

PERCEPTION OF ATTRACTIVENESS OF LIP FULLNESS: A STUDY
COMPARING 2-DIMENSIONAL VERSUS 3-DIMENSIONAL IMAGES

Kris H. Kim, D.D.S.

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Abstract

Introduction: The majority of studies on the perception of facial esthetics in orthodontics have been done using 2-dimensional (2D) silhouettes and outlines. Some others have used 2D photographic images to analyze perception of facial esthetics. At this time, there is lack of information on facial esthetic perception when 3-dimensional (3D) images are projected and analyzed.

Purpose: The purpose of this study is to determine if there is a difference in perception of attractiveness of differing lip fullness when faces are viewed in 2D vs. 3D.

Materials and Methods: The lip fullness of 3 patients was manipulated to produce 5 different grades of lip fullness. They were -6 mm, -3 mm, 0 mm, +3 mm, and +6 mm of lip protrusion or retrusion from the unaltered images. These manipulated images were made into a set of 2D profile images, and a set of 3D movie files. One hundred Caucasian female subjects, 40 orthodontic residents, and 5 orthodontic faculty members were surveyed. They were asked to rank the 2D and the 3D images in the order of most attractive to least attractive. The ranks for the 2D and the 3D images were compared. **Results:** There was significant difference ($P < 0.05$) in preference of lip

fullness for each of the patients both in 2D and 3D. However, in general, neutral to more protruded lips were preferred when laypersons were shown images in 2D, versus neutral to more retruded lips were preferred when they were shown images in 3D. Orthodontic residents and faculty on the other hand, seem to prefer more retruded lips in 2D and 3D compared to the lay public. **Conclusion:** Statistical comparison between the 2D and the 3D images were not possible because the rankings among the subjects had large variability.

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COMMITTEE IN CHARGE OF CANDIDACY:

Professor Rolf Behrents,
Chairperson and Advisor

Professor Eustaquio Araujo

Assistant Professor Ki Beom Kim

Assistant Clinical Professor Donald Oliver

DEDICATION

To my parents, who have supported me through all my education. I am extremely grateful for their hard work and sacrifice.

To my husband, Tae, who has been my mentor and my friend. His wisdom, personal strength and love, has been the greatest influence. He has changed my life.

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CHAPTER 1: INTRODUCTION

An improvement in soft tissue facial esthetics in orthodontics is one of the most important goals of treatment. As a consequence, many studies have been performed to understand the different characteristics of soft tissue. These include the different architecture of soft tissue in different individuals, soft tissue profile norms for populations, the response of the soft tissue to orthodontic treatment, and the interrelationship of the nose, chin, and lips in achieving harmonious soft tissue profiles.

It is just as important to study the perception of soft tissue esthetics as it is to study the actual physical characteristics of the soft tissue. Perception of facial beauty may differ among different populations, and may change with time.

The aim of this study is to further the current understanding of perception of facial beauty in the specialty of orthodontics.

CHAPTER 2: LITERATURE REVIEW

Beauty and Social Acceptance

Attractiveness can be an asset that sustains with an individual throughout their lives. Studies have shown that attractive men and women earn more income,¹ and teachers of attractive students have higher expectations of those students' IQ and performance.²

Orthodontic treatment has a significant effect on the esthetics of the lower half of the face.^{3,4} Therefore, it is important for clinicians to understand what people perceive as attractive so that patients can be treated to appropriate treatment goals.

Holdaway⁵ advised that as orthodontists we have a responsibility to give our patients the best possible facial balance and harmony, and that "we must also be concerned about doing this early enough in a child's development so that no permanent poor self-image concepts are acquired before we customarily begin our orthodontic corrections."

History of Orthodontic Diagnosis and Treatment Goals

In the early 1900s, Angle advocated that the main goal of orthodontics was to achieve an ideal Class I occlusion with a full complement of teeth.⁶ He believed that if the

teeth were in good occlusion then facial esthetics and harmony would follow.

Tweed,⁷ a student of Angle, became dissatisfied with the facial esthetics of patients previously treated to Angle's philosophy of full complement of teeth. Tweed stated that "Angle's philosophy of treatment was neither scientific nor clinically sound and that changes had to be made in treatment procedures." He suggested that facial esthetics is directly related to attaining upright mandibular incisors over the basal bone. He also recognized that for many of his patients, this was not possible without the removal of teeth.

In 1931, Broadbent⁸ introduced a method of standardization of the cephalometric radiographic technique. This caused a shift in emphasis to hard tissue analysis, diagnosis, and treatment goals based on hard tissue relationships.⁹ It was not until two decades later, that there was an increasing interest in evaluation of the soft tissue characteristics.¹⁰⁻¹³ In 1950, Riedel¹³ suggested that the "prime objectives in orthodontic treatment are directed towards improvements in function, improvements in esthetics, and the maintenance of these improvements." Riedel¹³ studied soft tissue profile outlines of the soft tissue from lateral cephalometric

radiographs of orthodontically treated and non-treated children and adults. These profile outlines were then evaluated by 88 orthodontists. He concluded that those profiles judged as having "good" faces had A point, B point, and upper and lower incisors in a "harmonious" relationship to each other.

In 1956, Downs¹¹ developed a simple technique of acquiring better soft tissue profile contours on the lateral cephalometric radiograph that could aid in soft tissue analysis. He suggested cutting an Eastman no-screen film into four strips and placing one strip in the cassette ahead of the front intensifying screen in the region of the soft tissue profile.

In the late 1950s, Burstone¹⁰ began to question the previously held notion that harmonious hard tissue relationships will result in "good" faces. He showed an example of patients (Figure 2.1) with similar dentoskeletal relationships, however, showing very dissimilar soft tissue profiles due to differences in soft tissue thickness and architecture. Burstone argued that soft tissue profile could be predicted from hard tissue "only if soft tissue formed a uniform veneer over teeth and bone." Because of the wide variability of soft tissue contours and thickness, it is important to study the soft tissue directly rather

than to place emphasis on the hard tissue architecture and making diagnosis and treatment planning decisions based on the hard tissue alone.

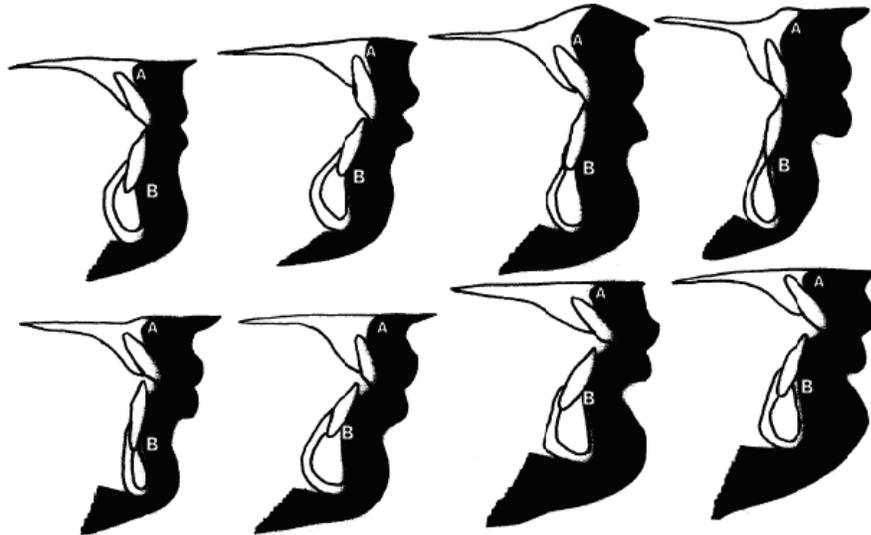


Figure 2.1 Different soft tissue architecture of patients with similar dentoskeletal relationships. (Modified from Burstone¹⁰)

