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Three Dimensional Analysis of the Effect of Skeletal Jaw Relationship on the Perception of Facial Aesthetics and Symmetry

by
Denise Devgon

THESIS
Submitted in partial satisfaction of the requirements for degree of
MASTER OF SCIENCE

in

Oral and Craniofacial Sciences

in the

GRADUATE DIVISION
of the
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

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ABSTRACT

Three Dimensional Analysis of the Effect of Skeletal Jaw on the Perception of Facial Aesthetics and Symmetry

Denise Devgon

Objective:

This study evaluates the perception of transverse jaw asymmetries in patients with varying degrees of sagittal jaw relationships. Secondly, it determines the asymmetry perception threshold in which raters are able to distinguish the deviation in mandibular asymmetry that affect their aesthetic and symmetry perception. In addition, the study seeks to compare that ratings between orthodontists and oral surgeons.

Methods:

Our sample consisted of 30 anonymized CBCT scans of adults (ages 11-30 years old). The reference images obtained from the CBCT's were categorized by Class I, Class II, and Class III using ANB angles values of -4.9 degrees to 5.8 degrees. ANB angle is routinely used for orthodontic treatment planning, it represents the difference between the SNA and SNB angles, providing an indication of the sagittal jaw discrepancy between the maxilla and mandible. An ANB angle ranging from 2+/-2 degrees is considered Class I discrepancy; ANB angle greater than 4.0 is considered to be a skeletal Class II discrepancy; an ANB angle less than 0 degrees is considered a skeletal Class III discrepancy. CBCT data (4 males, 2 females) were processed into 3D models lacking several confounding facts (ex: hair style and color, skin complexion, and eye color) were stripped away in the CBCT images.. Next, images were manipulated in the transverse direction via Morpho J software, using landmarks pogonion and gnathion to alter mandibular symmetry at intervals of 0%, 25%, 50%, 75% and 100%. Lastly, 153 orthodontists,

141 oral surgeons, 68 lay persons, and 59 other dental professionals rated the aesthetics and asymmetry of each model using a scale of 1-10 mm Visual Analog Scale (VAS) for asymmetry and a scale of 1-100 mm Visual Analog Scale (VAS) for aesthetics. No information was provided on the ethnicity, age, and biological sex of each CBCT model, allowing the raters to focus on shape.

Results:

As a general trend with our overall data of 421 assessors, our results indicate that in Class I, Class II and Class III faces, increasing mandibular asymmetry within a particular ANB angle was correlated with lower VAS scores for facial symmetry and aesthetics, therefore, the majority of shape changes were negatively perceived by raters.

However, the data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, is not indicative of decreasing perception of aesthetics and symmetry. The data concluded that when rating aesthetics, Class III faces were scored the highest followed by Class II then Class I faces. For symmetry, Class III faces were scored the highest followed by Class I then Class II faces. In addition, the threshold point with which raters are able to distinguish the deviation in mandibular esthetics and asymmetry affect aesthetic perception ranged from 50-75% mandibular deviation.

When correlating symmetry and aesthetics, the data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, there is not a linear decrease in perception of mandibular aesthetics and asymmetry. In Class I, symmetry and aesthetics were similarly affected, in Class II, aesthetic perception was more affected than symmetry and lastly in Class III, symmetry was more affected than aesthetics. More specifically, when evaluating 0% mandibular deviation to 100% mandibular deviation, the perception between symmetry and aesthetics, the percentage drop in VAS score ranged from 19-33%.

Next, the VAS scores of orthodontists vs. oral surgeons were compared. In our Class I, Class II, and Class III faces, oral surgeons rated the faces with an overall higher VAS score than orthodontists, indicating that orthodontists may be more particular and discerning of all faces.

Conclusions:

The data indicates that increasing or decreasing anteroposterior jaw position does not have the strongest impact on facial esthetics and symmetry. Our findings did not support the idea that balanced jaw associations are the most consistent predictor of perception of facial aesthetics and symmetry. We hypothesized that individuals will find patients with transverse jaw asymmetries and increased or decreased anteroposterior relationships less aesthetic than those with transverse jaw asymmetries and normal sagittal relationships.

The data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, is not indicative of decreasing perception of aesthetics and symmetry.

However, our overall results indicate that within a particular ANB angle, the majority shape changes were negatively perceived, in which, increasing mandibular asymmetry was correlated with lower VAS scores for facial aesthetics and symmetry.

Additional analysis indicating that is not a linear decrease in perception between symmetry and aesthetics, the range being from 19-33% decrease in VAS score from 0% mandibular deviation to 100% mandibular deviation.

Lastly, out of all of the subgroups of data collected, the orthodontic group were the most particular and discerning all of the original faces by scoring the lowest VAS scores for all subgroups. We conclude that inconsistencies seen in our results could be attributed to confounding factors such as soft tissue characteristics that may alter perception of aesthetics and asymmetry.

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A: Introduction

A1: Preface

Symmetry is defined as the quality of being made up of exactly similar parts facing each other or around an axis [32]. Facial symmetry has been subject to influence judgements of aesthetic traits of physical attractiveness and beauty [1]. Numerous recent studies have focused on the facial proportions and beauty as well as the phyco-social relation that it has on our daily lives [2]. Research shows cues that the human subconscious takes only 150 msec to judge facial attractiveness and that, in general, geometrically satisfying or aesthetically pleasing facial dimensions are correlated with the perception of positive characteristics, including personality, health, intelligence, and career success [1].

While looking back in history, the study of the face and the ability to alter its form have fascinated mankind for thousands of years, from Praxiteles, who sculpted geometrically pleasing facial dimensions in classical Athens, to Leonardo da Vinci, who painted faces along oval axes in Renaissance Italy [3,6]. Symmetry, specifically, continues to be an ideal of beauty in today's society as clinicians consistently use what is described as the "ideal" facial proportions and measurements based on modern cephalometric and anthropometric studies of population averages and ranges of normal variation to treatment plan patients [4]. However, most individuals have some level of asymmetry present in their facial structures and therefore is a common occurrence in the craniofacial complex [5,8]. This can be appreciated by comparing full-faced photograph with composites made of two right side or left sides [7,8]. When analyzing the human face, asymmetry indicates an imbalance or disproportionality between the right and left sides [7,8].

Orthodontics, defined as the treatment of irregularities in the teeth and jaws, focuses on both the facial and dental appearance and strives to achieve a balanced face, and this is influenced by facial balance or lack thereof: position of the teeth, skeletal pattern, and soft tissue thickness [9,10]. Facial proportions are evaluated in all three planes of space known as macroesthetics where the practitioner clinically evaluates, for example, important facial proportions, including symmetry, excessive/ deficient maxillary and/or mandibular prognathism/retrognathism as well as face height [8,9].

More specifically, sagittal jaw relationship represents the anteroposterior relationship between the maxillary and mandibular skeletal basis [9,10]. In orthodontics an important motivating factor for patients are facial esthetics, therefore, normalizing function and esthetics including correction of sagittal discrepancies are considered a common goal in patients undergoing orthodontic treatment to create a well-balanced, harmonious clinical outcome [9,10,11].

This can be appreciated as one of the common patients' chief skeletal concerns in orthodontics relate to sagittal jaw relationships and asymmetry with deviations in the mandible being one of the most noticeable characteristics of disharmony, particularly the lateral displacement of the mandible in relationship to the midsagittal plane [10,11,12].

Sagittal skeletal discrepancies may affect facial convexity and vice-versa, influencing our perception of asymmetry [13]. A convex profile indicates a skeletal Class II jaw relationship, and a concave profile indicates a Class III jaw relationship [9,10,13]. According to Proffit, there is a 28% prevalence rate of asymmetry in Class II skeletal jaw relationships, and it is reported that asymmetry is most commonly associated with Class III malocclusions [10].

There are different levels of asymmetry: subclinical, also known as mild asymmetry, moderate or severe and treatment of the asymmetry can range from orthodontic treatment to orthognathic surgery, depending on the degree of asymmetry present [8,9,10]. In addition, the degree of asymmetry present can also have a significant impact on a person's social and functional well-being [9,10,14].

