Original Article

Perioral age-related changes in smile dynamics along the vertical plane
A videographic cross-sectional study

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ABSTRACT

Objective: To evaluate the changes in characteristics of perioral musculature at rest and when smiling, with respect to age and gender, measured along the vertical plane in a randomly selected sample of a North Indian population.

Materials and Methods: Perioral musculature of 195 subjects (divided into three age groups) was recorded using standardized videographic methods. Two frames of each subject—at rest and widest posed smile—were analyzed for a comprehensive list of parameters. Data was evaluated using SPSS version 16 software. Two-way analysis of variance and post hoc least significant difference tests were conducted.

Results: Significant observations were increased resting upper lip length for females; decreased upper lip thickness, maxillary incisor exposure, and lip elevation for males; and increased smiling upper lip length for both sexes.

Conclusions: With age, the smile gets narrower vertically, especially for the male population. The pattern of change observed in the present study must be considered and incorporated during treatment planning to deliver healthier and long-lasting results to patients of all age groups. (*Angle Orthod.* 2013;83:468–475.)

KEY WORDS: Age-related changes; Dynamic smile analysis; Gender-related changes

INTRODUCTION

The smile—the window of interpersonal communication and social interactions, is a major determinant of facial attractiveness.[1] Improvement of facial and dental esthetics is one of the primary objectives for seeking orthodontic treatment. The smile, along with the associated perioral tissues, most visibly displays the results of orthodontic treatment, thus making it a major target of orthodontic mechanotherapy.[2]

Time has recently been recognized as the fourth dimension in evaluating facial esthetics.[3–6] Therefore, what is normal for an individual now may not remain so as that individual ages. Throughout life, aging is an inevitable process that all humans undergo.[7,8] This leads to many skeletal and soft tissue cellular changes that dramatically affect the overlying soft tissue envelope, the related muscles, and their functions.[8] The aging lips at rest have been described as undergoing changes, including thinning, inversion, redundancy, and increased lip length.[9] Appropriate knowledge of age-related smile changes and general age-specific guidelines can help the orthodontist to maximize dentofacial esthetics and obtain healthy, long-lasting results for patients of all age groups. Thus, the present study was undertaken to evaluate the age and gender-related changes in characteristics of perioral structures at rest and when smiling, measured along the vertical plane, in a randomly selected sample

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of a North Indian population using dynamic video recording to capture the tissues at rest and at widest posed smile.

MATERIALS AND METHODS

Subjects were randomly selected from among students, residents, faculty, patients, and guardians of patients presenting to various departments of the institute. Approval was obtained from the Ethical Committee of Santosh University to conduct this study.

Inclusion Criteria

- Between 15 and 55 years of age,
- No prior orthodontic treatment,
- Voluntary participation in the study.

Exclusion Criteria

- Mutilated dentition,
- Prosthodontic or cosmetic dental work visible when smiling,
- Gross facial/dental asymmetries,
- Excessive dental attrition,
- Lip irregularities, lip surgery, or lip enhancement,
- Inability to determine natural head position.

Subjects, who agreed to voluntary participation, were asked to fill out a short questionnaire concerning age, sex, place of origin, and history of prior dental treatment.[3] The nature of the study was described, and they were asked to sign a form giving consent to the use of their photographs in any form for the present study.

To obtain a statistically meaningful result, a power of 80% was needed, which required a minimum sample size of 180 subjects. To maintain a homogenous sample distribution with power greater than 80%, 66 subjects were selected in each age group (33 males and 33 females in each subgroup). Thus, the final sample consisted of 198 subjects (Table 1). Subjects were randomly selected and assigned to the appropriate study groups and subgroups according to their age and gender, respectively. Allocation of subjects to the subgroups ceased when the desired sample size was achieved. This ensured an equal/homogenous distribution of sample for ease of comparison.

Table 1. Distribution of the Study Population According to Gender and Age Groups

Gender	Age Group 1	Age Group 2	Age Group 3	Total
Male	32	32	32	96
Female	33	33	33	99
Total	65	65	65	195

[a] Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.

Videographic setup for recording the perioral structures of the subjects was based on previously established guidelines and is diagrammatically represented in Figure 1.[3,5] Subjects were made to sit upright on an adjustable stool and hold their head in a natural head position by looking straight at a distant object at eye level. If any subject was unable to orient the head in a natural position and required assistance or correction, they were guided for the same.[10] A plumb line was hung vertically alongside the subject's stool, indicating the true vertical. An inch ruler parallel to the plumb line, mounted on a stable wooden stand, was placed next to the stool to allow measurements at life size (1:1).