In an attempt to answer the following question, “do the teeth push the lips out into varying position? Or do the lips have a posture of their own independent of tooth position?,” Burstone⁴ studied a sample of edentulous young adult patients. Special bite rims were constructed that maintained the vertical dimension of the patients, however the anterior portions of the bite rims were cut away to make certain the wax provided no support for the lips. He found that subjects had normal to slightly retruded lips that seem to be in a position that was independent of teeth

and the supporting alveolar process. The lips did not fall back to contact the bite rim. He deduced that the sunken in lips seen in older edentulous patients may be a result of changes in the aging soft tissue as well as other factors.

In 1986, Park and Burstone¹⁴ studied thirty orthodontically treated patients who had lower incisors positions 1.5 mm anterior to the A-pogonion plane. They found that there was a large variation in the facial profiles even in cases treated to a cephalometric dentoskeletal standard. Therefore, treatment plans that are focused on the hard tissues only, may not address the soft tissue characteristics of the patient because soft tissue does not always respond the same in every patient.

During the last half century in orthodontics, there has been a shift in emphasis from achieving harmonious dentoskeletal relationship to increasing focus on facial esthetics.

Soft Tissue Profile Analysis

With the increasing interest in facial esthetics came increasing number of investigations on soft tissue. These included soft tissue profile norms based on cephalometric analysis of the contours of the lips, nose, and chin.

Lips

During the 1960s, there were development of many soft tissue analyses with reference lines and angles to measure patients' soft tissue contours.^{4,5,15-17}

In 1966, Merrifield¹⁶ established a reference line called the profile line (Figure 2.2) which was drawn from the tangent to the soft tissue chin and to the most anterior point of either the lower or the upper lip. The upper lip should be tangent to the profile line, and the lower lip should be equal to or slightly behind the profile line but by not more than 2 mm.

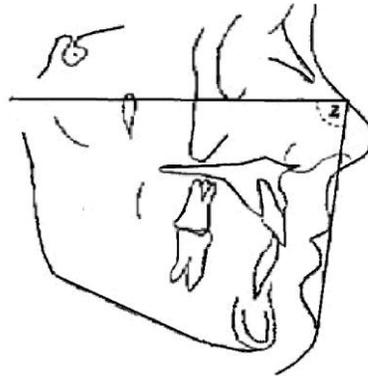


Figure 2.2 Z angle is formed by the profile line and the Frankfort horizontal plane. (Modified from Merrifield¹⁶)

Merrifield¹⁶ also developed an angular measurement for lip protrusion called the Z angle (figure 2.2). The Z angle is formed by intersection of the Frankfort plane and the profile line. The main purpose of this reference angle is to enable communication of the amount of lip protrusion

of a patient in general terms, since it measures only the most anterior lip. He found that in a non-orthodontic sample, the average Z angle was 81.4 degrees with a range of 71 to 89 degrees.

A year later, Burstone⁴ devised the reference plane subnasale-pogonion (Figure 2.3). He measured lip protrusion or retrusion from a perpendicular linear distance from subnasale-pogonion plane to the most prominent point on the upper and lower lips. He reported that the upper lip was positioned in front of Sn-Pg' line by $3.5 \text{ mm} \pm 1.4 \text{ mm}$, and the lower lip is in front of the line by $2.2 \text{ mm} \pm 1.6 \text{ mm}$. Therefore, the upper lip projects slightly more than the lower lip in relation to this line. Recently, this reference plan was used by Arnett in evaluating patients needing orthognathic surgery.

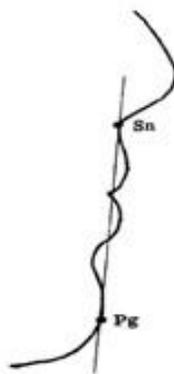


Figure 2.3 Lip protrusion is measured perpendicular to subnasale-pogonion line. (Modified from Burstone⁴)

Another reference plane called the esthetic plane was developed by Ricketts (Figure 2.4),¹⁷ which he defined as a line tangent to the tip of the nose and the chin in profile view of the patient. In reference to this line, Rickett's "law of lip relationship" states that "in the normal white person at maturity, the lips are contained within a line from the nose to the chin, the outlines of the lips are smooth in contour, the upper lip is slightly posterior to the lower lip when related to that line, and the mouth can be closed with no strain."¹⁷ He also found that the lower lip position in a significant sample of adults were located approximately 4 mm posterior to the E-line. The upper lip can be related to the lower lip as a reference.

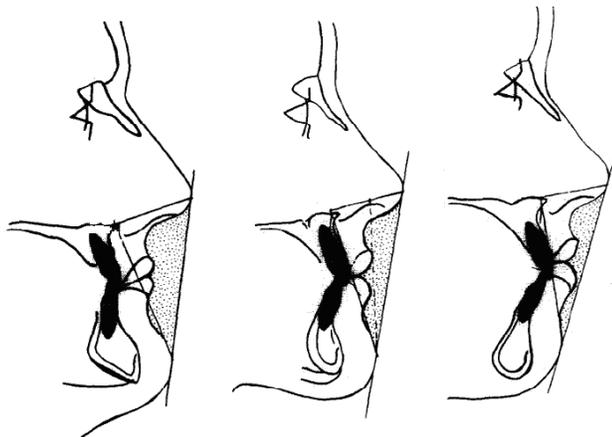


Figure 2.4 E plane is tangent to the nose and the chin. (Modified from Ricketts¹⁷)

Holdaway⁵ measured depth of the curvature of the upper lip (superior sulcus depth) by a reference line that is perpendicular to Frankfort horizontal and tangent to the

vermillion border of the upper lip. A range of 1 to 4 mm was acceptable with 3 mm being ideal. He states that during orthodontic treatment, "we should never allow this measurement to become less than 1.5 mm."⁵

Holdaway⁵ also defined the H line, which is a line tangent to the soft tissue chin and the upper lip. Soft tissue subnasale to the H line is ideally 5 mm with a range of 3 to 7 mm.⁵

Lip fullness can also be measured by the use of the H angle (Figure 2.5). H angle is an angular measurement between the H line to the soft tissue facial plane.⁵ However, measurements of H angle can range from 7 to 15 degrees depending on the convexity. As skeletal convexity increases, the H angle must also increase to achieve a harmonious facial profile.⁵