Previous studies have suggested that mandibular asymmetry below a certain limit is not noticeable [13]. This limit is termed "discriminative threshold," and may be used as a guide by oral surgeons and orthodontists to determine surgical planning [13]. If surgery is indicated, a majority of the surgical decision and results are highly dependent on the practitioners' perception of facial disharmonies including aesthetics and symmetry which may be significantly influenced by several potential factors such as the surgeons' ideas, ethnicity, and background [15]. This perception may also differ from those in other professions as well as the lay persons [9, 15].

In the past, researchers have used 2D imaging to analyze facial esthetics and now more commonly three- dimensional (3D) images are used as a reliable method. With these 3D images mathematical analysis can be used to measure the mandibular asymmetry present with respect to third dimension [13]. In addition, cone beam computed tomography (CBCT) imaging can relate soft tissue tissues to underlying hard tissue and with the aid of software allow for more accurate representation [16].

This thesis project seeks to understand the perception of mandibular asymmetry as it relates varying degrees of sagittal jaw discrepancies using CBCT studies. This study will also analyze the threshold of perception of mandibular asymmetry in Class I, Class II, and Class III faces, in addition to focusing on how professions may have an influence of perception of aesthetics and symmetry.

A2: Facial Esthetics/ Golden Proportions

The golden ratio or golden proportion has fascinated intellectuals from diverse fields of disciplines as it has been considered as the "ideal" ratio of beauty [17]. Interestingly, the golden ratio is found throughout nature, as it can be seen in the skeletons of animals and humans, along stems of plants, in the spirals of sea shells and in the wing dimensions of spots on months [17]. There is a specific numerical value, first termed by Mark Barr as "Phi", the mathematic ratio of 1:1.618 [17]. More so intriguing is has been postulated that Phi is found throughout the human form, for example, in the face, the fingers, the body and the teeth [17]. This proportion has been said to evoke an aesthetically pleasing effect and may have an impact on our perception of beauty regardless of race, age, sex and other variables [17].

As it relates to orthodontics, Ricketts was a pioneer, using a device called the golden divider for morphologic analysis of the teeth, skeleton and the soft tissue of the face [18]. He believed that the proportions allowed for structural harmony and balance and could be applied for treatment planning in clinical practice of dentistry, maxillofacial and plastic surgery [18]. More recently, Dr. Marquardt developed a golden mask of the face that includes all one and two dimensional geometric golden elements from the golden ratio, with the claim of the "ideal" facial archetype, further stating that beautiful faces are universal in containing the golden mask regardless of sex and race [19].

Although the golden proportion and the golden mask have been used to evaluate and analyze facial esthetics, recent research has shown discrepancies between races and sexes, and it still remains ultimately incomplete [6].

A3: Beauty and Culture

Although facial aesthetics may be subjective and culturally relative, researchers have found that there is a consensus on rating attractiveness across sexes and sexual orientations, ethnic groups, and ages [25]. There was a study in which infants as young as 2 years old preferred to view faces that adults found attractive and different cultures showed agreement about which particular faces were attractive [26, 27]. These particular results further the possibility that beauty may be dictated by nature rather than culture [28].

A4: Facial symmetry

Facial symmetry is described as the complete match in size, location, shape, and arrangement of each facial component in reference to the sagittal plane [20]. Most individuals have some level of asymmetry present in their facial structures and therefore is a common phenomenon in the craniofacial complex [5,8]. This can be appreciated by comparing full-faced photograph with composites made of two right side or left sides [7]. When analyzing the human face, asymmetry indicates an imbalance or disproportionality between the right and left sides [7]. In the faces below by oxford university press, asymmetries can be noted when right and left faces are superimposed on one another [7].

In orthodontics, one way to evaluate symmetry is by dividing the face in mesio-distal sagittal fifths [9,10]. According to recent research, the upper and lower limits of asymmetry with regards to aesthetics, remains to be determined [21].

A5: Profile Esthetics/ Measurement of skeletal sagittal discrepancy severity

Anteroposterior jaw relationship is of great importance in clinical and aesthetic diagnosis and treatment planning for orthodontic care [9,10]. Cephalometric analyses and linear measurements are routine tools used by orthodontists as an indicator of sagittal jaw discrepancies [9,10, 22]. SNA by definition indicates whether or not the maxilla is normal, retrognathic, or prognathic, while SNB indicates whether or not the mandible is normal, prognathic, or retrognathic [9,10]. The magnitude of the discrepancy between maxillary and mandibular jaw is measured by the ANB angle which calculates the difference between SNA and SNB [9,10].
A positive ANB angle indicates the maxilla is positioned anteriorly in relation to the mandible [9,10]. A negative ANB angle indicates that the maxilla is positioned posteriorly relative to the mandible [9,10].

According to Proffit: Skeletal Class I patients defined as ANB angle of 2º± 2 (SD), in which the maxillary and mandibular skeletal bases are in a normal relationship to one another [10]. Skeletal Class II patients defined as ANB angle of values >4º, which can result from either a maxilla that projects too far forward or a mandible that is too far back [10]. Skeletal Class III defined as ANB angle of values <0º, which can result from either a maxilla that projects too far forward or a mandible too far back [10]. For example, in the case of mandibular prominence, the mandible is positioned further anteriorly in relation to the maxilla, or in the case of maxillary insufficiency, the maxilla is positioned further posteriorly in relation to the mandible [9,10].

A6: SSD and facial attractiveness

According to Graber, an orthognathic face, exhibits a harmonious relationship between the cranium and the facial structures [9]. It is a combination of skeletal, dental and soft tissue balance, therefore, between the maxilla and mandible, between the maxilla and the maxillary dentition, between the mandible and the mandibular dentition, between the maxillary dentition and the mandibular dentition, and between the soft tissue profile and the underlying hard tissue [9]. An important determinant of facial attractiveness can be described by the facial profile and its overall contour of straight, convex, or concave [9,10, 22]. The angle of profile convexity has been found to have a significantly high association with ratings of attractiveness [9,10, 22].

A7: Visual Analog Scale

The VAS score has been extensively used in many aspects of dentistry, including profile, smile and dental esthetics [30]. It is a convenient, simple and rapid method with a horizontal line of fixed length, typically 100 mm. The ends are defined as extreme limits of the parameter being measured, anchored by descriptive words such as “No symmetric” (0 mm) to “Severe Asymmetry” (100) [22,30]. VAS scores are more sensitive to small changes while allowing for continuous measures which enhance data analysis [22]. There are, however, limitations to the VAS including but not limited to: raters incapable of equally discriminative judgements at each point on the scale, in addition to raters tending to spread their responses over the entire scale but avoiding the anchor words regardless of their actual preference [30].

A8: Anxiety

Anxiety disorders as a group are the most prevalent mental health conditions. According to research patients with depressive disorders have increased tendency to perceive emotionally neutral visual information as negative [31].

A9: Hypothesis and Aims

We hypothesize that individuals will more likely recognize transverse jaw asymmetries in patients with increased or decreased anteroposterior relationships than those with normal sagittal relationships. In addition, individuals will find patients with transverse jaw asymmetries and increased or decreased anteroposterior relationships less aesthetic than those with transverse jaw asymmetries and normal sagittal relationships. Lastly, we hypothesize that professions and orthodontists will be more discerning of transverse jaw asymmetries than laypersons and oral surgeons respectively.

AIM 1: To determine how aesthetics and symmetry are affected by deviations of the mandible in the transverse direction

AIM 2: To determine a percentile threshold in which individuals are affected by transverse jaw asymmetry

AIM 3: To determine if professional background impacts perception of aesthetics and symmetry

B: Materials and Methods

B1: CBCT Detailed images selection

We obtained 500 CBCT scans of faces obtained by and previously used by Young et al. (2015), These CBCT's were collected during routine orthodontic treatment planning and care at UCSF [32]. From a previous study by Decoste et. all, each subject consented for their data to be used for research purposes and subsequently scanned with a MercyRay CBCT scanner with a total radiation of 200 mSv according to the manufacturer. The individuals were seated in an upright position while an acquisition screen revolved around their heads [32]. The patient was instructed to hold still, teeth in occlusion, lips relaxed, informed not to swallow, and keep the tongue on the roof of their mouth with their head in natural position [32]. In addition, according to the data obtained by Decoste et. Al, the scanner settings were 110 kVp and 10 mA, generating a total of 512 slices in a 10 second scan, with a 19X19X19-cm field of view and voxel size of 0.38 mm. The images were reconstructed in CBWorks (version 2.1; Cyber Med, Seoul, Korea) and Avia (Hitachi Medical) and saved in a DICOM format [32].

