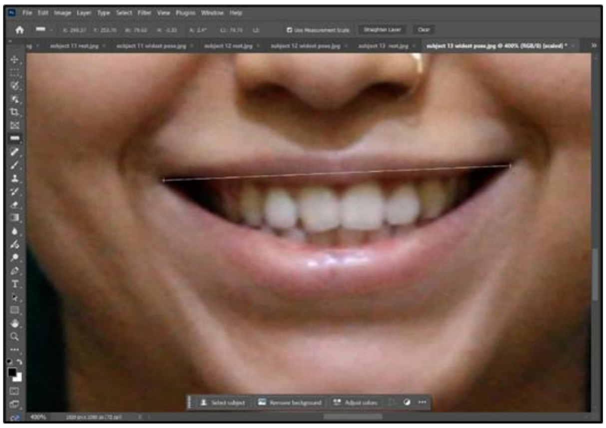

Fig 2.7: Outer intercomissural on widest smile frame

For **gingival contour**, we evaluated the gingival line, defined as a line joining the tangent of the gingival zenith the left or right central incisor and the corresponding canine. Three categories of the gingival line location were classified according to the relationship and differences in distance between the gingival zenith point of the central incisor and canine at the same side: straight gingival line type (both the gingival zenith points of the central incisor and canine are parallel to the horizon); upward gingival line type (the canine gingival zenith point is located apically to the central incisor); and downward gingival line type (the canine gingival zenith point is coronal to the central incisor). And then the distance between the lateral incisor gingival zenith points and the gingival line was measured using the software.

Fig 2.8: Gingival contour evaluation using the distance between the lateral incisor gingival zenith points and the gingival line on frontal intra-oral photograph

Statistical Analysis

The millimetric measurements obtained 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.

All analyses were performed on SPSS software.

RESULT

The data collected and analysed are summarized in Tables 2.1, 2.2, 2.3, and 2.4, provides understanding of the distinctive characteristics of dynamic smile aesthetics and gingival contour architecture within each malocclusion group. Evaluation of Dynamic Soft Tissue Aspects During Smile

The analysis of dynamic soft tissue parameters during a smile revealed several statistically significant differences among the malocclusion groups, as detailed in **Table 2.1** and **Table 2.3**

Table 2.1: Evaluation of dynamic aspect of soft tissue during smile in Angle's Class I, Class II div 1, and Class II div 2 malocclusions

Parameters		Mean	Std. Deviation	Std. Error
Upper lip length	**Class I**	23.56	1.795	0.401
	Class II Div. 1	18.64	1.598	0.357
	Class II Div. 2	20.71	1.550	0.346
Change in upper lip length	**Class I**	17.63	2.267	0.506
	Class II Div. 1	15.56	1.911	0.427
	Class II Div. 2	16.41	1.945	0.434
Maxillary Incisal display	**Class I**	9.08	1.442	0.322
	Class II Div. 1	9.34	1.942	0.434
	Class II Div. 2	8.55	1.372	0.306
Interlabial gap	**Class I**	13.01	2.543	0.568
	Class II Div. 1	11.42	2.557	0.571
	Class II Div. 2	12.38	3.019	0.675
Outer Inter commissural	**Class I**	72.26	4.081	0.912

width	**Class II Div. 1**	66.87	5.808	1.29
	Class II Div. 2	71.23	6.421	1.435

Table 2.2: Evaluation of gingival contour of anterior teeth in Angle's Class I, Class II div 1, and Class II div 2 malocclusions

Parameters		**Mean**	**Std. Deviation**	**Std. Error**
Gingival contour	**Class I**	1.22	0.257	0.057
	Class II Div. 1	0.49	0.606	0.135
	Class II Div. 2	0.45	1.241	0.277

Upper Lip Length

Upper lip length demonstrated a highly significant difference across the three malocclusion classes **(p<0.001)**. Specifically, Class I subjects exhibited the longest mean upper lip length (23.56±1.795 mm), followed by Class II Division 2 (20.71±1.550 mm), and Class II Division 1 (18.64±1.598 mm). The inter-group comparisons (Table 4) further elucidated these disparities: Class I was found to have a significantly greater upper lip length compared to both Class II Division 1 (mean difference = 4.920 mm, p<0.001) and Class II Division 2 (mean difference = 2.846 mm, p<0.001). Notably, Class II Division 2 also presented a significantly greater upper lip length when compared to Class II Division 1 (mean difference = −2.074 mm, p=0.001). These findings suggest that upper lip length is a distinct feature differentiating these malocclusion types, with Class I generally presenting a longer upper lip at rest.

