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# Dynamic Smile Analysis : Changes with Age

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Dynamic Smile Analysis: Changes with Age

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## Abstract

**Introduction**: The objective of this study was to define age-related changes in the human smile. The areas of interest were: upper lip length at smile and repose, upper lip thickness at smile and repose, maxillary incisal display at smile, interlabial gap height at smile, smile index, percent buccal corridors, intercommissural width at rest, smile height, and smile arc. A secondary objective was to study the perioral changes from rest to smile and compare them on the basis of age. **Materials and Method**: Video equipment was used to capture video for 261 subjects. Two frames for each subject were selected; one frame representing the lips and rest and the second representing the widest smile. After excluding 40 subjects the data for the remaining 221 subjects was analyzed. **Results**: There was a decrease of 1.5 to 2 mm in the maxillary incisor display during smile, with increase in age. Smile index significantly increased with increase in age. Most (78%) subjects displayed an average smile height. No subjects in the 50 and over age group displayed a high smile while no subjects in the 15-19 year old age group presented with a low smile. All the dynamic measures indicated there was a pattern of decreasing change from rest to smile especially evident after the 30-39 year old age group. **Conclusions**: This study helps to establish age related dynamic norms. As the person ages the smile gets narrower vertically and wider transversely. The dynamic measures indicate that the muscles' ability to create a smile decreases with increasing age.

# **Introduction**

## I. Introduction

Often, the main reason people seek orthodontic treatment is to improve dental esthetics. The smile, along with speech, is what most visibly displays the results of orthodontic treatment; therefore, smile esthetics becomes a major goal in orthodontic treatment. Ideal occlusion should certainly remain the primary functional goal of orthodontics but the esthetic outcome is critical for patient satisfaction. Janzen[1] noted that in addition to a well-balanced functional occlusion a well-balanced smile is an important treatment objective. This objective adds a significant dimension of successful orthodontic treatment, which is deeply appreciated by the patient and parent. Sarver and Ackerman[2] state that esthetic considerations are paramount in treatment planning; however, rigid rules cannot be applied to this process because almost an infinite variety of faces could be esthetic. Accordingly, it is important to have general guidelines that aid the clinician to optimize dentofacial esthetics, while satisfying other treatment goals. Irrespective of this, a majority of the orthodontic literature and diagnosis is based on the patient's profile and lips at rest while analyzing a static photograph and/or a lateral cephalogram.[3-17] A reason that smiles have not been readily studied in the past could be due to the difficulty in capturing a reliable, repeatable smile. Recent advances in technology have made it possible to study the smile through the use of videography.[18-20] By looking at the smile in a video, one can identify a more standardized smile (greatest width), thus minimizing the error when studying one snapshot. The goal of this study was to gain knowledge and understanding on how the smile changes with age.

## II. Biological Changes in Aging

Throughout life aging is an inevitable process that all humans undergo. This process deals with cellular changes possibly due to oxidative damage, genomic instability, mitochondrial DNA, and systemic control.[21] The aging lips at rest have been described by many as undergoing changes including thinning, inversion, increased lip length, and redundancy.[22, 23]

The histological features of aging human skin include notable changes in the epidermis and dermis. Changes in the facial skin can begin as early as the second decade of life. The facial skin, being exposed to sunlight, is susceptible to show signs of aging more rapidly than unexposed areas. The changes brought on by sun exposure and by aging do not differ in quality, only in quantity. In the epidermis there is a noticeably flat dermoepidermal junction, some nuclear atypia, loss of melanocytes, fewer Langerhans cells, variable thickness, along with variable cell size and shape. In the dermis there is atrophy due to fewer fibroblasts, fewer mast cells, fewer blood vessels, and shortened capillary loops. Furthermore, with age, dermal alterations are also seen in collagen, elastin, and glycosaminoglycans.[24-33]

Skin collagen has been shown to decrease linearly at a rate of approximately 1% per year of increasing age. This relationship has also been related to gradual thinning of the skin throughout life in males and significantly after 50 years of age for females.[26] The elastic fibers undergo profound age related changes in individuals 50 years or older. In aging skin the terminal elastic fiber arcades become progressively, but irregularly, thicker. Eventually the entire elastic fiber structure in the papillary dermis shrinks and sags. The distal branches do not reach the epidermis and some are broken off from the main structures remaining attached to the epidermis. Superficial blood vessels tend to collapse, disorganize, and even at times totally disappear. In contrast, the cutaneous nerves are little affected with age.[28, 31] The amount of hyaluronic acid and dermatan sulfate in the glycosaminoglycans has been shown to be reduced with increasing age.[25]

Muscles have been shown to have a significant reduction in cross-sectional area and density with age.[34, 35] With aging there is evidence of muscle wasting and weakness resulting from loss of functioning motor units. The surviving motor units are enlarged and show relatively slow twitches and firing rates.[36-38] Consequently, the isometric and dynamic strengths decline[35] and the time to peak tension is significantly prolonged with increasing age[39].

In an anthropometric and histologic analysis of the age-related changes of the craniofacial skeleton in 160 cadaver skulls it has been shown that aging leads to appreciable reduction of facial height correlated with loss of teeth, modest increase in facial width and depth (except areas associated with tooth loss), and general coarsening of bony prominences.[40]

II. Defining a Smile

A smile is defined as a change in one's facial expression by spreading the lips, often to signal pleasure. It's the result of a complex neurological pathway involving the cerebral cortex (nonmotor, premotor, and motor), seventh cranial nerve, and sensory feedback input from the trigeminal nerve at the premotor and motor cortex leading to contraction of the facial muscles. The facial muscles involved in a smile are the depressor septi nasi, levator labii superioris alaeque nasi, levator labii superioris, levator anguli oris, zygomaticus major and minor, buccinator, risorus, depressor anguli oris, depressor labii inferioris, and mentalis.  All of these muscles insert at the orbicularis oris and work in tandem to raise the upper lip and pull laterally at the corner of the mouth creating the smile.[14, 41-44]  The smile has been described by Akerman M.B. and J.L.[18] as being framed by the upper and lower lips.  Within this framework are the teeth and gingival scaffold.  The soft-tissue determinants of the display zone are lip thickness, intercommissure width, interlabial gap, smile index (width/height), and gingival architecture.  At the lateral borders the eye can perceive inner and outer commissures. The inner commissure is formed by the mucosa overlying the buccinator muscle where it inserts with the orbicularis oris muscle.

Researchers have classified smiles in the following two groups: posed and unposed.  The posed smile has been described to be sustained and the lip animations are fairly reproducible.  Contrarily, the unposed smile is involuntary and induced by enjoyment or delight.[3, 16, 45] Due to its reproducibility the posed social smile should be considered the most desirable for treatment planning and research; however, Burstone, in a published interview, stated that: "… it is very difficult for a posed smile to be reproducible, and therefore it cannot be an accurate guide for tooth position."[46]  This difficulty highlights the importance of a dynamic video record, as it ensures you capture the intended smile frame.

III. Review of Literature

Oral structures such as teeth, lips, and periodontium change with age.  These changes effect the smile and result in an aged look.  The following is a noteworthy study quantifying age and smile.  Choi et al[17] measured the exposure of maxillary and mandibular incisors in both resting and smiling positions in 230 Korean subject 20 to 69 years of age.  There findings were that the maxillary incisal display gradually decreased, with increase in age, by 2 mm at smile and 2.5 mm at rest.  This was accompanied by an increase in mandibular incisal display of 1 mm at smile and 1.5 mm at rest.