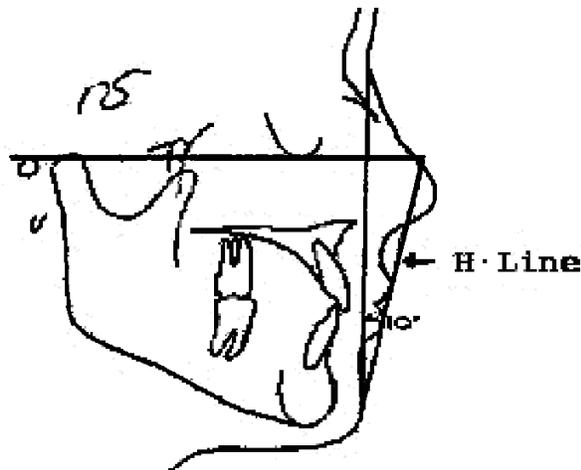


Figure 2.5 H angle formed by soft tissue nasion-pogonion and the H-Line (Modified from Holdaway⁵)

Holdaway⁵ also found that upper lip thickness at the base of the alveolar process is usually 15 mm with a 1 mm taper at the vermilion border level, therefore 14 mm. The usual thickness at the vermilion border level is 13 to 14 mm. This number is coincident with the findings of Merrifield¹⁶ of a non-orthodontically treated group with an average upper lip thickness of 13.7 mm. Excessive taper is indicative of the thinning of the upper lip as it is stretched over protrusive teeth.⁵

Peck et al.¹⁸ studied a group of 51 "beautiful" people. A cephalometric analysis was performed and they found that the sample were all within the range of the established cephalometric standards, however, they were on the fuller, more protrusive range of the established standards. Stated differently, the general public admires a slightly fuller, protrusive face than established mean cephalometric standards. More recently in 2002, Fernandez-Riveiro et al.⁹ found that both the upper lip and the lower lip protruded 4 mm beyond the reference line (subnasale-submentale) in both males and females.

The amount of acceptable lip protrusion is found to be also influenced by the contours of the nose and chin. Cox and van der Linden¹⁹ found that more lip protrusion was found acceptable when subjects had either a large nose or a

large chin.¹⁹ Czarnecki et al.²⁰ also found that both lip protrusion and retrusion were dependent on the position of the chin and the nose. More lip protrusion was acceptable with either a large nose or chin. However, three times more lip protrusion was allowed with a large chin than was accepted with a large nose.²⁰

Nose

Measurements of nasal prominence can be done similarly to that of lip prominence. Holdaway⁵ measured nasal prominence by the same line used for lip curvature. This is a line perpendicular to Frankfort horizontal and tangent to the upper vermillion border. The tip of the nose was measured from this line. Those noses less than 14 mm are considered small, while those above 24 mm are considered large.

Arnett and Bergman¹⁵ measures nasal projection by measuring from subnasale (Sn) to nasal tip (NT). They report nasal projection is normally 16 to 20 mm. They also suggest that decreased nasal projection contraindicates maxillary advancement.

According to Peck et al.,¹⁸ the nose is probably the most commanding feature of all the profile, however it receives very little serious attention in orthodontic

analysis. More investigation is needed regarding the nose and its contribution to facial esthetics.

Chin

The prominence of the chin highly influences the prominence of the lips needed to achieve a pleasing profile. Therefore, many investigations have been conducted to understand this interrelationship. Merrifield¹⁶ studied lateral cephalometric radiographs of 120 patients and measured the bony thickness of the chin by measuring bone ahead of the reference line Nasion-B point. He also measured the soft tissue chin thickness by measuring the soft tissue at the same point. He found that in a non-orthodontically treated group, the average chin thickness was 16 mm. He also found that individually the samples "routinely showed the chin measurement to be equal to or greater than the upper lip measurement." He observed that there was great variability in the thickness of the soft tissue overlying the bony chin. It was "not unusual to measure 2 mm of bony chin and 14 mm of integumental overlay; nor is it unusual to measure 6 mm of bony chin and 10 mm of soft-tissue overlay."¹⁶

In a study by Czarnecki et al.²⁰ of dental professionals, they found that a slightly more pronounced chin was favored for males as compared with females. The

least favored chin contours were the most retrusive for both males and females.

Ethnic Preferences

To investigate whether different ethnic groups have varying preferences with regards to facial esthetics, Foster²¹ surveyed a group of general dentists, orthodontists, art students, a black lay group, a Chinese lay group, and a white lay group. Profile silhouettes with differing lip fullness were created from a single headfilm of an 18 year old Caucasian girl. A series of profiles were sent to all the groups. Foster²¹ found that the black, Chinese and white lay groups all had a similar preference for the lips in males (within 0.7 mm), and for women (within 1.0 mm). The orthodontists preferred male profiles slightly fuller than that preferred by other groups by about 1.2 mm. All groups preferred fuller lips for younger ages, and also for females. A straighter adult male profile was preferred. The results of this study showed that all of the groups had very similar preferences. However, the profile silhouettes that they were asked to evaluate was that of a Caucasian female. If the groups were asked to evaluate profile preferences for their own ethnicity, the results may have been different from this study.

In a study by Martin²² in 1964, facial preferences of American whites, American blacks, and Nigerian blacks were investigated. All of the 3 groups were asked to judge 10 female facial photographs from the least Negroid to the most Negroid. Then the groups were asked to rank the photographs according to attractiveness. He found that the American whites and American blacks preferred the more Caucasian face, and the Nigerian blacks preferred the more Negroid face.

Mantzikos²³ investigated the profile preferences among a Japanese population. Five Japanese facial profiles were used to survey 2651 Japanese immigrants. These 5 profiles were the following: (1) bimaxillary dentoalveolar retrusion, (2) mandibular retrognathia, (3) mandibular prognathia, (4) bimaxillary dentoalveolar protrusion, and (5) orthognathia. He found that the orthognathic profile was the most preferred, followed by bimaxillary dentoalveolar retrusion. These findings are surprising considering that the average Japanese population has a slightly more bimaxillary protrusive profile compared to the average Caucasian population.²⁴

Lip versus Incisor Retraction

Orthodontic treatment can have significant influence on lip prominence. Therefore, it is important for

clinicians to determine the preference of the patients as well as understand how the lips respond to changes in position of the incisors.

A sample of Caucasian females who had passed their sixteenth birthdays was included in a study by Hershey,³ to determine the effects of incisor teeth on soft tissue profiles. He found that a given amount of hard tissue movement resulted in soft tissue response which varied widely among subjects. Similar to findings by Burstone,⁴ Hershey³ found that increasing variability in the soft tissue response to increased tooth retraction suggested that the perioral soft tissue may be self supporting, and that gross tooth movement may not always mean marked reduction of the profile contour. Hershey³ also attempted to localize the factors responsible for the lips not following the retraction of the teeth, however, he could not determine whether it was due to thickening of the lips or a creation of a void between the lips and the facial surface of the incisors.

Merrifield¹⁶ stated that the upper lip will thicken slightly following retraction of the upper incisors. He noted that there will be 1 mm of thickening of the upper lip for each 3 mm of retraction of the tip of the upper incisor and that the lower lip does not thicken but curls

backward as a result of upper anterior retraction.

Similarly, Holdaway⁵ observed that if the thickness of the upper lip at the vermilion border exceeds 18 mm, where the normal thickness is 14 mm, then the upper lip usually changes very little when the upper incisors are retracted.