An excel spread sheet obtained from Young et. al., provided information for each scan including but not limited to gender, age, ethnicity, ANB angle classification (measured on their reconstructed cephalogram). Personal identifiers were removed, therefore, lacking several confounding facts (ex: hair style and color, skin complexion, and eye color) [32].

From the original pool of 500 CBCT scans of patients, 6 CBCT scans of patients were used between the ages of 11-30 years old.

The 6 CBCT images were selected based on the following inclusion criteria:

(1) Criteria for inclusion are based on Proffit measurements
   - Skeletal Class I patients defined as ANB angle of 2º± 2 (SD)
   - Skeletal Class II patients defined as ANB angle of values >4º
   - Skeletal Class III defined as ANB angle of values <0º

(2) No apparent asymmetries

(3) No obvious vertical disproportions

(4) Ages 10-30 at the time when the CBCT was taken

The CBCT data was divided into categories on sagittal jaw discrepancies per the ANB angle as defined by Proffit and listed above.

Selection of the CBCT scan models

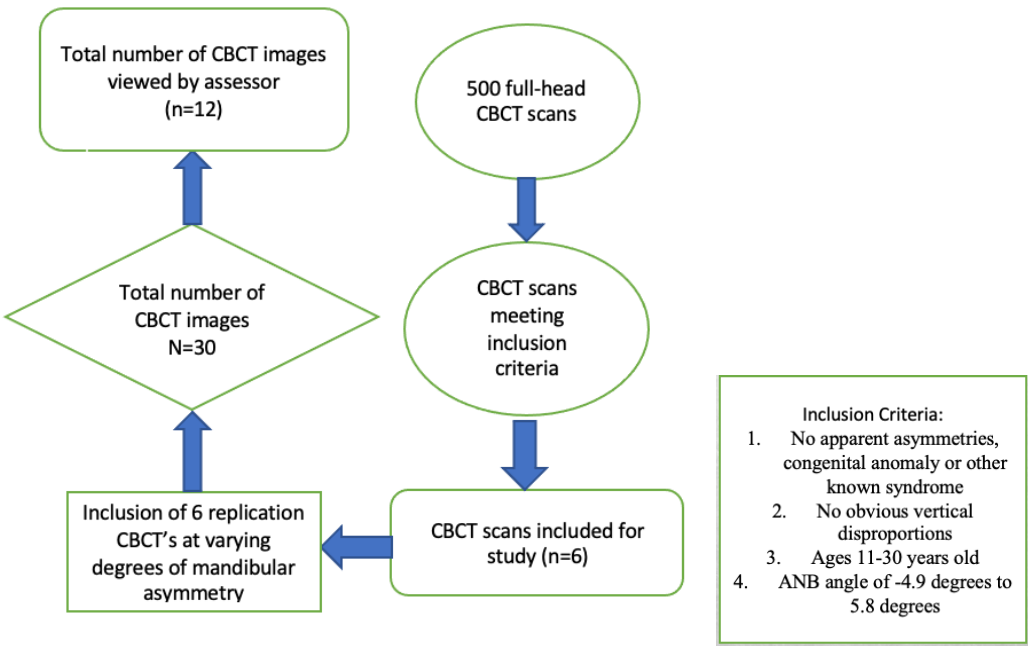


Figure 1:Selection of CBCT scanned models

Table 1: Breakdown of Class I, Class II, and Class III faces used in study

Skeletal Classification	# of Faces
Class I	1
Class II	3
Class III	2
Total	6

B2: 3D Models

Our sample consisted of 30 anonymized CBCT scans of adults (ages 11-30 years old). The reference images obtained from the CBCT's were categorized by Class I, Class II, and Class III using ANB angles values of -4.9 degrees to 5.8 degrees.

CBCT data (4 males, 2 females) were individually uploaded in the Morpho J software. A scale factor was used to generate and manipulate the direction of asymmetry on the mandible. Via the Morpho J software, these CBCT images were manipulated in the transverse direction using landmarks gnathion and pogonion to alter mandibular symmetry at intervals of 0%, 25%, 50%, 75% and 100%.

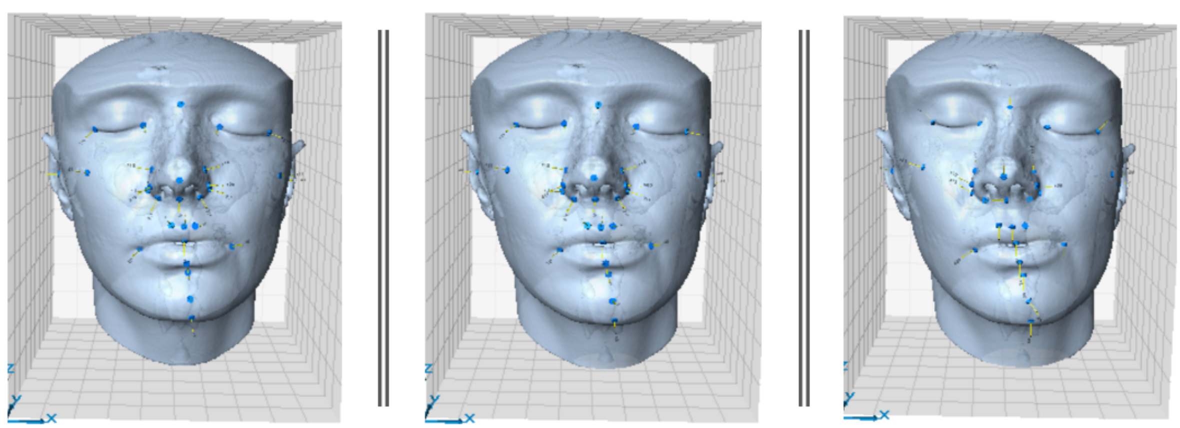


Figure 2: Sample of increasing mandibular asymmetry using Morpho J software

Next, 6 CBCT face scans were positioned using a reference plane of frankfort horizontal (input definition) and aligned using interpapillary line from the frontal view. A total of 30 video clips were created to depict the transverse jaw asymmetries at intervals of 0%, 25%, 50%, 75%, and 100%. Video clips were created using power point, allowing the face to rotate around the vertical axis of the head and perpendicular to the Frankfort horizontal.

Decoste et. al

Figure 3: Screen shot sample of video images (a) profile view left (b) frontal view (c) profile view right (Decoste et al.)

Each video generated was 20 seconds long, the face moving from the right profile view, to center, to left profile view. Not all raters received the same set of video clips as the total survey length was limited to 10 minutes excluding the screening and demographic questions: face scans were randomized in order and within each group of assessors. 12 out of 30 video clips were randomly chosen and presented to each of the participants.

B3: Assessors

Due to COVID-19, our protocol involved using the software Qualtrix to allow for the distribution of the survey. We recruited orthodontists, oral surgeons, lay people, and other dental professionals via websites such as Facebook, Instagram, and other social media platforms. Prior to the start of the survey, raters filled out a demographic questionnaire (add appendix) and the State-Trait Inventory (STAI) (Appendix). The STAI was used as with Decoste et al. to evaluate the anxiety of the raters, which has been shown in previous studies to lower judgement. We excluded raters with a score over 75.