For years dental literature has attempted to study and classify smiles in a static nature. To formulate a ‘standard of normalcy’ Tjan et al[13] looked at 454 full-face photographs of dental and dental hygiene students 20-30 years old with open smiles (displaying teeth). This study revealed that 48 (10.57%) persons were classified as having a high smile (shows entire length of maxillary anterior teeth and a continuous band of gingiva), 313 (68.94%) as having an average smile (75-100% of maxillary anterior teeth and the interproximal gingiva only), and 93 (20.48%) as having a low smile (display less than 75% of the anterior teeth). For parallelism of the maxillary incisal curve with the lower lip 385 (84.8%) subjects showed parallelism of the upper incisal curve with the inner curvature of the lower lip, 63 (13.88%) had a straight relationship, and six (1.32%) showed a reverse smile line. For position of the incisal curve relative to touching the lower lip the data revealed that 192 (46.61%) subjects showed the maxillary anterior teeth touching the lower lip, 134 (34.62%) were not touching the lower lip, and 61 (15.76%) had the incisal portions of the anterior teeth covered by the lower lip.

Yoon et al[17] looked at similar measurements as Tjan.  They analyzed 240 Korean university students with normal occlusion, no missing teeth, and none had any orthodontic or prosthodontic treatment.   For upper lip position an average smile (reveals 75-100% of maxillary anterior teeth) was most common.  With respect to upper lip curvature (relating the corners of the mouth to the lower border of the upper lip) they found that upward was rare (12%) while straight (45%) and downward (43%) smiles were relatively common. Similar to Tjan they also looked at parallelism for the maxillary anterior incisal curve with the lower lip and found that most were parallel (60%), some straight (34%), and only few with reverse (5%).

Owens et al[9, 10] engaged in a multicenter interracial study of facial appearance involving 44 African Americans, 42 Caucasians, 40 Chinese, 40 Hispanics, 44 Japanese, and 43 Koreans. They found a parallel smile to be most common (74%) with no race or gender differences.

In a study analyzing the lips at rest Vig and Brundo[47] found less maxillary incisor and more mandibular incisor exposure with increasing age. These results were similar to Choi et al[17] where the amount of maxillary incisal exposure gradually decreased with age while the mandibular incisal exposure increased in the resting position. Vig and Brundo[47] also correlated a long lip length with less maxillary incisor exposure at rest.

Peck et al[14] in a study of 115 North American whites with a mean age of 15.5 years found the upper lip length at rest to have no difference between the gingival smile line sample and the reference group. The mean value of both samples for the upper lip at rest was 22.3 mm. There was minimal difference found between males and females for upper lip length at rest with females averaging 21.2 mm and males averaging 23.5 mm.

Many cephalometric analyses have been performed to evaluate the soft tissue profile at rest and its changes with age. Subtelny[48] described an increase in the upper lip length of approximately 6.5 mm from 1 to 18 years of age. Nanda et al[8] described an overall increase in upper lip length from soft tissue subnasale to upper lip stomion from ages 7 to 18 years old. The average increase was 2.7 mm in males and 1.15 mm in the females with the total lip length at 18 years old of 22.5 mm and 20.2 mm, respectively. Sarnas et al[49] described a 0.5 mm increase in upper lip length from 21 years to 26 years old. Formby et al[7] further described the changes in the adult facial profile from 18 to 42 years of age as an increase in upper lip length of 0.83 mm resulting in a decreased incisor exposure.

IV. Smile and Attractiveness

A pleasing smile involves a harmonious relationship between the teeth, gingival scaffold, and the lip framework. The importance of physical and facial attractiveness, in which the smile arguably plays a large role, has been studied and related to job recruitment decisions, initial impressions, susceptibility to peer pressure, voting and juror decisions, and social interactions including dating decisions.[50-53] In a self-evaluation of facial features patients ranked the teeth and eyes as most important.[54] Ackerman[45] comments that an attractive smile is a requisite for winning elections, and a beautiful smile sells products for companies whose subliminal message in an advertisement is 'look better – feel younger'. Defining exactly what is considered pleasing or esthetic as a person ages is difficult. The fact that the American Board of Orthodontics does not consider the patients finished smile as scoring criteria for the clinical exam demonstrates the difficulty.

Hulsey[11] analyzed smiling photographs of forty (20 treated and 20 untreated) Caucasians between 15-25 years of age to judge attractiveness. He found that the harmony between the arcs of curvature of the incisal edges of the upper incisor teeth and the upper border of the lower lip is an important feature of an attractive smile and can be influenced by the orthodontist during treatment. The upper lip curvature was found to be upward in twenty-six subjects (65%), only four subjects (10%) had a straight upper lip, and ten subjects (25%) had upper lip curved downward. Interestingly, he found that the buccal corridor ratio appeared to be of no significance to an attractive smile. The last pertinent finding was that the most attractive smiles had the upper lip at the height of the gingival margin of the upper central incisors.

Moore et al[55] recently studied the influence of the buccal corridor on smile esthetics. They digitally altered the smiling images to produce a range of smile fullness then had a panel of 30 lay persons compare the 2 images in each pair for smile attractiveness. Contrary to Husley's finding, these results showed that a broader smile (minimal buccal corridors) was rated as most attractive. Consequently, Moore suggested that large buccal corridors should be included in the problem list during orthodontic diagnosis and treatment planning.

Parekh et al[56] studied the attractiveness of smile arc and buccal corridor space variations and found that excessive buccal corridors and flat smile arcs in both male and female smile are rated as less attractive by both orthodontists and laypersons. They also noted that flat smile arcs decrease the attractiveness ratings regardless of the buccal corridor.

V. Rationale for Study

When diagnosing a patient the hard and soft tissues are looked at in three dimensions: anterior-posterior, vertical, and transverse. Recently, time has been recognized as the fourth dimension.[19, 20] After orthodontic treatment, retainers are given to the patient to retain the post treatment occlusion to provide the patient with lasting function and esthetics. This post orthodontic occlusion is viewed by others through the soft tissue window when the patient smiles. Thus, knowledge into how the smile changes with time can help the orthodontist deliver healthier, long-lasting results.

In order to best study a smile and advance beyond taking static pictures recent articles have established guidelines describing a new method of capturing a dynamic smile in motion.[18-20] This method uses videography and computer software to record a smile. A digital video camera is mounted on a stand, placed at a fixed distance from the subject, the lens is set to be parallel to the true perpendicular and the face in natural head position, while the camera is raised to the level of the subject's lower facial third. The subject is asked to say "Chelsea eats cheesecake on the Chesapeake", relax, and then smile. This method usually produces a five-second clip which is downloaded to Apple Final Cut Pro for compression and conversion into an Apple QuickTime Viewer file. At roughly 30 frames per second the five-second clip produced 150 frames which could be analyzed. The researchers found the smile portion to be about 12-20 frames, from that the frame that represents the subjects best unrestrained social smile was selected, captured with a program called Screen Snapz, and saved as a JPEG file. This JPEG image was then opened in SmileMesh where 15 attributes to the smile could be measured.[18] Applying this method allows the researcher to find the smile frame of choice more accurately.

The most important part of an orthodontic treatment is the accurate diagnosis of the malocclusion and supporting hard and soft tissue structures. Developing a "standard of normalcy" for smiles is important as it would give guidelines for orthodontist to have better treatment results. This study will give the clinician a better understanding of how the patient’s smile changes with age allowing the orthodontist to consider age-related smile changes, during diagnosis and throughout treatment.

## Null Hypothesis

I. General Null Hypothesis

The smile does not undergo age related changes.

II. Specific Null Hypothesis

1. There is no difference between the anatomic and physiologic smile measurements with respect to age:
    a. intercommissural width at repose
    b. upper lip length at smile and repose
    c. upper lip thickness at smile and repose
    d. maxillary incisor display at smile
    e. interlabial gap height at smile
    f. smile index (width/height)
    g. percent buccal corridor
    h. change in upper lip length
    i. change in intercommissural width
    j. change in upper lip thickness
    k. smile height (h, a, l)
    l. smile arc (p, f, r)
2. There is no correlation between upper lip length at rest and the amount of maxillary incisor displayed during smile.