Two constant white light sources—SIMPLEX Tri Lite (with three 200-W bulbs in each)—(Foto India Co, Vishwakarma Nagar, New Delhi) mounted on their respective stands were placed on either side at a distance of 1.5 feet diagonally in front of the subject and adjusted for adequate illumination of the face of the subject.

A Nikon D5000 SLR camera with high definition video capturing ability (Dass Studios, Inner Circle, CP, New Delhi), mounted on a tripod to control its stability and height according to each subject, was placed 4 feet in front of the subject. A constant focal length of 105 mm with aperture of f/5.6 was maintained to standardize all videos. The camera lens was adjusted parallel to the apparent occlusal plane. The plumb line and inch ruler were included in the capture area. Subjects were asked to relax then smile. A 5-second video was captured that included each subject's lips at rest followed by full, unstrained, posed smile.[3–6]

Two frames of each subject were captured for the study using Pinnacle Studio version 8 software (Pinnacle Systems, Greater Kailash, New Delhi), a video editing program:

- One frame represented the subject's lips at rest or relaxed lip position.
- One frame represented the subject's widest posed smile.

The captured frames were converted to JPEG format and saved with appropriate subject number and rest/smile frame (example: 1 rest, 1 smile). The photographs were then opened in Microsoft Office Picture Manager 2007 (Microsoft Corporation Pvt. Ltd, Nehru Place, New Delhi), and any magnification was corrected with the help of the inch ruler incorporated in each photograph (1 inch = 96 pixels on the pixel ruler, indicating a life-size or 1:1 magnification of the photographs). This allowed direct and highly accurate measurements to be taken using the pixel ruler. All readings were then entered in a Microsoft Office Excel 97-2003 Worksheet and converted into millimeters for statistical analysis and reference (1 mm = 3.78 pixels). All procedures were undertaken by the same operator.

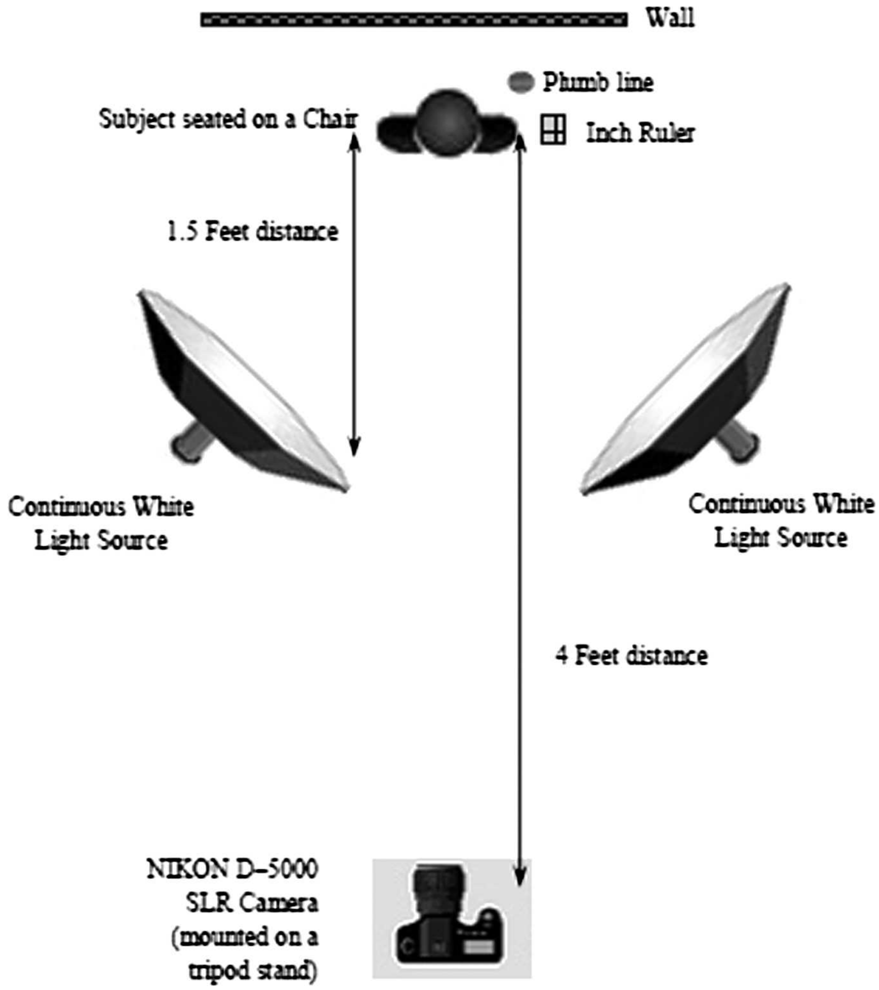

Figure 1. Diagrammatic representation of videographic setup.