B4: Demographic and Anxiety Questions

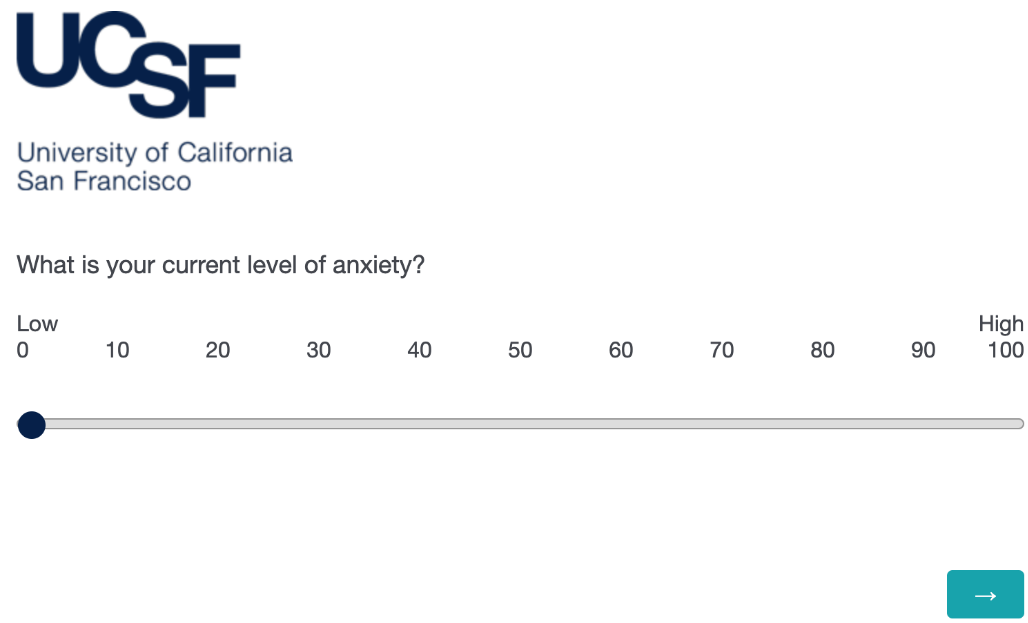


Figure 4: Question regarding current anxiety level

Figure 5: Question regarding raters aesthetic perception of their face

B5: Procedures

As indicated above, 6 CBCT face scans were positioned using a reference plane of Frankfort horizontal (input definition) and aligned using interpillary line from the frontal view. A total of 30 video clips were created to depict the transverse jaw asymmetries at intervals of 0%, 25%, 50%, 75%, and 100%. Video clips were created using power point, allowing the face to rotate around the vertical axis of the head and perpendicular to the Frankfort horizontal. Each video generated was 20 seconds long, the face moving from the right profile view, to center, to left profile view. Not all raters received the same video clips as the survey length was limited to 10 min, therefore, the faces scans were randomized in order and within each group of assessors. Due to COVID-19, our protocol involved using the software Qualtrix to allow for the distribution of the survey. We recruited orthodontists, oral surgeons, lay people, and other dental professionals via websites such as Facebook, Instagram, and other social media platforms.
153 orthodontists, 141 oral surgeons, 68 lay persons, and 59 other dental professionals, rated the aesthetics and asymmetry of each model using a scale of 1-100 mm Visual Analog Scale (VAS) for asymmetry with the following left and right anchors: “least symmetric” and “most symmetric” and a scale of 1-100 mm Visual Analog Scale (VAS) for aesthetics with the following left and right anchors: “least aesthetically pleasing” and “most aesthetically pleasing”. No information was provided on the ethnicity, age, biological se of each model, allowing the raters to focus on shape.

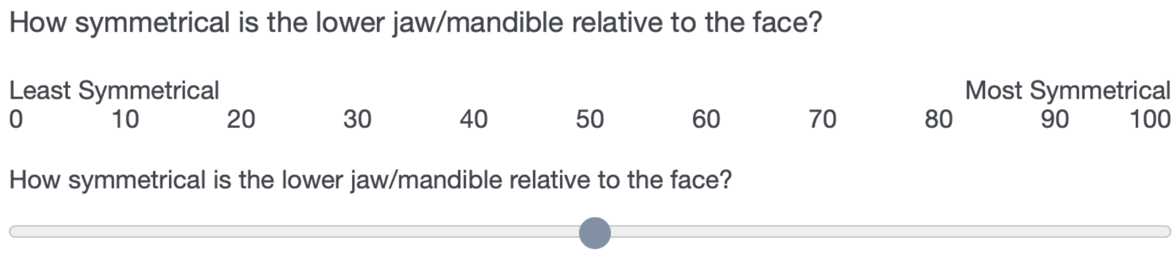


Figure 6: Sample of rating bar used to access symmetry

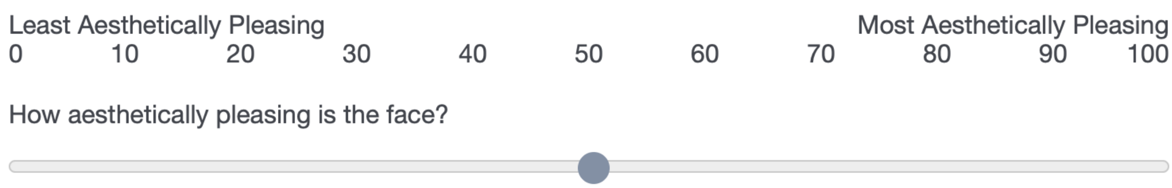


Figure 7: Sample of rating bar used to assess aesthetics

The raters were give a total of 20 seconds to view and rate the images. The total length of the survey was 10 min. The VAS scores were recorded via the software Qualtrix and measured by (JH) and averaged for each specific face.

B6: Sample Size and Recruitment

Due to COVID-19, our protocol involved using the software Qualtrix to allow for the distribution of the survey. We recruited orthodontists, oral surgeons, lay people, and other dental professionals via websites such as Facebook, Instagram, and other social media platforms.
153 orthodontists, 141 oral surgeons, 68 lay persons, and 59 other dental professionals. The STAI was used as with Decoste et al. to evaluate the anxiety of the raters, which has been shown in previous studies to lower judgement. We excluded raters with a score over 75.

Table 2: Breakdown of number of accessors by gender and profession

Variables	Number of Participants
Total Raters	463
Raters Included	421
Males	183
Females	277
Unlisted Gender	3
Orthodontists	153
Oral Surgeons	141
Laypersons	68
Other Dental Professionals	59

C: Results

C1: ANB angle

Since we hypothesized that the perception of facial symmetry and aesthetics appeared to be driven by changes in sagittal jaw relationships, our study assessed how well facial symmetry and aesthetics were correlated within a particular ANB as well as increasing ANB in Class I, Class II and Class III faces.

Our sample consisted of 30 anonymized, 3-dimentional (3D) CBCT scans of adults (ages 11-30 years old), lacking select confounding factors including but not limited to skin color and hair. The reference images obtained from the CBCT's were categorized by Class I, Class II, and Class III using ANB angles values ranging from -4.9 degrees to 5.8 degrees. No information was given to the raters regarding ethnicity, age, biological sex, allowing for focus on shape. These CBCT images were manipulated using Morpho J software in the transverse direction using gnathion and pogonion landmarks to alter mandibular symmetry at intervals of 0%, 25%, 50%, 75% and 100%. These images were then assessed and organized by assessors' professions of orthodontists, oral surgeons, other dental professionals, and laypersons.

When evaluating our data, we started by analyzing all the data collectively as the overall data and continued to break it down into more detailed groups and subgroups.