Change in Upper Lip Length

A significant difference was observed in the dynamic change in upper lip length during smiling (**p=0.009**). Class I subjects displayed the largest mean change (17.63±2.267 mm), indicating a greater vertical movement of the upper lip during smile. This was followed by Class II Division 2 (16.41±1.945 mm) and Class II Division 1 (15.56±1.911 mm). Inter-group analysis (Table 2.4) revealed that Class I demonstrated a significantly greater change in upper lip length when compared to Class II Division 1 (mean difference = 2.064 mm, p=0.006). However, no statistically significant differences were detected between Class I and Class II Division 2 (mean difference = 1.223 mm, p=0.151), nor between Class II Division 1 and Class II Division 2 (mean difference = −0.841 mm, p=0.402). This suggests that while Class I generally exhibits more upper lip movement during a smile, the difference is not consistently significant across all comparisons, particularly between Class I and Class II Div 2.

Maxillary Incisal Display

No statistically significant difference was found in maxillary incisal display among the three malocclusion classes (p=0.293). The mean incisal display values were relatively similar: Class I (9.08±1.442 mm), Class II Division 1 (9.34±1.942 mm), and Class II Division 2 (8.55±1.372 mm). The lack of significant differences in inter-group comparisons (Table 2.4) further supports that maxillary incisal display, as measured in this study, does not serve as a primary distinguishing feature among these Angle's classifications.

Interlabial Gap

Similarly, the interlabial gap did not show a statistically significant difference across the malocclusion groups (p=0.184). The mean interlabial gap values were Class I (13.01±2.543 mm), Class II Division 1 (11.42±2.557 mm), and Class II Division 2 (12.38±3.019 mm). No significant differences were identified in the inter-group analysis (Table 2.4). This suggests that the resting or dynamic interlabial gap may not be a strong differentiating factor for these specific malocclusion types.

Interlabial Gap

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Outer Intercommissural Width

A significant difference was observed in the outer intercommissural width (**p=0.007**). Class I subjects presented the widest mean outer intercommissural width (72.26±4.081 mm), followed by Class II

Division 2 (71.23±6.421 mm), and then Class II Division 1 (66.87±5.808 mm). Inter-group comparisons (Table 2.4) indicated that Class I had a significantly wider outer intercommissural width than Class II Division 1 (mean difference = 5.394 mm, p=0.009). Furthermore, Class II Division 2 also showed a significantly wider outer intercommissural width compared to Class II Division 1 (mean difference = −4.365 mm, p=0.040). No significant difference was found between Class I and Class II Division 2 (mean difference = 1.029 mm, p=0.827). These results suggest that the width of the smile, as reflected by the outer intercommissural width, is notably narrower in Class II Division 1 malocclusions compared to both Class I and Class II Division 2.

Evaluation of Gingival Contour

The evaluation of gingival contour of anterior teeth illustrated in **Table 2.1 and Table 2.3** also yielded significant findings:

Gingival Contour

A significant difference in gingival contour was found among the malocclusion groups (**p=0.006**). Class I subjects displayed a notably higher mean gingival contour score (1.22±0.257) compared to Class II Division 1 (0.49±0.606) and Class II Division 2 (0.45±1.241). Inter-group comparisons (Table 2.4) further confirmed that Class I had a significantly higher gingival contour score than both Class II Division 1 (mean difference = 0.727, p=0.017) and Class II Division 2 (mean difference = 0.766, p=0.011). This indicates that Class I malocclusions are associated with a more favourable or ideal gingival contour compared to both Class II Division 1 and Class II Division 2. Interestingly, there was no significant difference in gingival contour between Class II Division 1 and Class II Division 2 (mean difference = 0.038, p=0.988), suggesting similar gingival characteristics between these two Class II subtypes based on the measured parameter.