## Materials and Methods

I. Materials

1. Canon GL-2 miniDV camera
2. Gateway E2000 P04 computer
3. 15" Gateway FPD1530 monitor
4. ScenalyzerLive 4.0
5. Adobe Photoshop CS2
6. Microsoft Excel

Our study design was similar to that used by Ackerman and Sarver.[18-20] Some notable differences were the camera and software used. In this study, a newer miniDV camera (Canon GL-2) was used to create better resolution of JPEG files. A millimeter ruler was included in the study video to enable direct measurements. The videos were uploaded to ScenanlyzerLive 4.0, a PC based video analyzing program, which was utilized in this study as apposed to the Mac based program described by Ackerman and Sarver. Adobe Photoshop CS2 was used to measure the smile features on the JPEG files.

II. Subject Recruitment

University of Connecticut Institutional Review Board approval was obtained for the study and subject selection process (IRB Number: 07-045-1). The subjects were students/residents, staff, faculty, patients, and parents/guardians at the University of Connecticut Health Center. It was made clear to them that their decision to participate had no effect on their status as student, employee, or guardian. It was explained to potential subjects that this was a study on lip movements and their involvement would be anonymous, capturing chin to nose only, and involve a short questionnaire (Appendix A) followed by a 5 second video clip. Initial data were collected sequentially on 261 subjects. Of these subjects 40 were not included in the data analysis for the reasons shown in Table 1. The remaining 221 subjects were separated into five groups with the following age ranges: Group(G)1 (15-19 year old), G2 (20-29 year old), G3 (30-39 year old), G4 (40-49 year old), and G5 (50 years and older). A description of the sample is illustrated in Table 2 and 3. The ages ranged from 15-70 years of age and 59.7% (132 subjects) were female and the remaining 40.3% (89 subjects) were male. Furthermore, 59.3% (131 subjects) had a history of orthodontic treatment while 40.7% (90 subjects) reported no history of orthodontic treatment.

Table 1. Exclusion Criteria

| Reason for Exclusion | Total |
|---|---|
| Anterior prosthodontics | 26 |
| Video error | 1 |
| Did not smile | 6 |
| Head position off | 4 |
| Lip enhancements | 1 |
| Lip irregularity | 1 |
| Lips not at rest | 1 |
| Total | 40 |

Table 2. Description of Study Sample (age groups)

| Age group | Total (%) |
|---|---|
| 15-19 | 49 (22.2) |
| 20-29 | 64 (29.0) |
| 30-39 | 35 (15.8) |
| 40-49 | 42 (19.0) |
| 50+ | 31 (14.0) |
| Total (%) | 221 (100) |

Table 3. Description of Study Sample (Gender and history of orthodontic treatment)

| Gender | | History of Orthodontics | |
|---|---|---|---|
| Female (%) | Male (%) | Yes | No |
| 132 (59.7) | 89 (40.3) | 131 (59.3) | 90 (40.7) |

Inclusion criteria:

1. All people over 15 years of age
2. no active orthodontic treatment
3. ability to understand their voluntary involvement in the study and to answer questions on the questionnaire (Appendix A)

Exclusion criteria:

1. missing tooth visible in smile
2. prosthodontic work on teeth/tooth visible in smile
3. gross facial asymmetries
4. Excessive dental attrition
5. lip irregularities or history of lip surgery
6. inability to determine natural head position, occlusal plane, or any measurements
7. inability to hold the millimeter ruler parallel to the lens

If the potential subject met the inclusion criteria then they were initially included in the study. Then, at a later time, if any of the exclusion criteria were noticed while reviewing the video and resulting JPEG file the subject was excluded from the study.

<u>III. Method of Data Collection</u>

First, the subjects who agreed to voluntarily participate in the study were asked questions including age, sex, and history of orthodontic or prosthodontic treatment from a short questionnaire (Appendix A) that had their subject number at the top. Then a Canon GL-2 miniDV video camera was set on a tripod approximately 4 feet away from the standing subject. The subjects were instructed to hold their head in natural head position by looking straight into an imaginary mirror. If position required correction the researcher helped the subject into natural head orientation.[57] The camera lens was adjusted parallel to the apparent occlusal plane and the camera focused only on the mouth (from the nose to the chin) so the person could not be identified. Included in the capture area were two rulers with millimeter markings. The rulers were secured in a cross configuration so that if the subject accidentally rotated the ruler by accident the other side could be used to analyze the frame. The subjects were instructed to hold the millimeter ruler to their chin and say: "Subject number ____, Chester eats cheesecake by the Chesapeake, relax, and then smile". Recording began about 1 second before the subject began speaking and ended after the smile.

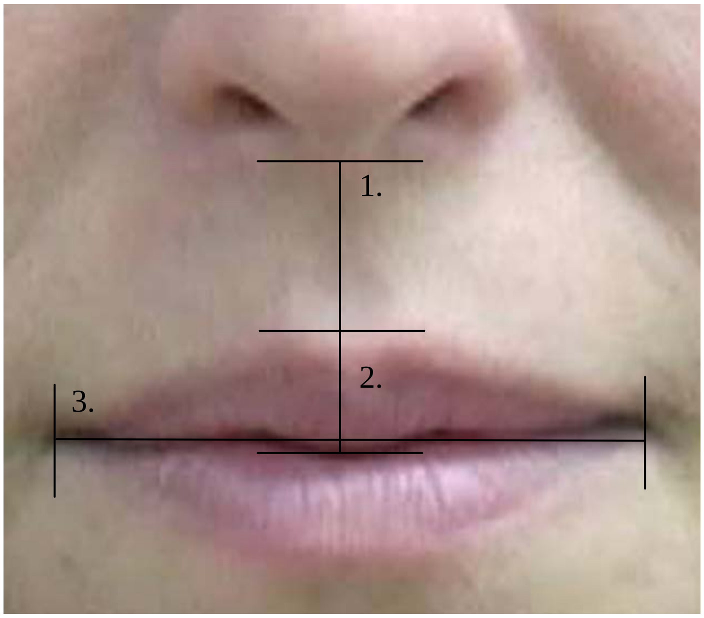
The video clip was then downloaded to a Gateway computer (E2000 P04) and uploaded to ScenalyzerLive 4.0 (Vienna, Austria) software, a video editing program. Each frame was analyzed and two frames were captured for the study. First, the one that represented the subjects lips at rest or relaxed lip position[58] and second, the frame representing the subjects' widest commissure to commissure posed smile. The captured frames were converted into a JPEG file by Scenanlyzer and then renamed within Microsoft Windows XP Professional with appropriate subject number and rest/smile frame (example: 1 rest, 1 smile, etc.).