Many other studies have been conducted to quantify the amount of lip retraction. Kasai²⁵ studied a group of Japanese women and found that with a mean retraction of upper incisors of 4.3 mm, there was an average of 1.9 mm retraction of the upper lip, and an average of 2.4 mm retraction of the lower lip. However, changes in the lower lip in response to tooth movement were more predictable than those of the upper lip. Kasai²⁵ suggested that variability in the changes in upper lip following incisor retraction may be explained by the complex anatomy and dynamics of the upper lip, such as it being suspended from the nose and the anterior nasal spine.

Rains and Nanda²⁶ studied orthodontic female patients over the age of fifteen, and found that there was an average upper incisor retraction of 3.1 mm and a subsequent retraction of the upper lip averaging 1.9 mm producing a ratio of 8:5 for upper incisor to upper lip retraction.

Talass et al.²⁷ examined cephalometric records of 80 Class II Division 1 treated and 53 untreated female

subjects. They found that with a mean retraction of 6.7 mm of maxillary incisor retraction, the upper lip retracted by an average of 4.3 mm and the anteroposterior position of the lower lip remained almost unchanged. The nasolabial angle of the untreated remained almost unchanged, whereas the treated sample had a significant change with a mean of 10.5 degrees. The thickness of the lower lip remained almost unchanged. The thickness of the upper lip remained unchanged in the control group, and increased by a mean of 2.3 mm in the treated group.

It seems that the prediction of upper lip retraction following incisor retraction is not reliable due to the large variability of upper lip response.²⁵⁻²⁷

Trends in Lip Fullness

Facial esthetic preference has been shown to change with the changing times. Auger and Turley²⁸ and Nguyen and Turley²⁹ studied the changes in female and male profiles depicted in fashion magazines during the twentieth century, respectively. They found that in both the female and the male profiles, there was a trend of increasing lip protrusion, lip curl, and vermillion display.

Correlated Studies

In order to determine the soft tissue esthetic goal of the patient, it is important to study the perception of the

lay public with regard to the attractiveness of soft tissue facial contours.

Cox and van der Linden¹⁹ created profile silhouettes of 241 females and 186 male young adults in Netherlands. Ten orthodontists and 10 laymen were asked to rearrange the silhouettes in the order of attractiveness. They found that subjects with good faces showed smaller distances from upper and lower incisal edges to Nasion-Pogonion. Persons with poor facial balance have more convex faces. They also found that between the evaluators (i.e., orthodontists vs. the laypeople), there were no significant differences in judgment.

Czarnecki et al.²⁰ also created profile silhouettes with varying nose, lips, and chin relationships, as well as changes in facial angle and the angle of convexity. These silhouettes were evaluated by 545 professionals. Czarnecki et al.¹⁶ found that in males, a straighter profile was preferred, in comparison with a slightly convex profile for the females.

De Smit and Dermaut³⁰ investigated the profile preferences of 249 adults by using constructed 2D profile silhouettes by varying the nasal dorsum, the anteroposterior profile, and the vertical profiles. They found that Class I was the most preferred profile followed

by Class II and Class III. A straight nasal dorsum was found to be more esthetic than a convex dorsum. Also flattening of the mental fold was less preferred than deepening of the mental fold.

Lines et al.³¹ surveyed a group of 347 dental professionals and non-dental professionals using 7 series of 5 facial profile silhouettes. The 7 series included varying degrees of (1) interlabial prominence angle, (2) chin prominence angle (3) nasal prominence relative to the chin angle, (4) nasal tip angle, (5) inferior labial sulcus angle, (6) nasal labial angle, and (7) columellar length angle. The participants were asked to choose the most attractive general profile, the most attractive female profile and the most attractive male profile. They found that there was a significant difference in preference between the female and male profiles. When attractive female profile selections were compared to those of males, a more prominent interlabial angle, less prominent chin, less prominent nose relative to the chin angle, a less acute nasal tip angle, slightly shallower mentolabial groove, a more obtuse nasolabial angle, and a smaller columella were preferred.

In contrast to previous facial profile perception studies involving silhouettes and outlines, Giddon et al.³²

produced 2-dimensional (2D) photographic profile images of four patients. They created digitally distorted images by varying the chin, upper lip, mandible, bimaxillary relationship, and lower face height. Each feature was presented to 24 judges as an "animation," where the features were distorted at a rate of 1.25 frames/second. The judges indicated zones of acceptance by pressing a button when the face was acceptable and releasing the button when the face became no longer acceptable. They found that this method of presenting facial stimuli appeared to be extremely sensitive, as indicated by the judges' ability to differentiate ≤ 1.0 mm of change in physical dimensions.

Using the method developed by Giddon et al.,³² Miner et al.³³ studied the perception of patients, their mothers, and the orthodontist. Three profile features (the upper lip, the lower lip, and the mandible) were warped and presented to the patients, their mothers, and the orthodontist as a 2-dimensional (2D) animation showing 4 frames per second, from retrusive to protrusive extremes. These warped images included the patient's own image, and a neutral profile of a 13 year old female. They found that all three groups preferred a more protrusive profile. The mothers, however,

had a smaller tolerance of profile change from their child's unaltered profile.

Sforza et al.³⁴ analyzed faces of a group of 231 white Italian adolescent boys and girls, ages 10-17 years. They collected 3-dimensional (3D) coordinates of 50 facial landmarks by using a computerized electromagnetic digitizer. These coordinates were used to estimate linear distances, angles, areas, and volumes. They found that the attractive adolescents had relatively more prominent lips, smaller noses, reduced nasolabial and interlabial angles, and reduced distances to the esthetic E-line.

More recently, Spyropoulos and Halazonetis³⁵ investigated soft tissue profile preferences of 10 orthodontists and 10 laypersons. They took 20 pretreatment profile photographs of consecutively treated patients. The soft tissue profiles of these 20 images were "averaged" into a single soft tissue profile. Then each of the 20 images was warped to all have identical profile outlines as the "averaged" profile. Also, a single "composite" face was created which was a derivative of morphing all of the 20 initial images. The author defines "warped" for images where only the shape was changed, and "morphed" when the procedure distorts and blends 2 or more images together to produce a final image that differs from the originals in

both shape and color. Judges were asked to evaluate the 20 initial unaltered images, the 20 warped images, and the single "composite" morphed image. They postulated if there is no difference in esthetic scores between the initial vs. the warped images, then "profile outline shape has no influence on facial esthetics."³⁵ They found that the morphed "composite" image always received the highest scores, and the warped images received only slight improvement in scores from the initial images. Within the warped images, there was a large variability in the attractiveness scores. Therefore, they concluded that "other factors may contribute more significantly to facial esthetics than profile outline shape."³⁵

Summary and Statement of Thesis

Perception of facial beauty is highly subjective. Many attempts have been made to standardize a methodology to describe beauty in the field of orthodontics by development of several different facial analyses.

Perception of facial beauty is also multifaceted. Many factors contribute to facial beauty of the lower face such as the nose, lips, and chin; as well as soft tissue thickness. There are also differences in ethnic preferences of the face, and these preferences change with the changing times.