The lines drawn and measurements taken on the rest and smiling frames are shown in Figures 2–5.

The following measurements were recorded on the Rest frame (Figure 4):

- Upper lip length,
- Upper lip thickness,
- Incisor show at rest.

The following measurements were recorded on the Smiling frame (Figure 5):

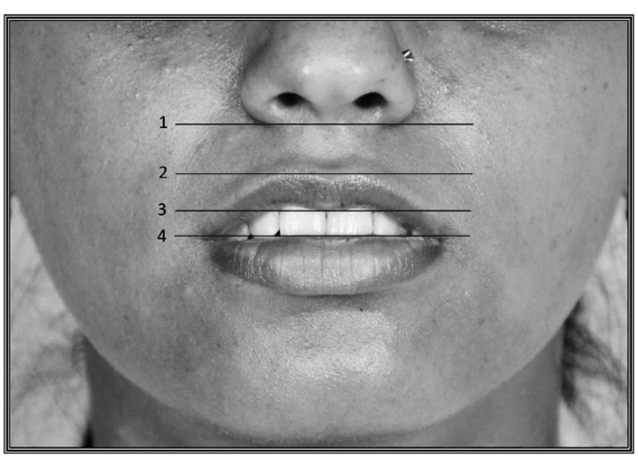

Figure 2. Lines drawn on Rest frame.

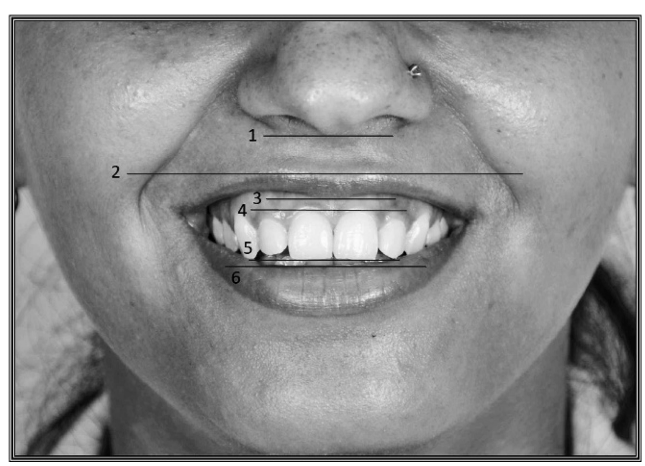

Figure 3. Lines drawn on Smiling frame.

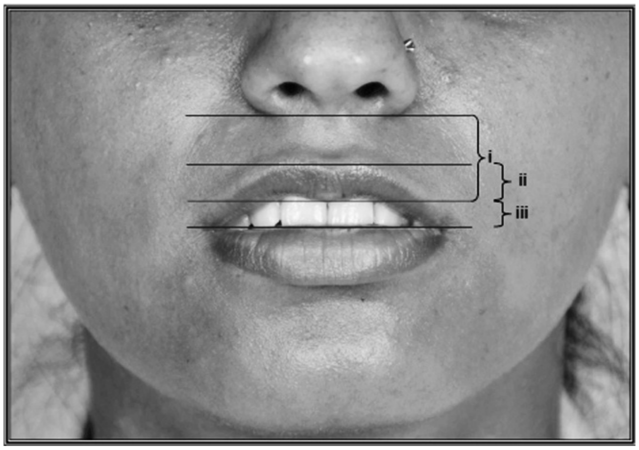

Figure 4. Measurements taken on Rest frame.

- Upper lip length,
- Upper lip thickness,
- Maxillary incisor display,
- Gingival display on smile,
- Mandibular incisor display,
- Interlabial gap at smile,
- Lip elevation/Change in upper lip length[3,4]: Upper lip length at Rest – Upper lip length on Smiling,
- Change in upper lip thickness[3]: Upper lip thickness at Rest – Upper lip thickness on Smiling,
- Smile height[3,11]: High, Average, Low, or N/A,
- Smile arc[3,11]: Parallel, Flat, Reverse, or N/A.