Each file was opened in Adobe Photoshop CS2 (San Jose, CA) and adjusted using the millimeter ruler in the frame. The following procedure was used to adjust each picture. First, the resolution was changed to 300 pixels/inch by going to image>image size. Then, the ruler function was chosen on Adobe Photoshop CS2 and set to millimeter. It was determined which cross configuration millimeter ruler was most parallel to the camera lens. If neither ruler was parallel then the subject was excluded from the study. Then, on the parallel end of the ruler a 10 mm length, close to the smile area, was measured. That number was divided into 10 (10/measurement on JPEG file) and multiplied by the width value found in image size screen (image>image size). The resulting number was copied and pasted in place of the width reading and the changes were applied to the JPEG file. To check the accuracy of these steps the 10 mm area on the ruler was measured again. If done correctly, this measurement would read 10 mm and thus direct measurements could be recorded from that JPEG file. In Adobe Photoshop CS2 the following measurements were obtained and entered into Microsoft Excel:

**Measurements on Rest Frame (Figure 1)**

1. Upper lip length- from subnasale to stomion superius
2. Upper lip thickness- vertical distance from the most superior point of cupid's bow to the most inferior portion of the tubercle of the upper lip
3. Intercommissural width

Figure 1

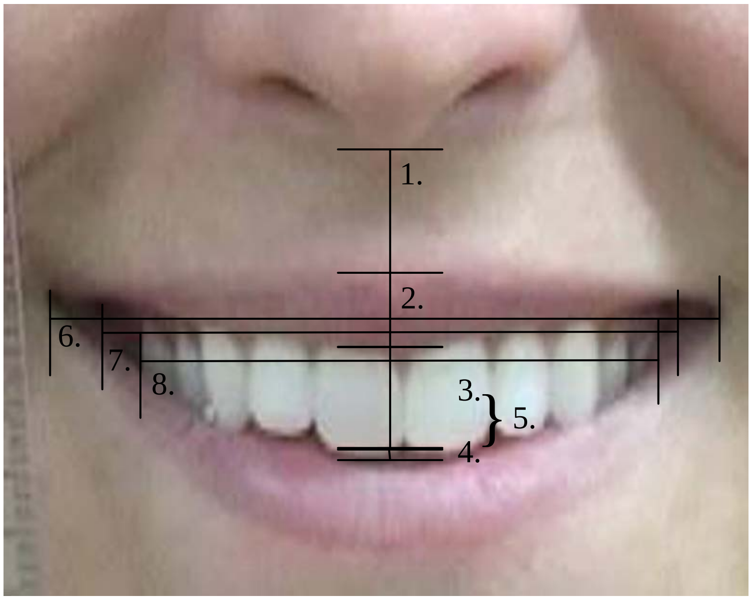



**Measurements on Smile Frame (Figure 2)**

1. Upper lip length- subnasale to stomion superius
2. Upper lip thickness- vertical distance from the most superior point of cupid's bow to the most inferior portion of the tubercle of the upper lip
3. Maxillary incisor display- stomion superius to maxillary incisor edge
4. Maxillary incisal edge to upper part of lower lip- stomion inferius to maxillary incisor edge
5. Interlabial gap at smile- direct measurement only taken if lower lip covers maxillary incisal edge, otherwise measurement #3 plus #4 is used
6. Outer intercommissural width
7. Inner intercommissural width
8. Visible maxillary dental width
9. The anterior smile height entered as high, average, low, or n/a (no dental display)

10. The curvature of the maxillary incisal edges and canine/premolar in relation to the lower lip line as parallel, flat, reverse, or n/a (lower lip covering maxillary incisor edge).

Figure 2




For the distance measurements, if the central incisors were not at the same levels two measurements were taken and the average used for that subject.

From the questionnaire the age (in years), sex (male or female), and history of orthodontic treatment (yes or no) were also entered in Excel. If the subject reported any anterior prosthodontic work or any history of lip surgery they were excluded from the study as per the exclusion criteria.

VI. Definitions

Tjan et al[13] described the smile height in three categories: (1) high - reveals the total cervicoincisal length of the maxillary anterior teeth and a contiguous band of gingiva, (2) average – reveals 75-100% of the maxillary anterior teeth and the interproximal gingival only, and (3) low- displays less than 75% of the anterior teeth. A fourth category to be introduced in this study is where smile height cannot be determined. They also described the curvature of the maxillary incisal edges and canine/premolar in relation to the lower lip line in three categories: (1) parallel- the maxillary incisal edges and cusp tips follow the curvature of the lower lip, (2) flat- the maxillary incisal edges and cusp tips display no curvature relative to lower lip line, and (3) reverse- the incisal edges and cusp tips have a reverse curve relative to lower lip line. A fourth category in this study is where the lower lip covers the maxillary incisal edges.

Yoon et al[17] described the smile arc parallelism of maxillary anterior incisal curve with the upper border of the lower lip by dividing into three categories: parallel, straight, and reverse. Parallel means that the incisal edges of the maxillary teeth are parallel to the upper border of the lower lip. Straight means that the incisal edges of the maxillary anterior teeth are in a straight line. Reverse means that the incisal edges of the maxillary anterior teeth curved in opposite direction compared to the upper border of the lower lip.

Moore et al[55] defined the buccal corridor as the difference between visible maxillary dentition width and inner commissure width divided by inner commissure width reported as a percentage. This percentage represents the amount of the inner commissure width occupied by the buccal corridor.

To quantify the frontal smile Ackerman et al[18, 19, 45] described smile index as the area framed by the lips during social smile. The smile index was determined by dividing the outer intercommissural width by the interlabial height during smile.

Vertical lip thickness was defined as the vertical distance from the most superior point of the peak of the lip to the most inferior portion of the tubercle of the upper lip.[59]

Many of these definitions have variations throughout the literature; however, those outlined above are used in this study.

## **Statistical Analysis**

I. Reliability

Two sets of reliability analyses were conducted. One set of analyses was conducted to obtain the Pearson correlation for time 1 and time 2 (one month apart) measurements recorded by the same rater. A second reliability analysis was performed to obtain the inter-rater reliabilities for 3 independent raters on measures of smile height and smile arc. The results are presented below.

A. Inter-rater Reliability Time 1 vs. Time 2

Pearson's correlations for the measurements taken by one rater at two points in time (1 month apart) were found to be highly acceptable, ranging from 0.84 to 0.99. The correlations between time 1 and time 2 for each item are presented below in Table 4.

Table 4. Inter-rater reliability (T1 vs T2)

| Smile Measure | Pearson's r |
|---|---|
| Upper Lip Length at Rest | 0.99 |
| Upper Lip Thickness at Rest | 0.99 |
| Intercommissural Width at Rest | 0.98 |
| Upper Lip Length at Smile | 0.98 |
| Upper Lip Thickness at Smile | 0.99 |
| Maxillary Incisal Display | 0.99 |
| Outer IC Width at Smile | 0.99 |
| Interlabial Gap Height at Smile | 0.99 |
| Smile Index (width/height) | 0.99 |
| Inner Commissural Width at Smile | 0.84 |
| Widest Dental Display at Smile | 0.97 |
| Percent Buccal Corridors | 0.88 |
| Change in Upper Lip Thickness | 0.98 |
| Change in Intercommissural Width | 0.98 |
| Change in Upper Lip Length | 0.96 |

Note: All correlations are statistically significant beyond the .001 level.

B. Inter-rater Reliability For Smile Height and Smile Arc

On average, the reliability across the 3 raters for smile height was 0.86, and the reliability for smile arc was somewhat lower at 0.68.

II. Analysis of Main Hypothesis

For all analyses an alpha level of 0.05 was used. A series of analyses of variance (ANOVAs) were conducted using age group (G1-G5) as the between-groups factor, with the dependent variables. To examine whether there were age differences in smile height and smile arc, $\chi^2$ (chi-square) analyses were conducted. Smile height and smile arc were measured on a categorical scale with four levels, while age represents an interval-level variable.

## **Results**

A series of analyses of variance (ANOVAs) were conducted using age group as the between-groups factor, with the dependent variables being upper lip length at rest, upper lip thickness at rest, intercommissural width at rest, upper lip length at smile, upper lip thickness at smile, maxillary incisor display at smile, interlabial gap at smile (height), smile index (ratio of width to height), percent buccal corridor, change in upper lip length (from rest to smile), change in upper lip thickness (from rest to smile) and change in intercommissural width (from smile to rest). Results are shown in Tables 5-9 below. For all analyses an alpha level of 0.05 was used. Table 10 displays the overall means for the various perioral measures.