Many of the studies on soft tissue esthetics have been done on 2D images. In real life, facial esthetics are viewed in 3D. It is the intent of this study to determine if there is a difference in perception of attractiveness of differing lip fullness when faces are viewed in 2D vs. 3D.

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Chapter 3: JOURNAL ARTICLE

Abstract

Introduction: The majority of studies on the perception of facial esthetics in orthodontics have been done using 2-dimensional (2D) silhouettes and outlines. Some others have used 2D photographic images to analyze perception of facial esthetics. At this time, there is lack of information on facial esthetic perception when 3-dimensional (3D) images are projected and analyzed.

Purpose: The purpose of this study is to determine if there is a difference in perception of attractiveness of differing lip fullness when faces are viewed in 2D vs. 3D.

Materials and Methods: The lip fullness of 3 patients was manipulated to produce 5 different grades of lip fullness. They were -6 mm, -3 mm, 0 mm, +3 mm, and +6 mm of lip protrusion or retrusion from the unaltered images. These manipulated images were made into a set of 2D profile images, and a set of 3D movie files. One hundred Caucasian female subjects, 40 orthodontic residents, and 5 orthodontic faculty members were surveyed. They were asked to rank the 2D and the 3D images in the order of most attractive to least attractive. The ranks for the 2D and

the 3D images were compared. **Results:** There was significant difference ($P < 0.05$) in preference of lip fullness for each of the patients both in 2D and 3D. However, in general, neutral to more protruded lips were preferred when laypersons were shown images in 2D, versus neutral to more retruded lips were preferred when they were shown images in 3D. Orthodontic residents and faculty on the other hand, seem to prefer more retruded lips in 2D and 3D compared to the lay public. **Conclusion:** Statistical comparison between the 2D and the 3D images were not possible because the rankings among the subjects had large variability.

Introduction

Attractive people have an advantage in our society. Attractive people are shown to get better grades in school and earn higher incomes.^{1,2} Orthodontic treatment can have a significant effect on the esthetics of the lower face,^{3,4} therefore, it is important for clinicians to understand the components that make up facial esthetics.

Since the 1950s, there has been increasing interest in the soft tissue aspect of orthodontic treatment. Many reference planes for analysis of soft tissue were developed.^{3,5-7} Also, the interrelationship of the nose and the chin in facial profiles were studied.⁸⁻¹¹ Cox and van der Linden¹¹ found that more lip protrusion was acceptable when subjects had either a large nose or a large chin.

In addition, many attempts have been made to quantify the soft tissue lip response to orthodontic treatment.^{3,4,6,7,12-14} At this time, prediction of upper lip changes following movement of incisor position is not reliable due to the large variability in the upper lip response.¹²⁻¹⁴

Studying the perception of facial beauty is as important as understanding its physical characteristics. Preferences of facial profiles have been shown to be

influenced by ethnic background,¹⁵⁻¹⁸ and changes with the changing times. Mantzikos¹⁵ found that a sample of Japanese judges preferred orthognathic to a slightly retruded profiles, whereas Martin¹⁶ found that a sample of Nigerian blacks preferred fuller profiles. Auger and Turley¹⁹ and Nguyen and Turley²⁰ have found that in both the male and the female profiles depicted in fashion magazines, there was a trend of increasing lip protrusion, lip curl, and vermilion display with time.

Numerous studies have been performed to understand the perception and preferences of soft tissue profiles. Many of these studies used 2-dimensional (2D) silhouettes or outlines to have judges rank profiles in order of attractiveness.^{10,11,21,22} Others have performed similar studies using 2D photographic profile images.^{23,24} There are limited numbers of 3D studies on facial esthetics. These include studies on the analysis of dynamic smiles,²⁵ and analysis of 3-dimensional (3D) proportional measurements of attractive faces.²⁶ At this time, there are no published studies on perception involving 3D facial esthetics. The purpose of this study is to determine if there is a difference in perception of attractiveness of differing lip fullness when faces are viewed in 2D vs. 3D.

Materials and Methods

Individuals Included in Lip Fullness Manipulation

Three Caucasian females were chosen for this study for manipulation of lip fullness. Individuals with pleasing soft tissue profiles were selected. The inclusion criteria were:

- 1) Vertical facial thirds within normal limits
- 2) Class I facial relationship
- 3) Upper and lower lips in harmony with each other
- 4) Soft tissue profile within normal limits and judged as having a good face

Manipulation of Lip Fullness

Three-dimensional facial photographs were taken of each patient using the 3dMDface™ system (Atlanta, Ga.). Existing cone beam radiographs were also obtained for each of the three patients. The cone beam radiograph (DICOM file) and the 3D image (.tsb file) of each patient were registered on each other using the 3dMDvultus™ software (Atlanta, Ga.).

To register, a soft tissue surface image of the patient was created using the DICOM file of the cone beam by adjusting the Hounsfield unit (Figure 3.1). This soft tissue surface radiographic image (DICOM file) was aligned

(Figure 3.2 and Figure 3.3) with the 3D photographic image (.tsb file). Then, the two images were registered by using the registration function of the 3dMDvultus™ software.



Figure 3.1 Surface image created from cone beam radiograph

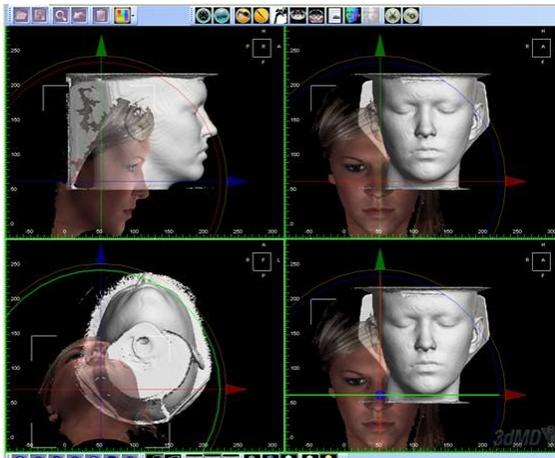


Figure 3.2 3D photographic image (.tsb file) and 3D surface file (from DICOM file) not yet aligned

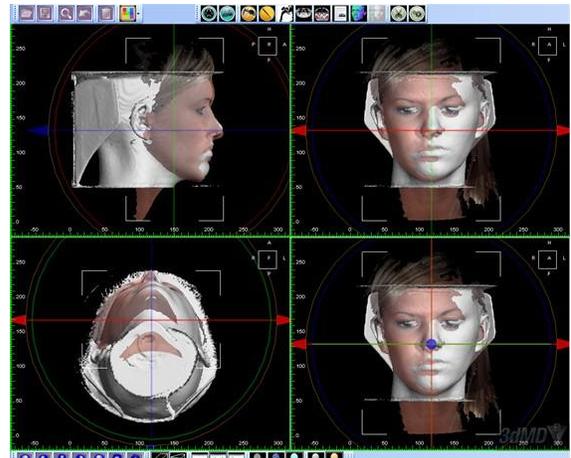


Figure 3.3 3D photographic image (.tsb file) and 3D surface file (from DICOM file) aligned, ready for registration

In order to adjust lip fullness, bone was first extracted from the DICOM file (Figure 3.4). Then simulated surgical cuts were made on the bone surface. The cuts were done so as to include the maxillary and mandibular teeth and alveolus as a single unit. These units of bone were moved as much as needed in the anteroposterior direction to cause the desired amount of lip retraction or protraction (Figure 3.5).