C2: Overall Data

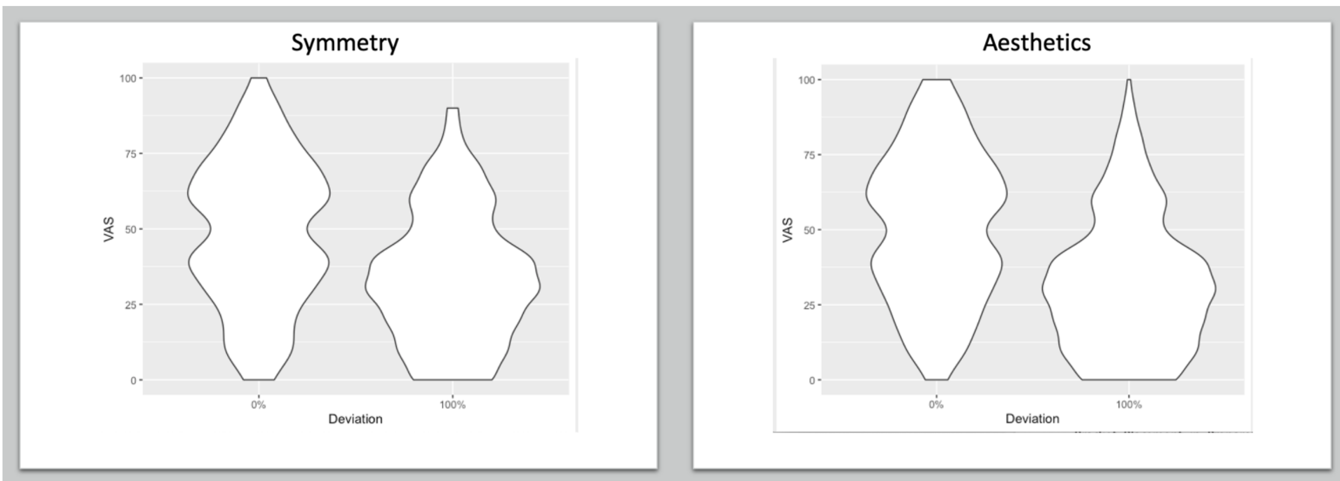


Figure 8: Violin plot representation of overall data distribution

The violin plot above depicts the distribution of the aesthetic and symmetry data. It can be noted that for both symmetry and aesthetics, at 0% the distribution varies greatly, with the majority of the data seen at two ranges of 37.5 and 62.5. At 100%, the distribution varies but not as significantly and is found to be approximately around 35.

The overall depiction of this data indicates that rater agreement at 0% mandibular deviation varies greatly with the majority of the distribution being higher than the distribution of the data for 100% mandibular deviation.

It should be noted that we hypothesized that assessors would rate 0% mandibular deviation higher than 100% mandibular deviation and although the above violin plot indicates this trend, the distribution of the data is more variable than expected.

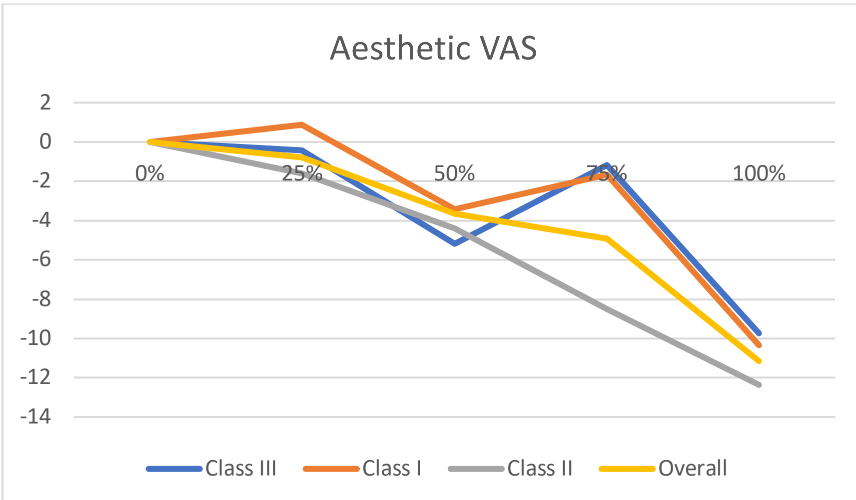


Figure 9: Line graph representation Aesthetic VAS scores with increasing mandibular asymmetry in Class I, Class II, Class III faces

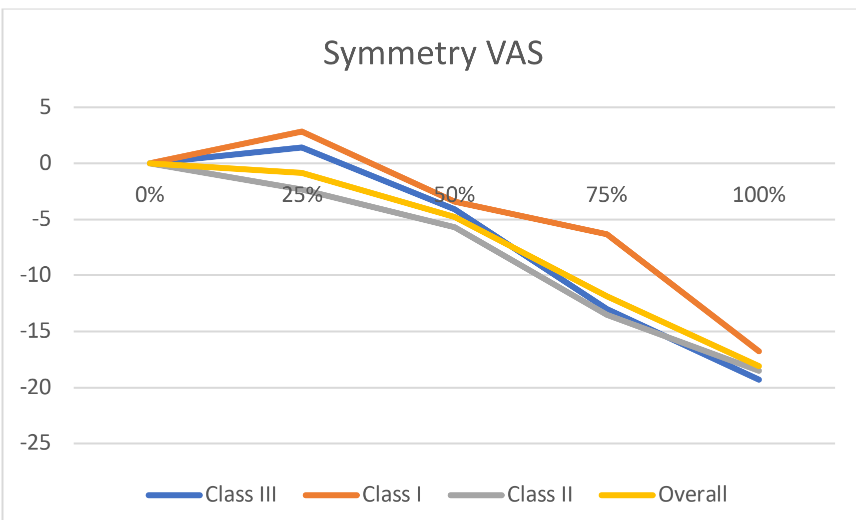


Figure 10: Line graph representation Symmetry VAS scores with increasing mandibular asymmetry in Class I, Class II, Class III faces

Our overall data is defined as a combination of 153 orthodontists, 141 oral surgeons, 59 other dental professionals and 68 laypersons.

When analyzing the above data, results were set to a scale of 0 to allow for comparison across Class I, Class II, and Class III faces.

C3: Aesthetics

As a general trend with our overall data of 421 assessors, our results indicate that in Class I, Class II and Class III faces, increasing mandibular asymmetry was significantly correlated with lower VAS scores for facial aesthetics.

When analyzing the ANB angles separately, Class II faces did follow the same trend as observed with the overall data, however, Class I and Class III faces data indicate deviations from this trend in which increasing mandibular asymmetry did not have a direct correlation with lower VAS scores for facial aesthetics. For example, as observed in the graph above in Class I faces, 25% mandibular deviation was rated higher than 0% mandibular deviation. The same trend in seen within Class III faces, where 75% mandibular deviation was rated higher than 50% mandibular deviation.

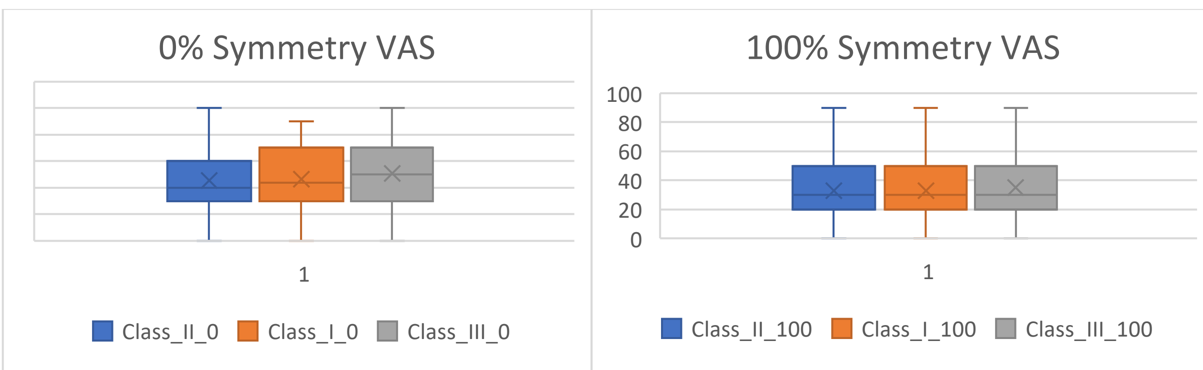
In addition, the data above indicates that in Class I and Class III faces, 75% mandibular deviation is noted as significant threshold drop of the VAS. In Class II faces, this is seen at 50% mandibular deviation. These indicate the threshold point with which raters are able to distinguish the deviation in mandibular asymmetry that affect aesthetic perception.

C4: Symmetry

Similar to the aesthetic data, a general trend with our overall data of 421 assessors indicate that in Class I, Class II and Class III faces, increasing mandibular asymmetry was significantly correlated with lower VAS scores for facial symmetry.