Table 5. Rest Frame- Analysis results for measures by age group. Means, standard deviations (SD), p-values, and post-hoc results are displayed.

| Smile Measure | Age Group | Mean (mm) | SD | p-value | post-hoc |
|---|---|---|---|---|---|
| Upper Lip Length at Rest | 1 (15-19) | 21.58 | 3.16 | .477 | n/a |
| | 2 (20-29) | 21.70 | 2.87 | | |
| | 3 (30-39) | 22.25 | 1.92 | | |
| | 4 (40-49) | 22.02 | 3.47 | | |
| | 5 (50 and Over) | 22.69 | 3.12 | | |
| Upper Lip Thickness at Rest | 1 (15-19) | 7.87 | 1.94 | <.001 | A |
| | 2 (20-29) | 8.28 | 1.84 | | A |
| | 3 (30-39) | 8.38 | 1.59 | | A |
| | 4 (40-49) | 6.51 | 1.67 | | B |
| | 5 (50 and Over) | 6.25 | 2.15 | | B |
| Intercommissural Width at Rest | 1 (15-19) | 49.53 | 4.30 | 0.015 | A/C |
| | 2 (20-29) | 51.24 | 3.78 | | B/C |
| | 3 (30-39) | 51.56 | 3.84 | | B/C |
| | 4 (40-49) | 49.92 | 4.09 | | C |
| | 5 (50 and Over) | 52.24 | 4.43 | | B |
| Means with the same letter are not statistically different at the 0.05 level of significance. | | | | | |

*Upper Lip Length at Rest.* Table 5 shows an increasing pattern of the upper lip length at rest of about 1.11 mm from age groups 1 to 5; however, this finding did not reach an acceptable level of statistical significance.

*Upper Lip Thickness at Rest.* Age groups 1, 2, and 3 have similar average lip thickness at rest, but these groups have larger lip thickness at rest than do age groups 4 and 5. Age groups 4 and 5 also appear to have similar average lip thickness measures at rest. The analysis confirms these observations. Overall, there are significant age related differences in lip thickness at rest ($F(4,216) = 11.85$, $p < .001$). Fisher's LSD post-hoc tests further reveal that groups 1, 2, and 3 exhibit significantly longer lip thicknesses at rest than do either groups 4 ($p < .001$) or 5 ($p < .001$). There were no significant differences in lip thickness at rest between groups 1, 2, and 3 or between groups 4 and 5.

*Intercommissural Width at Rest.* Overall, differences in intercommissural width at rest across the age groups is significant ($F(4,216) = 3.15$, $p = .015$). Post-hoc analysis (Fisher's LSD method used to compare pair-wise differences) indicates that age group 1 exhibits significantly smaller intercommissural width at rest than age groups 2 ($p = .028$), 3 ($p = .025$), and 5($p = .004$). Groups 2, 3, and 5 do not significantly differ from each other. Further, age group 4 exhibits significantly smaller intercommissural width at rest than does age group 5 ($p = .017$). No other differences were significant.

Table 6. Smile Frame- Analysis results for measures by age group. Means (mm), standard deviations (SD), p-values, and post-hoc results are displayed.

| Smile Measure | Age Group | Mean (mm) | SD | p-value | post-hoc |
|---|---|---|---|---|---|
| Upper Lip Length at Smile | 1 (15-19) | 16.84 | 2.94 | 0.061* | A |
| | 2 (20-29) | 16.83 | 2.53 | | A |
| | 3 (30-39) | 17.06 | 2.16 | | A* |
| | 4 (40-49) | 17.74 | 2.83 | | B |
| | 5 (50 and Over) | 18.30 | 2.78 | | B/C |
| Upper Lip Thickness at Smile | 1 (15-19) | 6.26 | 1.81 | .002 | A/B |
| | 2 (20-29) | 6.72 | 1.89 | | B |
| | 3 (30-39) | 6.61 | 1.74 | | B |
| | 4 (40-49) | 5.61 | 1.71 | | A/C |
| | 5 (50 and Over) | 5.39 | 2.09 | | C/D |
| Maxillary Incisor Display at Smile | 1 (15-19) | 8.76 | 1.90 | 0.001 | A |
| | 2 (20-29) | 9.02 | 2.12 | | A |
| | 3 (30-39) | 9.29 | 2.28 | | A |
| | 4 (40-49) | 7.62 | 2.27 | | B |
| | 5 (50 and Over) | 7.14 | 2.55 | | B |
| Interlabial Gap Height at Smile | 1 (15-19) | 12.00 | 2.83 | <.001 | A |
| | 2 (20-29) | 10.42 | 2.77 | | B |
| | 3 (30-39) | 10.70 | 2.85 | | B |
| | 4 (40-49) | 8.50 | 2.86 | | B/C |
| | 5 (50 and Over) | 9.01 | 3.03 | | B/C |
| Smile Index | 1 (15-19) | 5.63 | 1.67 | <.001 | A |
| | 2 (20-29) | 6.73 | 2.09 | | B |
| | 3 (30-39) | 6.55 | 2.19 | | A/B |
| | 4 (40-49) | 8.39 | 3.90 | | C |
| | 5 (50 and Over) | 8.05 | 3.98 | | C |
| Percent Buccal Corridor | 1 (15-19) | 10.82 | 4.77 | 0.02 | A/C |
| | 2 (20-29) | 11.25 | 5.40 | | A/C |
| | 3 (30-39) | 11.77 | 4.56 | | C |
| | 4 (40-49) | 13.53 | 5.69 | | B/C |
| | 5 (50 and Over) | 14.04 | 5.39 | | B/C |
| Means with the same letter are not statistically different at the 0.05 level of significance. Marginal significance (p=0.061) | | | | | |

*Upper Lip Length at Smile.* There were marginally significant differences (p=0.61) in upper lip length at smile (ULLS) between the five age groups. The pattern of findings suggests that the two youngest age groups had about the same ULLS, the two middle age groups had slightly larger ULLS than the youngest groups, and those 50 years of age or older had the largest average ULLS. Pair-wise post-hoc analyses using Fisher's LSD method were conducted to further specify the findings. These analyses indicated that age group 5 had significantly higher ULLS measures than did age group 1 (p = .018), age group 2 (p = .012), and were marginally higher than age group 3 (p = .061). No other differences were significant.

*Upper Lip Thickness at Smile.* The same general pattern of results found earlier with lip thickness at rest was also evident from the results of the analysis of lip thickness at smile. Overall, age differences in this measure were significant (F(4,216) = 4.28, p = .002). Fisher's LSD post-hoc tests reveal that age group 1 has significantly more lip thickness than age group 5 (p = .041); that age group 2 has significantly more lip thickness than either age group 4 (p = .003) or age group 5 (p = .001); and that age group 3 also has significantly more lip thickness than either age group 4 (p = .019) or age group 5 (p = .008).

*Maxillary Incisor Display.* Maxillary incisor display (MID) differed significantly as a function of age. The pattern of results in Table 6 suggests that there is generally higher MID in the first 3 age groups, as compared to age groups 4 and 5. Fisher's LSD post-hoc analysis confirmed that age group 1 had higher MID than either age group 4 (p = .029) or group 5 (p = .004), that age group 2 was also higher in MID than age group 4 (p = .007) or age group 5 (p = .001), and that age group 3 was higher than group 4 (p = .005) and group 5 (p = .001). Groups 1, 2, and 3 did not significantly differ from one another. The difference in MID between groups 4 and 5 was not significant either.

*Interlabial Gap Height*. There were significant differences in interlabial gap height (IGH) among the age groups. The results presented in Table 6 suggest that IGH was generally higher among the first 3 age groups compared to groups 4 and 5. Pair-wise differences using Fisher's LSD procedure indicates that group 1 was significantly higher in IGH than group 2 ($p = .004$), group 3 ($p = .042$), group 4 ($p < .001$), and group 5 ($p < .001$). Further, group 2 was significantly higher than either group 4 ($p = .001$) or group 5 ($p = .028$); groups 2 and 3 do not differ significantly, however. Group 3 was also significantly higher in IGH than group 4 ($p = .001$) or group 5 ($p = .020$). The IGH difference between groups 4 and 5 was not statistically significant.