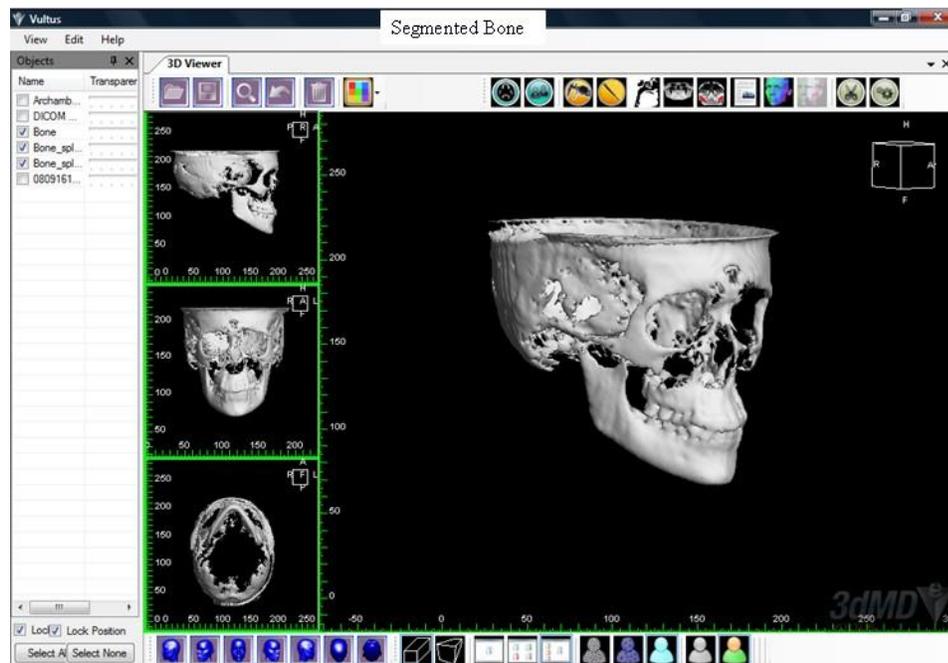


Figure 3.4 Bone image from cone beam radiograph

For each patient, 5 different grades of lip fullness images were created. These five images included:

- 1) Lips unaltered
- 2) Lips retracted 3mm
- 3) Lips retracted 6mm

- 4) Lips protracted 3mm
- 5) Lips protracted 6mm

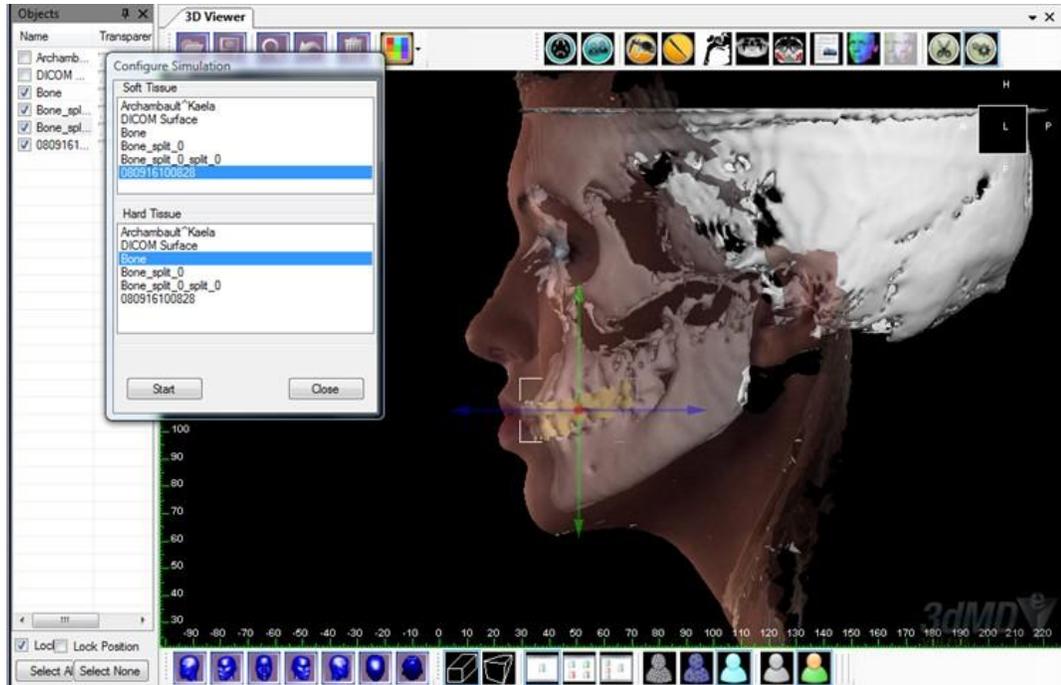


Figure 3.5 Simulation to protract or retract the lips by moving the highlighted alveolar bone and teeth.

These images were created as 3D images initially using the 3dMDvultus™ software. These 3D images were then created into rotating movie files (.avi files) with the 3dMDpatient™ software. These 360 degrees movies were edited to remove the views of the back of the head. The movie thus showed the patients' head rotating 180 degrees from the profile views of the patients facing left to the view of the patients facing right. The heads were rotated at approximately 10 seconds/180 degrees. These movies were the 3D movies used in the survey.

Once the movie files were made, photographic snapshots were made from these movie files with the profile views of the patients facing right. These snapshot images were created for 5 grades of lip fullness for each of the 3 patients. These snapshot images were the 2D profile images used in the survey.

Layout of Images used in the Survey

100 subjects were shown 6 PowerPoint slides that contained the following:

Slide 1 = 2D images of subject 1 showing 5 different grades of lip fullness

Slide 2 = 3D movies of subject 2 showing 5 different grades of lip fullness

Slide 3 = 2D images of subject 3 showing 5 different grades of lip fullness

Slide 4 = 2D images of subject 2 showing 5 different grades of lip fullness

Slide 5 = 3D movies of subject 1 showing 5 different grades of lip fullness

Slide 6 = 3D movies of subject 3 showing 5 different grades of lip fullness

The images on each slide were laid out in random order from A through E. Images marked A, B, and C were laid out on the first row, and images marked D and E were laid out on the second row of each slide. The slides were projected on a 5 feet by 6 feet screen. The size of each head on the slide approximated life size.

Subjects

Flyers were posted in the Allied Health Building of Saint Louis University (Appendix A). When subjects consented to the survey, they were given the Survey Information form (Appendix B).

One hundred laypersons were asked to view 6 PowerPoint slides (see CD). Each slide contained a set of five images. Subjects were asked to choose the most attractive and the least attractive image. Then, out of the three unselected images, they were asked to choose the most attractive and the least attractive image (Appendix C). The subjects were asked to repeat this procedure for the remaining 5 slides.

Later, a parallel study was conducted, where 40 orthodontic residents and 5 faculty members were asked to view the same 6 PowerPoint slides (see CD) and perform the same procedures as the laypersons.