Class I malocclusions generally presented with a longer upper lip, greater change in upper lip length during smile, wider outer intercommissural width, and a more favourable gingival contour. Class II Division 1 malocclusions consistently showed a shorter upper lip and narrower outer intercommissural width compared to Class I and often Class II Division 2. While maxillary incisal display and interlabial gap did not show significant variations, the observed differences in other parameters provide valuable insights for orthodontic diagnosis, treatment planning, and achieving optimal smile aesthetics tailored to specific malocclusion characteristics.

Table 2.3: Comparison between the dynamic aspect of soft tissue during smile and gingival contour among Angle's Class I, Class II div 1, and Class II div 2 malocclusions.

Parameters		Mean	Std. Deviation	p-value, S/NS
Upper lip length	**Class I**	23.56	1.795	**<0.001, HS**
	Class II Div. 1	18.64	1.598	
	Class II Div. 2	20.71	1.550	
Change in upper lip length	**Class I**	17.63	2.267	**0.009, S**
	Class II Div. 1	15.56	1.911	
	Class II Div. 2	16.41	1.945	
Maxillary Incisal display	**Class I**	9.08	1.442	0.293, NS
	Class II Div. 1	9.34	1.942	
	Class II Div. 2	8.55	1.372	
Interlabial gap	**Class I**	13.01	2.543	0.184, NS
	Class II Div. 1	11.42	2.557	
	Class II Div. 2	12.38	3.019	
Outer Inter commissural width	**Class I**	72.26	4.081	**0.007, S**
	Class II Div. 1	66.87	5.808	

	Class II Div. 2	71.23	6.421	
Gingival contour	**Class I**	1.22	0.257	**0.006, S**
	Class II Div. 1	0.49	0.606	
	Class II Div. 2	0.45	1.241	

p ≤ 0.05 – Significant, CI = 95 %

Table 2.4: Inter group comparison between the dynamic aspect of soft tissue during smile and gingival contour among Angle's Class I, Class II div 1, and Class II div 2 malocclusions.

Variable	(I) group	(J) group	Mean Difference (I-J)	p-value, S/NS
Upper lip length	**Class I**	**Class II Div. 1**	4.920	**<0.001, HS**
		Class II Div. 2	2.846	**<0.001, HS**
	Class II Div. 1	**Class II Div. 2**	-2.074	**0.001, S**
Change in upper lip length	**Class I**	**Class II Div. 1**	2.064	**0.006, S**
		Class II Div. 2	1.223	0.151, NS
	Class II Div. 1	**Class II Div. 2**	-0.841	0.402, NS
Maxillary Incisal display	**Class I**	**Class II Div. 1**	-0.253	0.872, NS
		Class II Div. 2	0.534	0.547, NS
	Class II Div. 1	**Class II Div. 2**	0.788	0.275, NS
Interlabial gap	**Class I**	**Class II Div. 1**	1.592	0.161, NS
		Class II Div. 2	0.630	0.745, NS
	Class II Div. 1	**Class II Div. 2**	-0.962	0.505, NS
Outer Inter commissural width	**Class I**	**Class II Div. 1**	5.394	**0.009, S**
		Class II Div. 2	1.029	0.827, NS
	Class II Div. 1	**Class II Div. 2**	-4.365	**0.040, S**
Gingival contour	**Class I**	**Class II Div. 1**	0.727	**0.017, S**
		Class II Div.	0.766	**0.011, S**

		2		
	Class II Div. 1	**Class II Div. 2**	0.038	0.988, NS

p ≤ 0.05 – Significant, CI = 95 %

DISCUSSION

This research identified several key distinctions across the malocclusion groups. Specifically, Class I malocclusions were associated with a greater mean upper lip length, a more pronounced change in upper lip length during smiling, a wider outer intercommissural width, and a more favourable gingival contour. In contrast, Class II Division 1 malocclusions generally exhibited a shorter upper lip and a narrower outer intercommissural width. Maxillary incisal display and interlabial gap, however, did not show statistically significant differences among the groups.