*Smile Index.* The age groups also significantly differ with respect to the smile index. Fisher's LSD post-hoc tests indicate that group 1 has a significantly lower average smile index than either group 2 ($p = 037$), group 4 ($p < .001$ ) or group 5 ($p < .001$). Group 2 also has a significantly lower smile index than either group 4 ($p = .003$) or group 5 ($p = .034$). Group 3's average smile index is also significantly lower than group 4 ($p = .005$) or group 5 ($p = .032$). The differences between groups 1 and 3, groups 2 and 3, and groups 4 and 5 were not statistically significant.

*Percent Buccal Corridor.* There were significant differences in percent buccal corridor (PBC) measures among the age groups. There was a generally increasing pattern in PBC as a function of age that is evident in Table 6. Fishers's post-hoc tests revealed that group 1's average PBC was significantly lower than group 4 ($p = .015$) or group 5 (p =

.009). Similarly, group 2 had lower PBC than either group 4 (p = .030) or group 5 (p = .018). No other differences were significant.

Table 7. Analysis results for dynamic measures by age group. Means (mm), standard deviations (SD), p-values, and post-hoc results are displayed.

| Smile Measure | Age Group | Mean (mm) | SD | p-value | post-hoc |
|---|---|---|---|---|---|
| Change in Upper Lip Length | 1 (15-19) | 4.74 | 1.84 | .188 | n/a |
| | 2 (20-29) | 4.88 | 1.72 | | |
| | 3 (30-39) | 5.20 | 1.92 | | |
| | 4 (40-49) | 4.28 | 1.97 | | |
| | 5 (50 and Over) | 4.40 | 1.83 | | |
| Change in Upper Lip Thickness | 1 (15-19) | 1.61 | 1.10 | .002 | A |
| | 2 (20-29) | 1.56 | 1.51 | | A |
| | 3 (30-39) | 1.77 | 1.49 | | A |
| | 4 (40-49) | 0.90 | 1.02 | | B |
| | 5 (50 and Over) | 0.86 | 1.03 | | B |
| Change in Intercommissural Width | 1 (15-19) | 13.86 | 4.43 | <.001 | A |
| | 2 (20-29) | 13.63 | 3.41 | | A |
| | 3 (30-39) | 12.88 | 4.81 | | A |
| | 4 (40-49) | 11.01 | 3.09 | | B |
| | 5 (50 and Over) | 10.68 | 3.75 | | B |
| Means with the same letter are not statistically different at the 0.05 level of significance. | | | | | |

*Change in Upper Lip Length.* There was a generally increasing pattern of change in upper lip length until age group 3 after which the change in upper lip length decreases significantly (p=.030) to age group 4 and remains lower for age group 5. The post-hoc analysis revealed that there is no statistically significant difference between the age groups on measure of change in upper lip length.

*Change in Upper Lip Thickness.* The data show age groups 1, 2, and 3 exhibit similar changes in lip thickness at smile, as do age groups 4 and 5. Further, the first 3 age groups appear to have larger changes in lip thickness from rest to smile than do the two older groups. Analysis confirms these observations. Overall, age differences in change in lip thickness from rest to smile was significant (F(4,216) = 4.28, p = .002). Further, Fisher's

LSD post-hoc tests show that age groups 1, 2, and 3 have significantly larger changes in lip thickness from rest to smile than do groups 4 and 5 (all p-values $< .05$). Differences between groups 1, 2, and 3 are not significant. Differences between groups 4 and 5 are also not significant.

*Change in Intercommissural Width.* Significant differences in change in intercommissural width (CICW) were evident between age groups; however, a post-hoc analysis (Fisher's LSD procedure) reveals that age groups 1, 2, and 3 exhibit significantly larger CICW as compared to age groups 4 and 5. There were no significant differences in CICW between age groups 1, 2, and 3 or between age groups 4 and 5.

*Correlation between Upper Lip Length at Rest and Maxillary Incisor Display on Smile.* The correlation between upper lip length at rest and the amount of maxillary incisor displayed during smiling was not significant ($r(174) = .025$, $p = .738$). There was no evidence that upper lip length at rest was associated with the amount of maxillary incisor displayed during smile.

To examine whether there were age differences in smile height and smile arc, $\chi^2$ (chi-square) analyses were conducted. Smile height and smile arc were measured on an ordinal scale with four levels, while age represented an interval-level variable. For all analyses an alpha level of 0.05 was used.

Table 8. Smile Height- Percentages of subjects in 5 age groups at various measures. (p=.001)

| | Age Group | | | | | |
|---|---|---|---|---|---|---|
| Smile Height | 1(15-19) | 2(20-29) | 3(30-39) | 4(40-49) | 5(50+) | Total % (n) |
| High | 20.4 | 25.0 | 26.5 | 10.0 | 0.0 | 17.6 (39) |
| Average | 79.6 | 71.9 | 70.6 | 77.5 | 79.3 | 73.8 (163) |
| Low | 0.0 | 3.1 | 2.9 | 12.5 | 20.7 | 6.3 (14) |
| No dental display | 0 | 0 | 2.9 | 4.8 | 6.5 | 2.3 (5) |

*Smile Height.* Age was found to be significantly associated with smile height ($\chi^2(12) = 32.23$, p = .001). The pattern in Table 8 indicates that, generally, younger age groups (1, 2, and 3) were more likely to have a higher smile height than the older age groups (4 and 5). Moreover, older subjects (group 5) were more likely to exhibit low smile height than the other 4 age groups. Of the very small percentage of subjects who fall into the no dental display category of smile height, none were observed in age groups 1 or 2.

Table 9. Smile Arc- Percentages of subjects in 5 age groups at various measures. (p=.005)

| | Age Group | | | | | |
|---|---|---|---|---|---|---|
| Smile Arc | 1(15-19) | 2(20-29) | 3(30-39) | 4(40-49) | 5(50+) | Total % (n) |
| Parallel | 57.1 | 69.8 | 55.2 | 56.7 | 37.5 | 48.4 (107) |
| Flat | 42.9 | 22.6 | 41.4 | 36.7 | 58.3 | 31.7 (70) |
| Reverse | 0.0 | 7.5 | 3.4 | 6.7 | 4.2 | 3.6 (8) |
| Lower lip covers MIE | 0.0 | 17.2 | 17.1 | 28.6 | 22.6 | 16.3 (36) |

MIE= maxillary incisal edge

*Smile Arc.* Smile arc and age were associated ($\chi^2(12) = 28.40$, p = .005); generally, about the same percentage of parallel, flat, and reverse smile arcs were noted within each of the 5 age group categories. However, Table 9 shows that of those with lower lip covering maxillary incisal edge, there was a higher percentage in age group 4 and 5 than in the other 3 age groups, specifically none in the youngest age group.