Statistical Analysis

The Kruskal-Wallis test was performed. It is a non-parametric analogue of the one-way ANOVA. This test was performed to determine whether the subjects ranked each of the patients similarly.

Also, the Wilcoxon test, a non-parametric equivalent of the paired t-test, was performed. It is used for ranked

data. This test can compare how the subjects evaluated 2D profile images vs. the 3D movie images.

Results

In order to be able to compare the preferences of the lay persons regarding lip fullness, the following statistical parameter had to be met. The Kruskal-Wallis test (non-parametric equivalent of the one-way ANOVA) should show that among the 3 patients, the preferences of lip fullness should be ranked similarly. Therefore, the P values of this test should show no statistically significant difference (e.g. 2-dimensional image of 6 mm of lip retraction should be ranked similarly for the 3 patients). If the above criterion is met, then the Wilcoxon test (non-parametric equivalent of the paired t-test) could be performed to determine if there is statistically significant difference in perception between the 2D and the 3D images.

The results for 100 laypersons by the Kruskal-Wallis test (Table 3.1) for all of the 2D images and the 3D images with lip fullness of -3 mm, 0 mm, and +3 mm show statistically significant difference indicated by the P value less than 0.05. Lip fullness images of -6 mm and +6

mm shown in 3D were found to be not ranked significantly different ($P > 0.05$). Therefore, there were no statistically significant agreement in ranking among the patients except for the two extremes of -6 mm and +6 mm of lip fullness shown in 3D.

The results for the 40 orthodontic residents and 5 orthodontic faculties by the Kruskal-Wallis test (Table 3.2) for all of the 2D images and the 3D images show statistically significant difference indicated by the P value less than 0.05. Therefore, evaluators ranked the images significantly different from one another.

Table 3.1 Kruskal-Wallis test for subjects 1, 2, and 3 N=100 laypersons

Lip Position (mm)	2D -6mm	3D -6mm	2D -3mm	3D -3mm	2D 0mm	3D 0mm	2D +3mm	3D +3mm	2D +6mm	3D +6mm
P value	*0.001	0.420	*0.000	*0.000	*0.000	*0.000	*0.000	*0.004	*0.000	0.143
λ^2	14.025	1.734	19.283	57.183	31.064	16.958	46.034	11.309	32.018	3.891

*P < 0.05 indicates significant differences in ranking among the 3 subjects that were compared

Table 3.2 Kruskal-Wallis test for subjects 1, 2, and 3 N=40 orthodontic residents and 5 faculty

Lip Position (mm)	2D -6mm	3D -6mm	2D -3mm	3D -3mm	2D 0mm	3D 0mm	2D +3mm	3D +3mm	2D +6mm	3D +6mm
P value	*0.000	*0.001	*0.000	*0.000	*0.000	*0.000	*0.023	*0.000	*0.005	*0.000
λ^2	36.995	14.584	27.144	21.781	34.116	28.188	7.531	15.474	10.745	20.605

*P < 0.05 indicates significant differences in ranking among the 3 subjects that were compared

Even though statistical significance was found for the patients' analysis with the Kruskal-Wallis test (Table 3.1 and Table 3.2), the Wilcoxon test was performed. The

results of the test (Table 3.3 and Table 3.4) are as follows.

Table 3.3 Wilcoxon test between 2D and 3D at specified lip fullness

N=100 laypersons

Lip Position (mm)	2D -6mm vs. 3D -6mm	2D -3mm vs. 3D -3mm	2D 0mm vs. 3D 0mm	2D +3mm vs. 3D +3mm	2D +6mm vs. 3D +6mm
P value	*0.000	0.530	*0.001	*0.000	*0.000
Z value	-7.926	-0.628	-3.286	-6.712	-5.953

*P < 0.05 indicates significant differences in ranking between the 2D and the 3D at the specified lip fullness

Table 3.4 Wilcoxon test between 2D and 3D at specified lip fullness

N=40 orthodontic residents and 5 faculty

Lip Position (mm)	2D -6mm vs. 3D -6mm	2D -3mm vs. 3D -3mm	2D 0mm vs. 3D 0mm	2D +3mm vs. 3D +3mm	2D +6mm vs. 3D +6mm
P value	0.700	*0.004	0.395	0.256	*0.000
Z value	-0.385	-2.891	-0.850	-1.137	-4.323

*P < 0.05 indicates significant differences in ranking between the 2D and the 3D at the specified lip fullness

Although it cannot be tested statistically because no agreement in ranking was found among the 3 patients, looking at the overall data for the average rankings for 2D and 3D, some general observations were made. It appears that, in general, neutral to slightly protruded lips were preferred when the patients' faces were shown in 2D to laypersons (Figure 3.5). When the faces of the patients were shown in 3D to laypersons, neutral to more retruded lips were preferred (Figure 3.6). For the 40 orthodontic residents and 5 faculties, they seem to prefer neutral to

more retruded lips in both 2D and 3D images (Table 3.7 and Table 3.8).

**Table 3.5 Average ranking for 2D Images for the 5 different grades of lip fullness (in mm)
N=100 laypersons**

Subjects	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
1	0 mm	-3 mm	-6 mm	+3 mm	+6 mm
2	+3 mm	0 mm	-6 mm	+6 mm	-3 mm
3	0 mm	+6 mm	-3 mm	+ 3 mm	-6mm

**Table 3.6 Average ranking for 3D Images for the 5 different grades of lip fullness (in mm)
N=100 laypersons**

Subjects	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
1	0 mm	-3 mm	-6 mm	+3 mm	+6 mm
2	-6 mm	0 mm	- 3 mm	+6 mm	+3 mm
3	0 mm	-6 mm	+3 mm	+6 mm	-3 mm

**Table 3.7 Average ranking for 2D Images for the 5 different grades of lip fullness (in mm)
N=40 orthodontic residents and 5 faculty**

Subjects	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
1	0 mm	-3 mm	3 mm	-6 mm	+6 mm
2	0 mm	-6 mm	-3 mm	+3 mm	+6 mm
3	-3 mm	-6 mm	0 mm	+3 mm	+6 mm

**Table 3.8 Average ranking for 3D Images for the 5 different grades of lip fullness (in mm)
N=40 orthodontic residents and 5 faculty**

Subjects	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
1	0 mm	-3 mm	+6 mm	-6 mm	+3 mm
2	-3 mm	0 mm	-6 mm	+3 mm	+6 mm
3	0 mm	-6 mm	+3 mm	-3 mm	+6 mm

Discussion

The results of this study found that there was no apparent pattern of preferred lip fullness either in 2D or

3D (Table 3.1 and Table 3.2). Out of the 5 different grades of lip fullness shown in 2D and 3D, only the two extremes of lip fullness (-6 mm and +6 mm) were shown to be discriminable consistently by the 100 laypersons.

The findings from the Kruskal-Wallis test also showed that it is not valid to compare the perception of the subjects for 2D versus 3D (Table 3.3 and Table 3.4, Wilcoxon test), because the perception of the same lip fullness among patients 1, 2, and 3 were significantly different. In other words, depending on the particular face the subjects were judging, the same values of lip fullness were ranked differently.