When analyzing the ANB angles separately, Class II faces did follow the same trend as observed with the overall data, however, Class I and Class III faces data indicate deviations from this trend in which increasing mandibular asymmetry did not have a direct correlation with lower VAS scores for facial symmetry. For example, as observed in the graph above for both Class I and Class III faces, 25% mandibular deviation was rated higher than 0% mandibular deviation. In addition, the data above indicates that in Class II and Class III faces, 50% mandibular deviation is noted as significant threshold drop of the VAS. In Class I faces, this is seen at 75% mandibular deviation. These indicate the threshold point with which raters are able to distinguish the deviation in mandibular asymmetry that affect aesthetic perception.

C5: 0-100% VAS score comparison

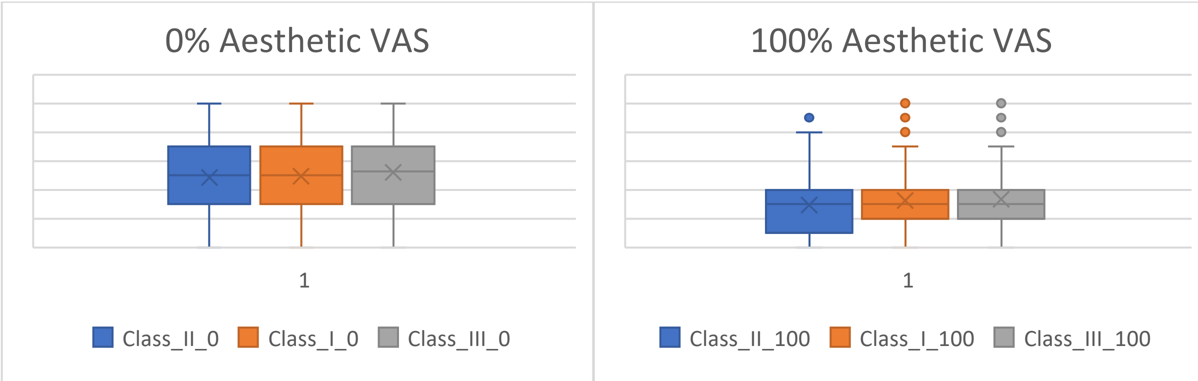


Median Values from graphs above:

Class I	47.31
Class II	47.19
Class III	53.51

Class I	33.30
Class II	38.08
Class III	36.80

Figure 11: Box plot of 0% and 100% symmetry VAS scores in Class I, Class II, and Class III faces



Median Values from graphs above:

Class I	47.9	Class I	34.56
Class II	49.45	Class II	32.82
Class III	55.94	Class III	43.27

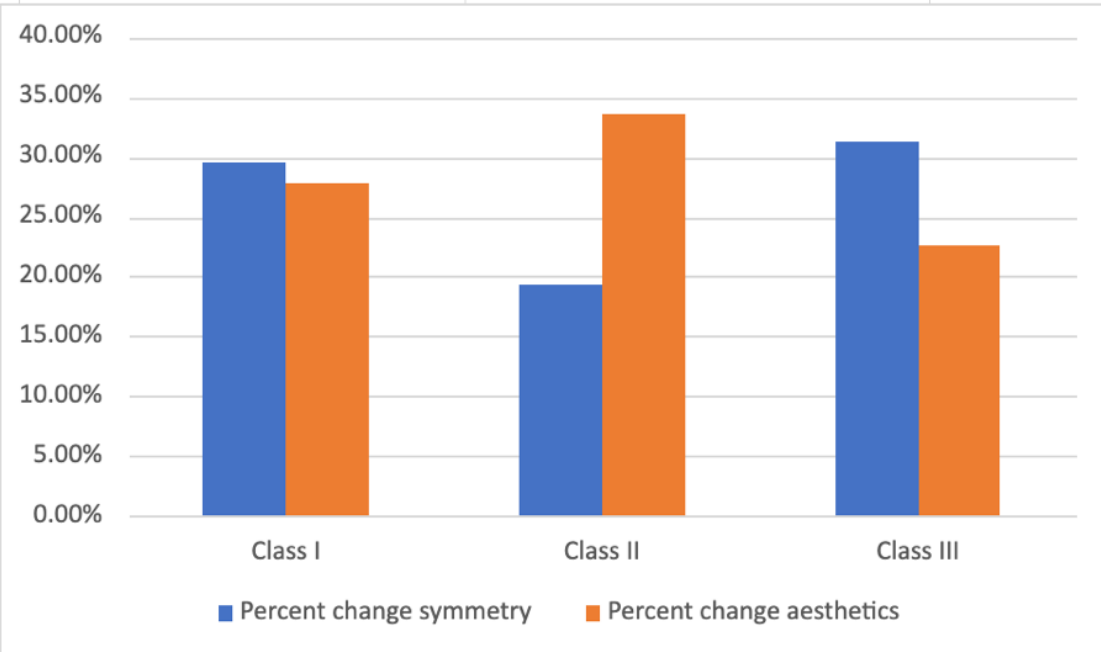
Figure 12: Box plot of 0% and 100% aesthetic VAS scores in Class I, Class II, and Class III faces

C6: Aesthetics and Symmetry with differential ANB angles (Class I, Class II, Class III) with increasing mandibular asymmetry

Additionally, we hypothesized that the perception of facial symmetry and aesthetics appeared to be driven by changes in sagittal jaw relationships, therefore, our study also assessed how well perception of facial asymmetry and aesthetics were correlated to each other within a particular ANB angle, as well as to increasing ANB angles, including Class I, Class II, and Class III faces. To evaluate this data, the scale was not set to 0 to allow for assessment of differences in rating of the VAS score. The data indicates that within a particular ANB angle, there is a correlation between perception of facial aesthetics and symmetry as can be seen by the median values listed in the above tables.

In addition, we hypothesized that individuals will find patients with transverse jaw asymmetries and increased or decreased anteroposterior relationships less aesthetic than those with transverse jaw asymmetries and normal sagittal relationships. However, the data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, there is not a linear decrease in perception of mandibular aesthetics and asymmetry. Our data concluded that when rating aesthetics, Class III faces were scored the highest followed by Class II then Class I faces. For symmetry, Class III faces were scored the highest followed by Class I then Class II faces. We hypothesize that these results could be due to confounding factors such as soft tissue and facial characteristics that may influence the assessors' perception to a greater extent than the ANB angle.

C7: Percentile changes in VAS scores when evaluating aesthetics and symmetry from 0-100% mandibular asymmetry



	Percentile change Symmetry*	Percentile change Aesthetics*
Class I	29.61 %	27.84 %
Class II	19.30 %	33.62 %
Class III	31.22 %	22.6 %

*Percentile change from 0-100% mandibular asymmetry

Figure 13: Percentile change in VAS scores when evaluating aesthetics and symmetry from 0-100% mandibular asymmetry

Similar to previous data presented, it can noted from the chart above the correlation between symmetry and aesthetics within a particular ANB angle with increasing mandibular asymmetry. Additional analysis can be observed, being the trend noted is not a equal decrease in perception between symmetry and aesthetics, the range being from 19-33% decrease in VAS score from 0% mandibular deviation to 100% mandibular deviation. The graph above depicts in Class I, symmetry and aesthetics were similarly affected, in Class II, aesthetic perception was more affected than symmetry and lastly in Class III, symmetry was more affected than aesthetics.

C8: VAS scores in subgroups

Within our data, we analyzed the VAS scores for subgroups. We started by analyzing the professional subgroup and continued to break it down into more detailed subgroups. For this particular analysis, we solely looked at the starting point (original face), therefore, when each particular face is at 0% manipulation of mandibular asymmetry.

Starting off with our largest groups of professionals, defined as a combination of 153 orthodontists, 141 oral surgeons, and 59 other dental professionals, we compared the VAS scores to those of laypersons. In our Class I, II and III faces, professionals rated the faces with an overall lower VAS score than the lay persons. The p values for aesthetics indicate that this was significance as the p<0.05, however, for symmetry the data indicates that it is not significant.