Data was analyzed using the SPSS (Statistical Package for Social Sciences) version 16 statistical software (SPSS South Asia Pvt. Ltd., Nehru Place, New Delhi). Analysis of variance and post hoc least significant difference tests were performed to evaluate the changes with age for the male and female sample population. Pearson correlation coefficient was calculated to evaluate the association between the upper lip length at rest and maxillary incisor exposure on smiling. Chi-square analysis was conducted to examine the difference in percentage of population exhibiting each type of smile height and smile arc (graded on a categorical scale with four levels designated as 1 to 4) in various age groups for both the sexes. Statistical significance was set at 5% ($P < .05$).

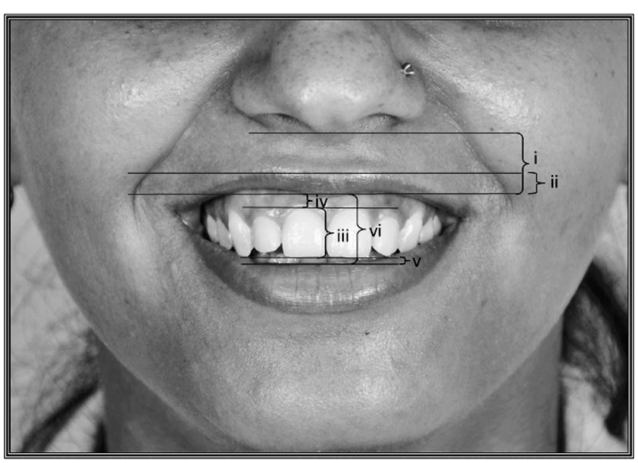

Figure 5. Measurements taken on Smiling frame.

RESULTS

The female and male populations exhibited significant differences in the pattern of variation of the study parameters with age.

The statistically significant changes with age observed for the female population were that upper lip length increased significantly at rest ($P = .013$) as well as on smiling ($P = .000$) (Tables 2 and 3). For the male population, the significant changes were decreased upper lip thickness at rest ($P = .014$), increased upper lip length on smiling ($P = .001$), and decreased lip elevation ($P = .008$) from rest to smile (Tables 4 and 5). The maxillary incisor display when smiling decreased with marginal significance ($P = .026$) for the male population but was nonsignificant for the female population.

Change in all other parameters was found to be nonsignificant for both the sexes (Tables 2–5): decreased incisor show at rest, decreased gingival display when smiling, increased mandibular incisor display when smiling, and decreased interlabial gap when smiling. The Pearson correlation indicated a significant relation between increased resting upper lip length and decreased maxillary incisor display when smiling for both the sexes (Table 6).

Among the female subjects, average smile height was the most common type across the three age groups, followed by high smile type (Table 7). Low smile height was the least common type. Among the male subjects, average smile height was the most common type, closely followed by low smile height (Table 7). None of the subjects presented with a lack of tooth exposure on smiling.

A higher percentage of female subjects presented with parallel smile arc across the three age groups (Table 8). Among the male subjects, flat smile arc was more common compared to parallel smile arc, with a visible increase in the former, through older age groups (Table 8).

DISCUSSION

The aging human face is known to undergo appreciable changes in facial esthetics and smile dynamics, which has been attributed to racial background, soft tissue changes, remodeling of underlying skeletal framework, and muscular changes.[7–9,11–13] Dental and skeletal changes lead to loss of skeletal volume and reduced vertical dimension.[14] The orthodontic practice has witnessed a significant increase in

Table 2. Comparison of Parameters at Rest Among Females of Various Age Groups Using the ANOVA and Post Hoc LSD Tests[a]

Parameter, mm	Age Group	Mean	Standard Deviation	*P* Value (ANOVA Test)	Post Hoc LSD Test Analysis Age Group		*P* Value
Upper lip length	1	19.61	2.02	.013**	1	2	.078
	2	20.63	2.08		1	3	.004**
	3	21.32	2.79		2	3	.231
Upper lip thickness	1	8.03	1.11	.827	1	2	.624
	2	7.88	1.20		1	3	.57
	3	7.86	1.44		2	3	.938
Incisor display at rest	1	0.88	2.00	.242	1	2	.858
	2	0.39	1.10		1	3	.124
	3	0.33	1.06		2	3	.174

[a] ANOVA indicates analysis of variance; LSD, least significant difference. Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.
* $P = .05$; ** $P = .01$; *** $P = .001$; **** $P = .0001$.

the number of adult patients seeking orthodontic treatment. This necessitates the need for an in-depth knowledge of specific changes in smile dynamics based on age and gender for different population groups to ensure appropriate treatment planning for patients of varying age groups.