There are several factors that could have affected the study. Many of the previous studies of profile preferences used silhouettes or outlines of faces.^{10,11,21,22} Using silhouettes have the advantage of reducing the information so that only the profile outline can be isolated. However, this study used photographic images of the patients. Spyropoulos et al²⁴ found in a study where 2D photographic images of the face were used, there was a large variability in the attractiveness scores even when all of the faces were warped to have the same profile outlines. Therefore, they concluded that "other factors may contribute more significantly to facial esthetics than profile outline

shape."²⁴ Similarly, in this study, small changes in lip fullness may have made little difference in perception when the overall facial esthetics were judged.

Another limitation of this study was that subjects were asked to evaluate 3 different faces, and may have reacted differently to each of the faces. It has been shown that contours of the nose and chin may influence preferences for lip fullness.¹¹ Also, other features of the face may have had a stronger affect on the overall perception of the face than the lip manipulation that was performed. The above effect may have varied significantly among the patients' images.

In addition, there were some limitations of the 3dMDvultusTM software that was used to perform the lip manipulations. With the manipulation of the lips in the anteroposterior direction, there were some undesired changes that occurred to the nose and the chin. The soft tissue changes that took place with the movement of the bony unit were done on a mesh model (Figure 3.6). On this model, changes in position of a specific point affected the position of adjacent points. Points closer to the altered point were moved in greater amount than points further away. Therefore, most of the changes in soft tissue

occurred in the area of the lips, however, there were also small changes in the contours of the nose and chin.

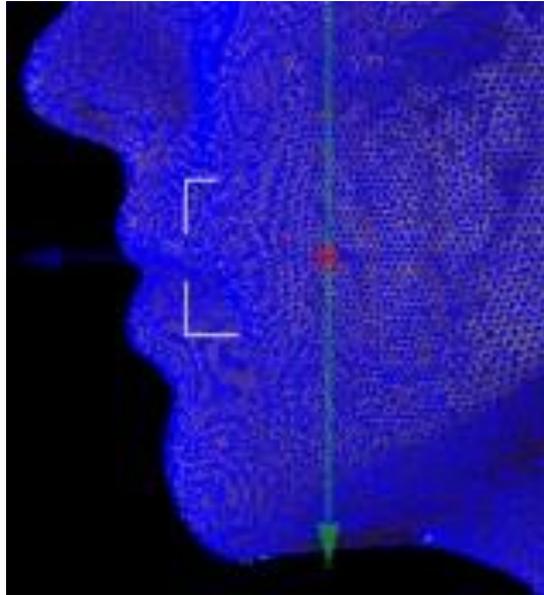


Figure 3.6 Mesh model

Although direct comparison of the 2D and 3D was not possible statistically, due to the absence of agreement in ranking among the subjects (Table 3.1 and Table 3.2), some general observations were made. When the laypersons were shown 2D images, there was a tendency to prefer neutral to more protruded lip fullness (Table 3.5). This result is consistent with the findings in many previous studies where slight lip protrusion was found to be preferred.^{9,10,19,22,27} In contrast, when the laypersons were shown the same faces as above but in 3D, there was a tendency to prefer neutral to more retruded lip fullness (Table 3.6). The orthodontic residents and faculty, however, seem to prefer neutral to

more retruded lips in both 2D and 3D (Table 3.7 and Table 3.8). The initial images of the subjects were neutral to slightly full in lip contour, therefore, even fuller lips may have been less esthetic to the orthodontic residents and faculty.

Between the laypersons and the orthodontic residents and faculty, the latter group was more consistent in their rankings. Neither of the groups were informed before the survey which part of the face had been altered. They were given instructions to rank the appearance of the overall face. However, the orthodontic residents and faculty group, knowing that this study was an orthodontic study, may have been more focused on the lip area.

Many comments were received from subjects after the survey was completed. Some found it was harder to evaluate the 3D images because they were moving, and it was hard to analyze faces when they kept changing position. Others found that not having the hair as part of the facial image was disturbing. Others wanted to have all of the 3D images moving at the same time in same positions. In this study, the 3D images were moving at the same rate but were not synchronized.

A way to improve future investigations on the perception of 3D images might be to use still images that

represent the face at increments of 10 to 20 degrees. In this way, the images will not be moving constantly, therefore, the subjects may be better able to make decisions about the face.

Another suggestion is to isolate a smaller area for manipulation. For example, alteration of the chin may be easier to perceive in that it will less likely affect the nearby structures and its perception. Alteration of the lip fullness as was done for this study may have made the nose and the chin seem more or less prominent. Therefore, subjects may have focused on the nose or the chin rather than the lips when making decisions about attractiveness.

Conclusion

Statistical comparison in this study between the 2D and the 3D images were not possible because the rankings among the subjects had large variability. This large variability may have been caused by the use of real photographic images in this study. There may have been "too much information" in the photographs that may have influenced the overall perception of the face. Further investigations are still needed in 3D photographic imaging and its usefulness in the field of orthodontics.

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FREE TOOTHBRUSH TAKE A 5 MINUTE SURVEY

Esthetic Perception Study

We are conducting a study on the public's perception of facial esthetics. You will be asked to evaluate the attractiveness of a number of facial images. The survey will take approximately five minutes. A manual toothbrush will be given at the end of the survey in appreciation of your time.

Thank you,

Kris Kim, DDS
Orthodontic Resident
Saint Louis University
Center for Advanced Dental Education

APPENDIX B

Survey Information

Thank you for choosing to participate in this survey. We are conducting a study to determine the public's perception of facial esthetics.

You will be shown sets of five images on the computer screen. Please evaluate each image, then, follow the instructions on the "Survey Questionnaire" form.

Sincerely,

Kris Kim, DDS
Orthodontic Resident
Saint Louis University
Center for Advanced Dental Education

APPENDIX C

Survey Questionnaire

What is your age: ____18-25 ____26-33 ____34-41 ____42+
Male_____ Female_____

SET 1

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____ Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____ Least Attractive _____

SET 2

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____ Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____ Least Attractive _____

SET 3

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____ Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____ Least Attractive _____

SET 4

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____

Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____

Least Attractive _____

SET 5

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____

Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____

Least Attractive _____

SET 6

a) Please select the most attractive and the least attractive images out of the five images:

Most Attractive _____

Least Attractive _____

b) Out of the three unselected images, please select the most attractive and the least attractive images:

Most Attractive _____

Least Attractive _____

VITA AUCTORIS

Kris Hyemin Kim was born in July 24, 1980 in Pusan, South Korea. She grew up in South Korea until her family immigrated to Killeen, Texas in 1990. Her family relocated to Seattle, Washington in 1992. She attended Meadowdale High School in Lynnwood, Washington. In 2002, she received her B.S. degree in Biochemistry from University of Washington. During dental school, she married Tae Oh on June 11th of 2005. In 2006, she received her D.D.S. degree from University of Washington. During her orthodontic residency on July 22, 2006, her son Jaelen was born. She is planning to receive a M.S.D. degree from Saint Louis University Orthodontics Program in January, 2008. She will be returning to Seattle, Washington upon graduation to join Tae and Jaelen.