Table 3: Professional vs. Laypersons VAS scores in Class I, Class II, and Class III faces

	Class I (Aesthetics/ Symmetry)	Class II (Aesthetics/ Symmetry)	Class III (Aesthetics/ Symmetry)
Professionals	40.73/ 43.43	42.97/ 43.39	40.66/ 41.43
Laypersons	47.93/ 49.19	48.28/45.73	45.84/ 44.86

Table 4: Professionals vs. Laypersons p values for aesthetics and symmetry

	p values aesthetics	p values symmetry
Class I	0.00353814	0.17106303
Class II	0.00028517	0.12252177
Class III	0.00501674	0.08748841

Next, we compared the VAS scored of orthodontists vs. oral surgeons. In our Class I, Class II, and Class III faces, oral surgeons rated the faces with an overall higher VAS score than orthodontists. The p values for aesthetics and symmetry indicate that significance as the $p<0.05$, indicating that orthodontists were more particular and discerning of all faces.

Table 5: Orthodontists vs. Oral Surgeons VAS scores in Class I, Class II, and Class III faces

	Class I (Aesthetics/Symmetry)	Class II (Aesthetics/Symmetry)	Class III (Aesthetics/ Symmetry
Orthodontists	36.64/38.77	39.24/ 39.09	35.84/37.16
Oral Surgeons	43.40/45.13	45.16/46.11	44.88/ 45.13

Table 6: Orthodontists vs. Oral Surgeons p values for aesthetics and symmetry

	p values aesthetics	p values symmetry
Class I	0.002204887	0.002493052
Class II	2.90347E-06	7.40022E-08
Class III	1.00729E-09	3.60469E-07

D: Discussion

Deviations in the mandible are one of the most noticeable characteristics of disharmony, particularly the lateral displacement of the mandible in relationship to the midsagittal plane [13]. In this study, we sought to evaluate perception of transverse jaw asymmetries in patients with varying degrees of sagittal jaw relationships. We hypothesized that maxillary-mandibular skeletal relationship (ANB) is a significant predictor of perception of mandibular asymmetry. There are four key findings that we report: 1. Our findings did not support the idea that balanced jaw associations are the most consistent predictor of facial aesthetics and symmetry. The data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, is not indicative of decreasing perception of aesthetics and symmetry; 2. Within a particular ANB angle, the majority shape changes were negatively perceived, in which, increasing mandibular asymmetry was correlated with lower VAS scores for facial aesthetics and symmetry; 3. Additional analysis indicating that is not a linear decrease in perception between symmetry and aesthetics, the range being from 19-33% decrease in VAS score from 0% mandibular deviation to 100% mandibular deviation; 4. Out of all of the subgroups of data collected, the orthodontic group were the most particular and discerning all of the original faces by scoring the lowest VAS scores for all subgroups.

Most older studies have used largely two-dimensional (2D) methods such as photographs, silhouettes, line drawings and cephalometric analysis to investigate facial morphology and aesthetics [13]. Considering the complexity of the face, 2D images lack the ability to capture influential factors affecting perception ,therefore, 3D methods allow for more reliable information [13]. In addition, for example, Duran et al., have evaluated mandibular asymmetry by manipulating the chin in intervals of 2mm, 4mm, 6mm, 8 mm and 10 mm. Our study used 3D generated alteration of CBCT's to alter facial asymmetry at intervals unique to each individual CBCT to assess the perception of increasing mandibular asymmetry related to differences in sagittal jaw relationships.

E: Conclusion

Inconsistent with our hypothesis, we found that increasing or decreasing anteroposterior jaw position does not have the strongest impact on facial esthetics and symmetry. Our findings did not support the idea that balanced jaw associations are the most consistent predictor of perception of facial aesthetics and symmetry. We hypothesized that individuals will find patients with transverse jaw asymmetries and increased or decreased anteroposterior relationships less aesthetic than those with transverse jaw asymmetries and normal sagittal relationships. However, the data indicates that the severity of the skeletal sagittal relationship was increased, as in Class I, Class II and Class III relationships, as measured by ANB, there is not a linear decrease in perception of mandibular symmetry and esthetics.

In addition, our overall results indicate that within a particular ANB angle, the majority shape changes were negatively perceived, in which, increasing mandibular asymmetry was correlated with lower VAS scores for facial aesthetics and symmetry. Therefore, within a particular ANB angle, there is a correlation between perception of facial aesthetics and symmetry.

Additional analysis indicating that is not a linear decrease in perception between symmetry and aesthetics, the range being from 19-33% decrease in VAS score from 0% mandibular deviation to 100% mandibular deviation. In our Class I, II and III faces, professionals rated the faces with an overall lower VAS score than the laypersons. The p values for aesthetics indicate that this was significance as the $p<0.05$, however, for symmetry the data indicates that it is not significant. Lastly, in our Class I, Class II, and Class III faces, oral surgeons rated the faces with an overall higher VAS score than orthodontists. The p values for aesthetics and symmetry indicate that significance as the $p<0.05$, indicating that orthodontists were more particular and discerning of all faces. We conclude that inconsistencies seen in our results could be attributed to confounding factors such as soft tissue characteristics that are altering perception of aesthetics and asymmetry.

F: Limitations

Subjectivity is present when evaluating facial aesthetics and symmetry. In this study, we attempted to remove confounding factors by removing the presence of extrinsic and intrinsic distracting variables that what could influence raters' perception, however, there are limitations that were met.

In our study, we removed skin color, hair and no information was given regarding ethnicity and age. Even though our focus was evaluating perception of facial symmetry and aesthetics, confounding factors were present, most notably soft tissue differences present in each particular face.

The CBCT sample selection in the current study comprised of 6 CBCT with varying degrees of ANB. Our Class I consisted of N=1, Class II N=3 and Class III N=2. Indeed, there was not an equal distribution of faces in which soft tissue disparities may have had a large influence of raters scoring that could not be averaged if for example, a similar number of each classified face had been used.

In a future study, it would be interesting to look at facial aesthetics and symmetry in which one particular face is used with altering degrees of mandibular asymmetry. By using the same face, confounding factors such as soft tissue disparities could be eliminated to get a true sense of the impact of ANB on perception of aesthetics and symmetry.