The observed variations in smile characteristics and gingival contour can be attributed to the unique skeletal and dental features inherent to each malocclusion class. The finding that Class I subjects exhibited the longest mean upper lip length (23.56 mm), followed by Class II Division 2 (20.71 mm) and then Class II Division 1 (18.64 mm), is a crucial observation. This difference, particularly the shorter upper lip in Class II Division 1, can be explained by the underlying skeletal and dental discrepancies. Class II Division 1 malocclusions are frequently characterized by a retrognathic mandible, a prognathic maxilla, or both, often accompanied by proclined maxillary incisors44. These features can lead to increased lip strain at rest or a more everted lip posture, which can make the upper lip appear shorter or necessitate greater muscular effort for lip competence45. Conversely, Class II Division 2 malocclusions, with their retroclined maxillary incisors, may allow for a more relaxed lip posture, contributing to an intermediate upper lip length46.

The significant difference in the dynamic change of upper lip length during smiling, with Class I showing greater movement (17.63 mm) than Class II Division 1 (15.56 mm), suggests variations in the dynamic muscular activity of the perioral region. A greater change in upper lip length in Class I may indicate a more uninhibited or natural smile pattern, where the lip muscles can contract more freely46.

In contrast, the underlying skeletal or dental constraints in Class II Division 1 cases might limit the extent of upper lip movement. The absence of significant differences between Class I and Class II Division 2, and between Class II Division 1 and Class II Division 2, suggests that while Class I has a distinct pattern, the dynamic lip movement between the two Class II subtypes might be more nuanced or influenced by individual muscular variations not solely dictated by the Angle classification47.

The lack of statistically significant differences in maxillary incisal display (Class I: 9.08 mm, Class II Div 1: 9.34 mm, Class II Div 2: 8.55 mm) and interlabial gap (Class I: 13.01 mm, Class II Div 1: 11.42 mm, Class II Div 2: 12.38 mm) across the malocclusion classes is noteworthy. This outcome may be influenced by compensatory mechanisms, where individuals with different malocclusions adapt their lip and muscle function to achieve a certain level of incisal display that is perceived as aesthetically acceptable regardless of their malocclusion type46.

Additionally, individual variability in lip length, muscle tonicity, and vertical facial proportions can obscure differences that might otherwise be expected based solely on skeletal or dental classifications. While some studies discuss intercanine width in Class II malocclusions, direct comparisons of interlabial gap across all three Angle classes are less consistently reported as significantly different48.

The significant difference in outer intercommissural width, with Class I (72.26 mm) and Class II Division 2 (71.23 mm) exhibiting wider smiles than Class II Division 1 (66.87 mm), aligns with the general understanding of these malocclusions. Class II Division 1 malocclusions are frequently associated with constricted maxillary arches and a tendency towards a narrower dental arch form, which can directly impact the width of the smile49. The wider smile in Class I reflects a more harmonious arch relationship, while Class II Division 2, despite its anteroposterior discrepancy, may not necessarily present with the same degree of transverse constriction as Class II Division 1, thus allowing for a wider commissural spread50.

The finding that Class I subjects displayed a significantly higher mean gingival contour score (1.22) (indicating a more ideal contour) compared to both Class II Division 1 (0.49) and Class II Division 2 (0.45) is a significant result. This can be attributed to the typically more favourable incisor position and alignment in Class I malocclusions, which allows for healthier and more symmetrical gingival margins. In Class II Division 1, proclined maxillary incisors can sometimes lead to thinner gingival biotypes or recession, while in Class II Division 2, retroclined incisors might lead to crowding or altered gingival levels due to the compensatory uprighting of the incisors.

The absence of a significant difference in gingival contour between Class II Division 1 and Class II Division 2 suggests that while both deviate from the Class I ideal, the specific incisor inclinations in these Class II subtypes might lead to similar overall impacts on gingival architecture as measured by our parameter51.

The observation of varying upper lip lengths across malocclusion classes is consistent with previous studies. Khurshid et al. (2023)48 found that upper lip length varied significantly across different sagittal malocclusion classes. Ioi et al. (2010)52 and Sarver and Ackerman (2003)25 have also emphasized the significant influence of anteroposterior jaw relationships and incisor inclination on lip position and length. These consistent findings underscore the importance of skeletal and dental bases in determining resting lip posture.