Age-related changes should ideally be evaluated by undertaking a longitudinal study on an appropriate sample size over a long span of time. However, with such studies it is often difficult to manage follow-up for a large sample population over an extended period of time. This can be overcome by a cross-sectional study that allows evaluation of a larger sample size within a shorter duration of time. Though less precise in determining the exact magnitude of change, cross-sectional studies do give a good idea about the pattern and nature of the changes involved.

Thus, the present cross-sectional study was undertaken to analyze and quantify the pattern and magnitude of age- and gender-related changes in the characteristics of perioral musculature at rest and when smiling for a North Indian population. A comprehensive list of parameters in the vertical plane was evaluated with respect to age for both the sexes.

Table 3. Comparison of Parameters when Smiling Among Females of Various Age Groups Using the ANOVA and Post Hoc LSD Tests[a]

Parameter, mm	Age Group	Mean	SD	*P* Value (ANOVA Test)	Post Hoc LSD Test Analysis Age Group		*P* Value
Upper lip length	1	12.97	2.21	.000****	1	2	.016**
	2	14.41	2.25		1	3	.000****
	3	15.42	2.65		2	3	.088
Upper lip thickness	1	6.65	1.24	.563	1	2	.296
	2	6.29	1.11		1	3	.471
	3	6.41	1.75		2	3	.744
Maxillary incisor display	1	9.01	1.33	.348	1	2	.339
	2	8.84	1.44		1	3	.155
	3	8.49	1.64		2	3	.636
Gingival display when smiling	1	0.77	1.45	.179	1	2	.08
	2	0.30	0.70		1	3	.162
	3	0.39	0.97		2	3	.719
Mandibular incisor display	1	1.67	1.49	.599	1	2	.585
	2	2.02	1.58		1	3	.642
	3	1.83	1.06		2	3	.313
Interlabial gap when smiling	1	11.23	2.60	.974	1	2	.866
	2	11.12	2.38		1	3	.828
	3	11.09	3.07		2	3	.962
Lip elevation/change in upper lip length	1	6.64	1.49	.186	1	2	.300
	2	6.22	1.63		1	3	.068
	3	5.90	1.74		2	3	.425
Change in upper lip thickness	1	1.45	0.90	.682	1	2	.390
	2	1.59	1.04		1	3	.766
	3	1.38	1.00		2	3	.574

[a] ANOVA indicates analysis of variance; LSD, least significant difference; SD, standard deviation. Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.
* $P = .05$; ** $P = .01$; *** $P = .001$; **** $P = .0001$.

Table 4. Comparison of Parameters at Rest Among Males of Various Age Groups Using the ANOVA and Post Hoc LSD Tests[a]

Parameter, mm	Age Group	Mean	SD	*P* Value (ANOVA Test)	Post Hoc LSD Test Analysis		
					Age Group		*P* Value
Upper lip length	1	21.64	2.67	.061	1	2	.494
	2	21.19	2.63		1	3	.103
	3	22.73	2.65		2	3	.022*
Upper lip thickness	1	8.28	1.53	.014**	1	2	.046*
	2	7.53	1.32		1	3	.004**
	3	7.19	1.60		2	3	.365
Incisor show at rest	1	0.26	1.08	.488	1	2	.936
	2	0.28	0.91		1	3	.320
	3	0.06	0.25		2	3	.283

[a] ANOVA indicates analysis of variance; LSD, least significant difference; SD, standard deviation. Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.
* $P = .05$; ** $P = .01$; *** $P = .001$; **** $P = .0001$.

Dynamic videographic methods enabled recording and evaluating the subjects' perioral structures with utmost precision and accuracy.[3,6]

With age, females were found to undergo a gradual and consistent increase in lip length. The resting upper lip length increased gradually and gained significance beyond the fourth decade of life, ie, between group I and group III ($P = .013$, Table 2). However, the smiling upper lip length showed signs of early change (Table 3), ie, increased significantly from group I to group II ($P = .016$) and became highly significant between group I and group III ($P = .000$).