Table 10. The overall means for various perioral measures. Means (mm) and SD are displayed.

| Smile Measure | Mean (mm) | SD |
|---|---|---|
| Upper Lip Length at Rest | 21.96 | 2.97 |
| Upper Lip Thickness at Rest | 7.58 | 2.01 |
| Intercommissural Width at Rest | 50.80 | 4.14 |
| Upper Lip Length at Smile | 17.25 | 2.70 |
| Upper Lip Thickness at Smile | 6.20 | 1.90 |
| Maxillary Incisal Display | 8.52 | 2.28 |
| Interlabial Gap Height at Smile | 10.27 | 3.08 |
| Smile Index (width/height) | 6.94 | 2.91 |
| Percent Buccal Corridors | 12.04 | 5.29 |
| Change in Upper Lip Length | 4.72 | 1.85 |
| Change in Upper Lip Thickness | 1.38 | 1.31 |
| Change in Intercommissural Width | 12.65 | 4.07 |

## Discussion

This study was undertaken to analyze the age related changes of a human smile. To get a better idea of age related changes a long-term prospective longitudinal study would be ideal. The current literature has numerous studies on the smile, anterior dental display, and smile esthetics; however, most have been done using static pictures or direct measurements.[3-5, 9-17, 47, 55, 56] A major drawback of using static pictures is the inability to know if the researcher has captured the intended frame in that one snapshot. To overcome this difficulty, recently, the use of digital video has been introduced in the orthodontic literature.[18-20] Now researchers have the ability to be precise by choosing from about 150 frames (for a 5 second video at 30 frames per second).

Reliability analysis of the results indicates that the measures ranged from substantial to outstanding.[60] Smile arc had a reliability score of .68 between the three raters; this is due to the subjective nature of determining a smile arc. Smile height also has a level of subjectivity when determining if a smile is average or low. For the other measures (Table 4) the commissural measures had the least reliability because often there was wrinkling at the commissure, especially in older individuals.

Skeletal and soft tissue cellular changes are known to occur in the aging human.[21, 24-33] Age related changes to muscle structure and function have also been described.[34-39] Other researchers have studied the age related changes as they pertain to lip length and maxillary incisor exposure; however, to our knowledge this is the first study to examine a comprehensive list of smile parameters with respect to age. It serves to advance the knowledge base of age related changes with the lips at rest, the lips while smiling, and the dynamic relationship between the lips at rest and smiling. Analyzing the literature which addresses the attractiveness of a smile with the results of this study and others that detail age related changes will prove to be an invaluable tool for the orthodontist. The smile parameters examined were maxillary incisor display on smile, upper lip length at rest, upper lip length at smile, interlabial gap height at smile, smile index, percent buccal corridor, intercommissural width at rest, change in upper lip length, change in intercommissural width, smile height, and smile arc. With the results of this study the orthodontist has a better understanding of how perioral structures change with age.

For maxillary incisor display at smile our results (Table 6) show a significant decrease after 40 years of age. Compared to 30-39 year old group there was a significant decrease of 1.67 mm and 2.15 mm in the 40-49 year old and 50 years and older groups, respectively. Similarly, Choi et al[17] and Vig et al[47] reported that maxillary incisor display at rest decreased with increasing age. Vig et al[47] noted a decrease in maxillary incisor exposure of about 3.41 mm from the less than 29 years old group to the over 60 years old group. Choi et al[17] examined both maxillary incisor display at rest and smile. They described a decrease in maxillary incisor display of about 2.5 mm at rest and 2 mm at smile between the 20-29 year old age group and the 60-69 year old age group.

Relaxed-lip posture is a muscle-determined position; therefore, it cannot have the reproducibility that is associated with measurements on hard structures. The recording of lip posture is further complicated by the fact that we are dealing with muscles innervated by the seventh cranial nerve. The seventh nerve is closely associated with the autonomic nervous system and has connections at a higher level with the hypothalamus, which means that emotional state can strongly influence the contraction or lack of contraction of the muscle fibers of the lip. With care the investigator or clinician can obtain records of the relaxed-lip position that are relatively reproducible.[58] Every attempt was made to ensure that both frames for each subject were not affected by emotional input.

For upper lip length at rest our results (Table 5) indicate an increasing trend from the youngest to oldest age group of 1.11 mm, although it was not statistically significant. Formby et al[7] showed an increase of 0.83 mm from 18 to 42 years of age. Furthermore, the overall average lip length (Table 10) was found to be 21.96 mm. This confirms previous research by Peck et al[14] at 22.3 mm and Burstone[58] at 20 mm for girls and 24 mm for boys.

In our study we attempted to correlate the upper lip length at rest to the amount of maxillary incisor display at rest. Our results show that there was no correlation for upper lip length at rest and the amount of maxillary incisor display at smile. This was in agreement with Peck et al[14] who looked at North American white subjects with a mean age of 14.4 years and compared the lip length at rest between those with a gingival smile and the reference group. Conversely, Singer[61] and Peck et al[16] found that those with gingival smiles had slightly longer lips at rest. Since upper lip length at rest was not related to maxillary incisal display at smile, what could be the cause of the decreased smiling maxillary incisal display?

The change in upper lip length, intercommissural width, and upper lip thickness are novel concepts introduced in this research. These measures relate lip measurements at rest and smiling. These measures give insight into the inherent activity of the facial muscles involved in raising and widening a smile. The data in Table 7 show that the change in upper lip length from rest to smile tends to get slightly larger on average from the 15-19 year old group through the 30-39 year old group by 0.46 mm. Then, there was a decrease in this measure for the 40-49 year old group by 0.92 mm compared to the 30-39 year old group and 0.46 mm compared to the 15-19 year old group. This decrease suggests that at about 40 years of age the there was a decrease in the muscles' ability to raise the upper lip by 0.46-0.92 mm. Also, the lips at rest lengthen on average 1.11 mm between the 15-19 and the 50+ year old groups. Combining both results the incisors in relation to the lips will have 1.57-2.03 mm less display on smiling as the person ages. This contributes greatly to the aged look of maxillary anterior teeth hidden by the upper lip during smile.

McNamara et al[59] recently found the vertical upper lip thickness to be the most influential variable in smile esthetics. Our study showed that lip thickness at rest (Table 5) and smile (Table 6) decreased 1.62 mm and 0.87, respectively between the 15-19 year age group to the 50 year and over group. This decrease in thickness quantifies the empirical observations of thinning lips by many researchers and practitioners. The overall average lip thickness at rest and smile (Table 10) are 7.58 mm and 6.2 mm.

Ackerman M.B. and Akerman J.L.[18] introduced smile index as a soft tissue determinant of a smile. The smile index is the smile width divided by the smile height (interlabial gap height). Our findings (Table 6) show that interlabial gap height significantly decreases with age, from 12 mm (15-19 year old group) to 9.01 mm (50 years and older group). As a result of this the smile index increases between the same age groups. These data provide evidence that as the person ages the smile tends to get relatively wider transversely and narrower vertically.

Buccal corridor is an interesting aspect of a smile and is mentioned often in the literature but with varying definitions. Regardless of the definition used one must be aware of the lighting as it affects the researcher's ability to differentiate between the inner and outer commissures.[18] In this study, every attempt was made to keep ambient lighting constant. The results in Table 6 show that the percent of buccal corridor increases with age. Specifically, in the 15-19 year old group the average percent buccal corridor was 10.82% while the 50 years and older group the average was 14.04%. This change is in line with the previously mentioned results for smile index which shows that the aging smile gets wider transversely and narrower vertically. Interestingly, Hulsey[11] found that the buccal corridor ratio appeared to be of no significance to an attractive smile. Moore et al[55] recently studied the influence of the buccal corridor on smile esthetics on digitally altered smiling images by lay people. Contrary to Hulsey's finding, these results showed that a broader smile (minimal buccal corridors) was rated as most attractive. Parekh et al[56] found excessive buccal corridors to be rated as less attractive by both orthodontists and laypersons.

The data in Table 5 show that the intercommissural width at rest increased with age by 2.71 mm from the 15-19 year old group to the 50 years old and over group. This increase could be due to loss of skin elasticity and volume which increases the wrinkles at the corners of the lip. Generally, wrinkles at the corners of the lips at rest create a situation where it was difficult to identify the commissures. In these situations the anatomical information from the smiling picture proves useful.

The change in intercommissural width also decreased with age (Table 7). From the 15-19 year old group to the 50 and over group this measure decreased by 3.18 mm.