Trotman and Faraway (2004)53 demonstrated that facial movements are affected by skeletal malocclusion, with skeletal Class I individuals showing different lip movements compared to those with severe skeletal Class II. This suggests that the inherent skeletal harmony in Class I may facilitate a more extensive range of lip motion during a smile.
The study's finding of no significant difference in maxillary incisal display or interlabial gap among the malocclusion groups contrasts with some literature. For instance, Tjan et al. (1984)6 described an average smile as exhibiting approximately the full length of the maxillary anterior teeth. Abdarazik et al. (2017)46 reported a significant difference in incisal show among various dentoalveolar malocclusion groups during a social smile. The discrepancy in our findings might be due to the compensatory mechanisms mentioned earlier, where patients adapt their lip posture to achieve an aesthetically acceptable incisal display regardless of their malocclusion type. Additionally, variations in measurement methodologies or specific sample characteristics across studies could contribute to these differences.

The observation that Class II Division 1 malocclusions are associated with a narrower outer intercommissural width is consistent with the literature. Bishara et al. (1994)45 extensively studied arch width changes, and it is generally understood that Class II Division 1 cases often present with constricted maxillary arches. Roden-Johnson et al. (2005)54 also found that laypersons and dental professionals preferred broader arch forms displayed during smiling. The concept of smile width and its impact on aesthetics, including the presence of "buccal corridors," has been a long-standing consideration in smile design, as highlighted by Frush and Fisher (1958)55.

The finding of a more ideal gingival contour in Class I malocclusions compared to Class II subtypes aligns strongly with previous research. Kokich et al. (2006, 2007)56 extensively discussed the importance of gingival contour for smile aesthetics, noting that asymmetries, especially closer to the midline, are readily identified as unaesthetic by both dental professionals and laypersons. Furthermore, studies by Kaya et al. (2017)57 have shown that gingival thickness, a component of gingival biotype, can vary with Angle classification, with thinner gingiva observed in Class III cases, which indirectly supports the idea of variations across malocclusion types. The relationship between incisor position and gingival health is well-established, where proper alignment in Class I contributes to healthier gingival margins.

Future research could build upon these findings by conducting longitudinal studies to track the development of smile characteristics and gingival contour in individuals with different malocclusions over time, particularly following orthodontic intervention. Incorporating advanced 3D imaging and sexual dimorphism could provide more precise and comprehensive data on dynamic lip movements. Further investigations could also explore the correlation between specific skeletal parameters (e.g., vertical facial height, anteroposterior jaw discrepancies) and the observed soft tissue and gingival characteristics to gain a deeper understanding of the underlying etiological factors. Expanding the sample size to include more diverse populations would also enhance the generalizability of the results.

CONCLUSION

The findings indicate significant differences among the groups for several parameters. Upper lip length was notably longer in Class I compared to Class II Div 1 and Class II Div 2. Change in upper lip length during smiling was greatest in Class I, significantly differing from Class II Div 1. Outer intercommissural width was widest in Class I and Class II Div 2, both significantly wider than Class II Div 1. Gingival contour was significantly more favourable in Class I compared to Class II Div 1 and Class II Div 2. Conversely, Maxillary Incisal display and Interlabial gap showed no statistically significant differences across the malocclusion classes.

In essence, Class I malocclusions generally presented with more aesthetically favourable dynamic smile and gingival characteristics. These results highlight the importance of considering specific malocclusion types in orthodontic diagnosis and treatment planning to achieve optimal smile aesthetics.

The results have direct practical implications for orthodontic diagnosis and treatment planning. Clinicians should recognize that patients with different malocclusion types may present with unique smile characteristics that require tailored treatment approaches. For instance, the narrower smile width and shorter upper lip in Class II Division 1 patients suggest that treatment goals should consider these inherent features to achieve optimal aesthetic outcomes. Similarly, the more favourable gingival contour in Class I emphasizes the importance of achieving ideal incisor position and alignment to promote healthy and aesthetically pleasing gingival margins in all orthodontic cases. Understanding these specific differences can guide orthodontists in setting realistic treatment expectations and communicating effectively with patients regarding their smile potential.

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