Of greater significance are the changes that the perioral musculature undergoes in the dynamic state, ie, during the process of producing a smile. The change in upper lip length (lip elevation) and upper lip thickness from rest to smile are measures that give an insight into the inherent activity of the facial muscles involved in raising the perioral musculature when smiling. The upper lip elevation from rest to smile showed marginally significant decrease with age (decreased by 0.74 mm).

The observed pattern of change can be attributed to two factors:

Table 5. Comparison of Parameters when Smiling Among Males of Various Age Groups Using ANOVA and Post Hoc LSD Tests[a]

Parameter, mm	Age Group	Mean	SD	*P* Value (ANOVA Test)	Post Hoc LSD Test Analysis		
					Age Group		*P* Value
Upper lip length	1	14.91	2.75	.001***	1	2	.253
	2	15.69	2.77		1	3	.000****
	3	17.53	2.66		2	3	.008**
Upper lip thickness	1	6.55	1.48	.168	1	2	.316
	2	6.17	1.50		1	3	.06
	3	5.83	1.54		2	3	.371
Maxillary incisor display	1	8.44	2.21	.026*	1	2	.087
	2	7.47	1.91		1	3	.008**
	3	6.92	2.54		2	3	.324
Gingival display when smiling	1	0.31	0.68	.477	1	2	.238
	2	0.13	0.54		1	3	.399
	3	0.18	0.53		2	3	.735
Mandibular incisor display	1	1.93	1.44	.235	1	2	.091
	2	2.65	1.64		1	3	.457
	3	2.24	1.93		2	3	.338
Interlabial gap when smiling	1	10.90	2.76	.185	1	2	.858
	2	10.76	2.77		1	3	.095
	3	9.66	3.26		2	3	.135
Lip elevation /change in upper lip length	1	6.74	1.92	.008**	1	2	.017**
	2	5.50	1.90		1	3	.004**
	3	5.21	2.29		2	3	.573
Change in upper lip thickness	1	1.74	1.17	.307	1	2	.184
	2	1.36	1.19		1	3	.184
	3	1.36	0.95		2	3	1.000

[a] ANOVA indicates analysis of variance; LSD, least significant difference; SD, standard deviation. Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.
* $P = .05$; ** $P = .01$; *** $P = .001$; **** $P = .0001$.

Table 6. Correlation Between the Change in Upper Lip Length and Maxillary Incisor Display when Smiling with Age for the Female and Male Population

	Maxillary Incisor Display	
Upper Lip Length	Pearson Correlation	Significance (Two-Tailed)
Females	.294	.003**
Males	.212	.038*

* $P = .05$; ** $P = .01$; *** $P = .001$; **** $P = .0001$.

(a) Loss of resting tonicity of perioral muscles that support and maintain the length of the upper lip (levator labii superioris alaeque nasi, levator labii superioris, incisivus labii superioris, zygomaticus major, and zygomaticus minor), reflected by the lip lengthening at rest and evident at a later age.

(b) Decrease in the muscles' ability to raise the upper lip due to reduced function of lip musculature, as depicted by reduced lip elevation and smiling lip length. Loss of function apparently begins at an early age.

The male population exhibited slight variation in the pattern of change in lip length with age. The resting lip length increased slightly, after the fourth decade of life, with marginal significance between group II and group III ($P = .022$). This indicates that the loss of resting lip tonicity is of a lesser magnitude for males than females. Smiling upper lip length also increased at a later age, being significant between group II and group III ($P = .008$) and highly significant between group I and group III ($P = .000$). Upper lip elevation decreased very significantly ($P = .008$, Table 5) with age (decreased by 1.53 mm). The reduction in resting tonicity and muscle activity present at a later age in males, unlike females, where function is affected early. Concordant findings of early soft tissue changes in females compared to males have been reported by Bishara and Jakobsen.[15] Geld et al.[4] noted an increase in lip elevation by 1.4 mm with age in the male population. Desai et al.[3] had reported a similar but nonsignificant change in the upper lip elevation (decrease by 0.34 mm) with age.