This would seem to contradict the results showing an increase in percent buccal corridor; however, the resting intercommissural width increased with age by 2.71 mm. Consequently, these results are consistent with the idea that activity and function of muscles involved in the smile decrease with age.

The results for change in lip thickness (Table 7) continued to provide evidence of decreased muscle action as the amount of change in lip thickness decreases with age. This value decreases by about 0.75 mm. A possible area of future research is to study the effect of flaring incisors on lip thickness.

For smile height, the most profound finding was inversion of the data (Table 8) from age group 1 to 5. In addition, our data in Table 8 showing 73.8% of subjects displaying average anterior smile height are higher than other reports; however, it supports the data that average anterior smile height was the most common finding. Tjan et al[13], Yoon et al[17], and Maulik et al[62] all reported that average anterior smile height to be most common (68.9%, 56%, and 56.9% respectively). Table 8 also shows that about 5 subjects (2.3%) did not show their teeth to the extent where smile height could not be calculated. This value increased with increasing age. With regards to the esthetics of anterior smile height, Hulsey[11] found that the most attractive smile had the upper lip at the height of the gingival margin of the upper central incisors (average smile height in this study was defined as 75-100% of incisor display). Kokich et al[63] found that 3 mm of gingival display was rated unattractive by layperson and orthodontists.

Smile arc is highly dependent on the head posture (angle of elevation) as the head moves and the conversational distance.[46, 64] Every effort was made to keep the subjects apparent occlusal plane parallel to the camera. Our results in Table 9 found parallel smile arc to be the most common at 48.4%. This agrees with the data put forth by Tjan et al[13], Yoon et al[17], and Owens et al[10] who reported 84.8%, 60%, and 74% respectively. Contrarily, Maulik et al[62] found flat smile arc to be most common at 49%. This difference could be due to the subjective nature of the smile arc measurement. Our finding of 3.6% of subjects presenting with a reverse smile arc was consistent with the previous literature. Tjan et al[13], Yoon et al[17], and Maulik et al[62] all found reverse smile arc to occur in 1.32%, 5%, and 10% respectively. All three of the studies mentioned above agree with our findings that reverse smile arc was the least common finding. Interestingly, Table 9 suggests that as people age they are more likely to smile with the lower lip covering the maxillary anterior incisal edges. As people age they become more self conscious of their dentition not wanting to show their teeth, creating a situation where the smile arc and height can't be determined. For our sample 13.3% of the subjects presented with lower lip covering maxillary incisal edges during their smile frame. This was very similar to Tjan et al[13] and Yoon et al[17] both of whom found 15.76% and 10% of their subjects with the incisal portions of the anterior teeth covered by the lower lip.

The orthodontist must keep in mind that sometimes esthetic results cannot be achieved without including hard and soft tissue surgical changes.[2, 30] Caution must be taken to carefully examine the lips at rest and smile while diagnosing the etiology of a high/low lip line because the resulting treatments would be different. When diagnosing a case it should be noted if the absolute length of the lips is too short or long. If either of these situations was seen surgery may be necessary to correct the length of the lips to create the proper lip-tooth relationship. The age-related perioral changes are called senile lip changes. These changes highlight the importance of having age related norms introduced as a reference for treating patients. With age the lips undergo a number of predictable changes that affect the dental display. Atrophy of the muscles and fat occurs to decrease lip volume, loss of lip architecture, and lip lengthening. To correct these senile changes specific soft tissue fillers are injected in precise locations to remedy the loss of architecture and/or volume. It may also be necessary to have a surgical lip lift procedure to correct the lip lengthening.[22, 65-67]

In this study no correlation was found between the upper lip length at rest and the amount of maxillary incisor displayed during smile. Since the absolute length appears not to be correlated a more significant factor could be the activity of the muscles involved in creating the smile. This leads to situations where the upper lip is of normal length but has either hypermobility or hypomobility. In either case, the amount of maxillary incisor displayed during smile would be affected. A recent study used botox to treat excessive gingival display due to hypermobility of upper lip on smiling. Although this study showed effectiveness of the procedure it was transitory and predicted to return to base line at about 30 to 32 weeks.[42] If the lips are of normal length but hypomobile it is prudent to implement the smile exercises outlined by Gibson.[43, 68] The effect of these isometric and isotonic exercises have been studied and the results show that they are effective in improving the attractiveness of the smile; however, the effects last only as long as the smile exercises are continued.[17]

As cross-sectional study design there are inherent drawbacks. Also, as the data were collected in the orthodontic department it was difficult to get a larger sample size in the older age group. Horizontal tooth wear of maxillary anterior teeth is a continuous phenomenon. [69] We tried to control for excess dental attrition by including it in the exclusion criteria. No subjects were removed from the study for this specific reason as it was difficult to assess without a thorough clinical exam. This lack of consideration to dental attrition could have affected the results.

A majority of the orthodontic diagnosis and treatment planning is done during late childhood to early adolescent years. Dental retention is important to maintain the final results; however, with the results of this study the orthodontist can deliver results that truly last a lifetime. Sarver and Ackerman[2] state that esthetic considerations are paramount in treatment planning; however, rigid rules cannot be applied to this process because almost an infinite variety of faces could be esthetic. As norms for beauty do not exist, the orthodontist must have an eye for beauty, hand skills for art, and knowledge of an individual's anatomical smile window. Accordingly, it is important to have general guidelines that aid the clinician to optimize dentofacial esthetics, while satisfying other treatment goals. Since time has been introduced as the fourth dimension of treatment planning long-term knowledge of dentofacial changes are paramount to clinical success.[19, 20] The results from this research provide the orthodontist with confidence, knowledge, and understanding of how the perioral soft tissue changes with age. It's important for the clinician to work within these changes. This study quantifies many aspects of smile changes that were assumed in the past. Thus, knowledge into how the smile changes with age can help the orthodontist deliver healthier, long-lasting results.

## Conclusion

Future studies could be set forth to evaluate the attractiveness of measures that have not been widely studied including, but not limited to, smile index, lip thickness, and the lower lip covering the maxillary incisor edges. The conclusions of this study are:

1. Upper lip length at rest lengthens as the person ages by 1 mm. This lengthening along with the decrease in change of the upper lip length from rest to smile result in a significant decrease in maxillary incisor display at smile of 1.5 to 2 mm with increase in age.
2. From the 15-19 year old group to the 50 and over group the upper lip thickness at rest and smile decreased significantly by about 1.5 mm.
3. Smile index significantly increased indicating as the person ages the smile gets narrower vertically and wider transversely.
4. For all three dynamic measures there was a pattern of decreasing change from rest to smile especially evident after the 30-39 year old age group. This indicates that the muscles' ability to create a smile decreases with increasing age.
5. No subjects in the 50 and over age group displayed a high smile while no subjects in the 15-19 year old group displayed a low smile. Most (78%) subjects displayed an average smile height.
6. A majority of the subjects had parallel and flat smile arcs, 48.4% and 31.7% respectively.

## **Appendix A**

Questionnaire: A Dynamic Smile Analysis in Young Adult Individuals
Shyam Desai, DMD
Department of Orthodontics
University of Connecticut Health Center

Subject #

Age

| | | |
|---|---|---|
| Sex | Male | Female |
| Have you ever had orthodontic treatment? | YES | NO |
| If yes to above, | | |
| Have you had maxillary expansion? (RPE, rapid palatal expansion) | YES | NO |
| Have you had teeth removed for orthodontic treatment? | YES | NO |
| Have you ever had any facial surgery? | YES | NO |
| If yes to above then where? | | |
| Have you ever had prosthodontic treatment? | YES | NO |
| If yes to above, | | |
| Did you ever have any crowns, bridges, veneers, dentures, or partial dentures? | YES | NO |

If yes, point to where they are. ____________________________________

____________________________________________________________

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