Loss of function, together with increased resting upper lip length, contributes greatly to the aged look of maxillary anterior teeth hidden by the upper lip during a smile. The maxillary incisor display decreases with marginal significance ($P = .026$) for the male population and nonsignificantly for the female population. Its direct clinical relevance is reflected in the diagnosis and treatment planning of adult patients. A comprehensive lip/smile analysis should be undertaken to evaluate the effect on incisor display in the static as well as dynamic state before considering possible treatment options. Intrusion of anterior teeth for management of deep bite malocclusion in different age groups should be planned with care. Intrusion in the upper arch may be preferred in younger individuals for bite correction. However, for adult patients especially males beyond the third or fourth decade of life, since there is a natural tendency for reduced maxillary incisor display, further intrusion may adversely affect smile esthetics. In such situations, intrusion of mandibular anteriors may be the better treatment option without compromising smile esthetics.

Mandibular incisor display increases nonsignificantly with age for both the sexes, drawing attention toward mandibular midline considerations in adult patients. For moderate anterior crowding cases, single mandibular incisor extraction may sometimes be the preferred treatment approach. However, in adult patients proximal reduction of incisors should be considered to maintain the mandibular midline for optimizing esthetics.

Lip thickness in the vertical plane reduces early in life for males ($P = .014$, Table 4). Apparently, the intrinsic fibers of lip musculature that are responsible for maintaining the thickness of lip[16] must be affected, resulting in thinning of lips. However, females did not show appreciable change in lip thickness, implying that the intrinsic fibers of lip musculature are little affected by the aging process in females.

With increasing age, females showed a higher percentage of average smile height (60.6%, 81.8%, and 78.8% for groups I, II, and III, respectively) than the males (59.40%, 65.60%, and 43.80% for groups I, II, and III, respectively). Males showed a higher percentage of subjects with low smile type with increasing age (18.80%, 28.10%, and 43.80% for groups I, II, and III, respectively). None of the subjects presented with a lack of tooth exposure on smiling. Tjan et al.,[17] Yoon et al.,[11] Maulik and Nanda,[18] and Desai et al.[3] all reported average anterior smile height to be most common (68.9%, 56%, 56.9%, and 73.8%, respectively).

Table 7. Percentage of Anterior Smile Height Types Among Various Age Groups of the Female and Male Population[a]

Anterior Smile Height	Age Group, Females (n = 33)				Age Group, Males (n = 32)			
	1	2	3	*P* Value	1	2	3	*P* Value
High	30.30%	18.20%	21.20%	.081	21.90%	6.30%	12.50%	.101
Average	60.60%	81.80%	78.80%		59.40%	65.60%	43.80%	
Low	9.10%	0.00%	0.00%		18.80%	28.10%	43.80%	

[a] Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.

Table 8. Percentage of Smile Arc Types Among Various Age Groups of Female and Male Sample Population[a]

Smile Arc	Age Group, Females (n = 33)			*P* Value	Age Group, Males (n = 32)			*P* Value
	1	2	3		1	2	3	
Parallel	78.80%	57.60%	63.60%	.246	46.90%	34.40%	28.10%	.389
Flat	18.20%	39.40%	27.30%		46.90%	62.50%	56.30%	
Reverse	0%	0%	0%		3.10%	0.00%	3.10%	
N / A	3%	3.1%	9.1%		3.10%	3.10%	12.50%	

[a] Age groups: 1 = 15–25 years; 2 = 30–40 years; 3 = 45–55 years.

A higher percentage of female subjects presented with parallel smile arc across the three age groups (78.8%. 57.6%, and 63.6% for groups I, II, and III, respectively). Among the male subjects, flat smile arc was more common as compared to parallel smile arc, with a visible increase in the same, with older age groups.

The present study clearly outlines a comprehensive picture of the nature of soft tissue changes in smile dynamics for adults of a North Indian population. However, the overall changes are also affected by underlying skeletal/hard tissue changes with age. It is therefore prudent to consider all aspects in unison while interpreting and evaluating the soft tissue parameters to arrive at the most appropriate treatment plan for a patient at any age.

CONCLUSIONS

- The North Indian population exhibits significant age-related and gender-specific changes in characteristics of their perioral musculature, at rest as well as when smiling, with age.
- The reduction in maxillary incisor display when smiling with age for males and females is the combined effect of increase in resting upper lip length and diminished elevation of upper lip (1.53 mm for males and 0.74 mm for females) and activity of musculature to produce a smile.
- Significance of mandibular midline considerations increases with age, especially for adult males.
- The musculature responsible for elevation of upper lip to produce a smile undergoes generalized and gradual weakening with age, resulting in shortening of the smile framework in the vertical dimension.

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