G: Sample of Faces

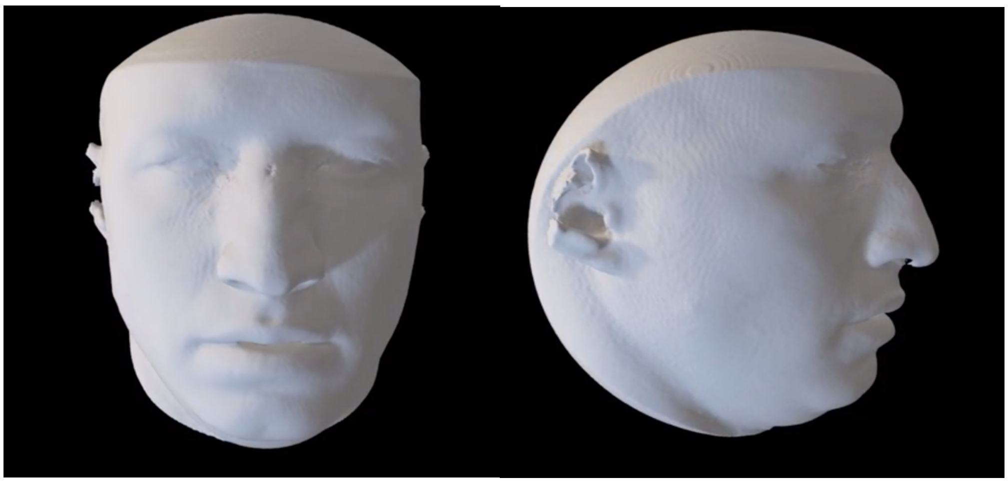


Figure 14: Face 176, Class I, ANB= 1.4 degrees

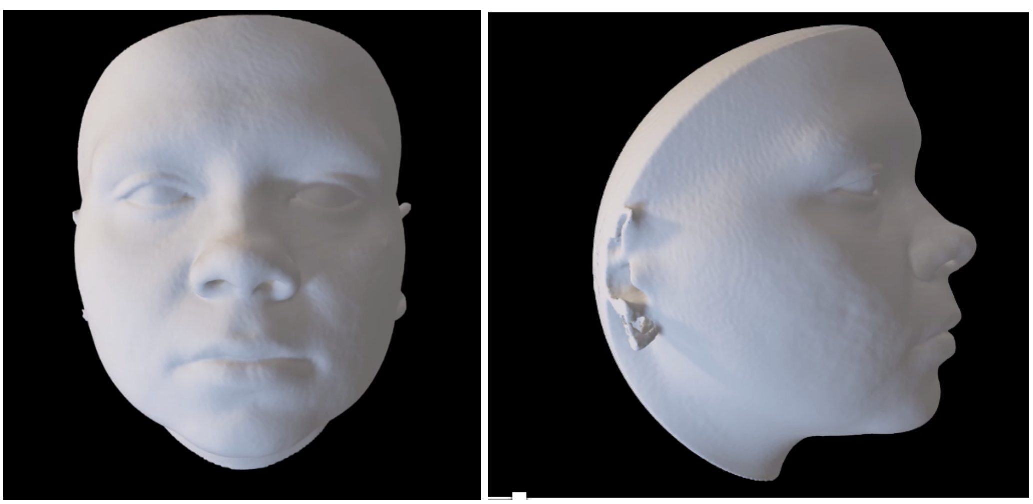


Figure 15: Face 101, Class II, ANB=3.7 degrees

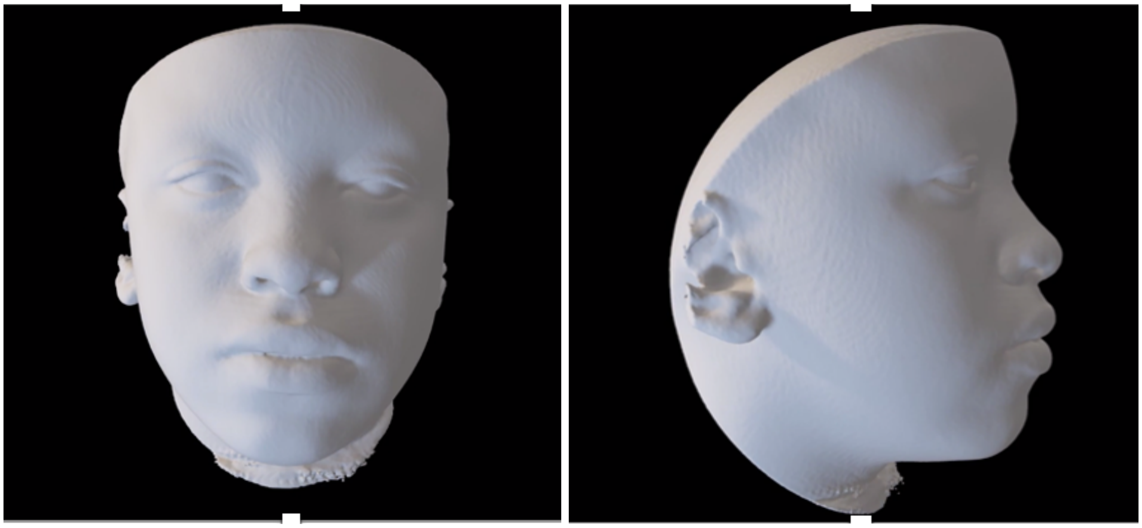


Figure 16: Face 41,Class II, ANB=4.2

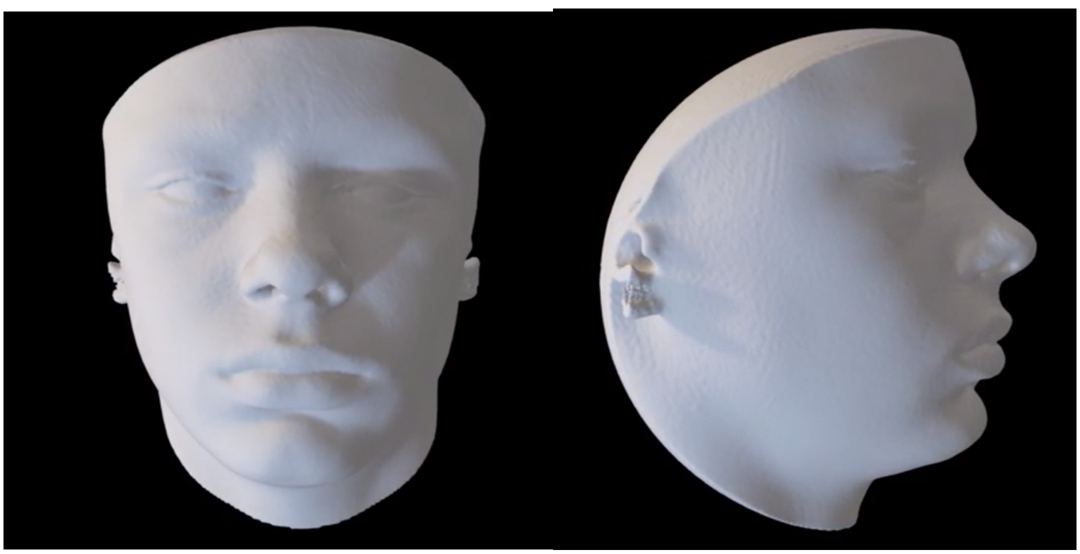


Figure 17: Face 202, Class II, ANB=5.8 degrees

Figure 18: Face 123, Class III, ANB= -4.2

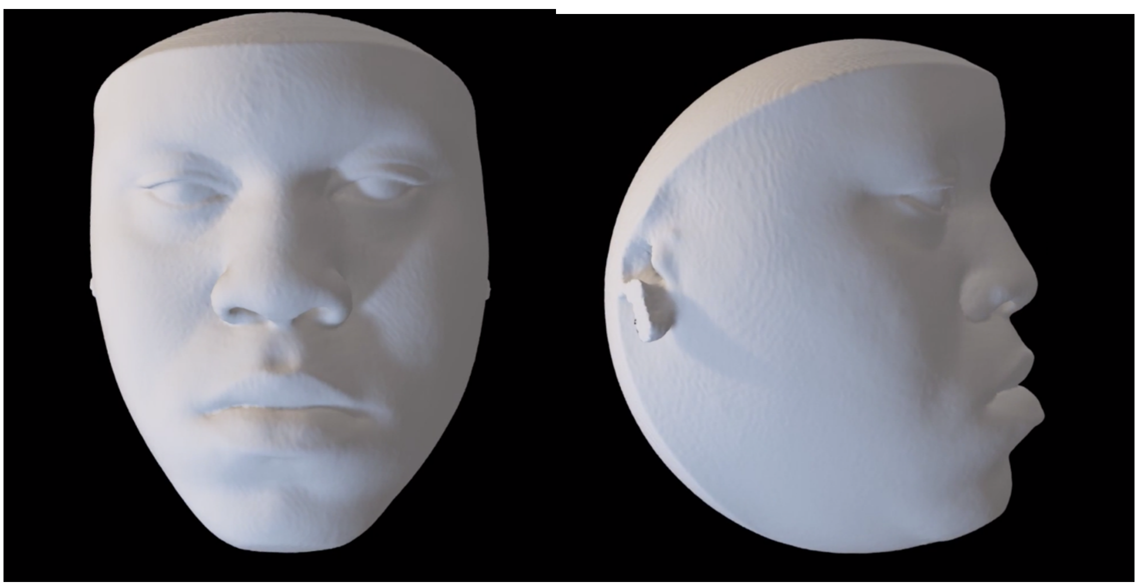


Figure 19: Face 275, Class III, ANB= -4.9 degrees

H: References

[1] Bashour, Mounir. “History and Current Concepts in the Analysis of Facial Attractiveness.” Plastic and reconstructive surgery (1963) 118.3 (2006): 741–756. Web.

[2] Little, Anthony C et al. “Facial attractiveness: evolutionary based research.” *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* vol. 366,1571 (2011): 1638-59. doi:10.1098/rstb.2010.0404

[3] Naini, Farhad B, James P Moss, and Daljit S Gill. “The Enigma of Facial Beauty: Esthetics, Proportions, Deformity, and Controversy.” *American journal of orthodontics and dentofacial orthopedics* 130.3 (2006): 277–282. Web.

[4] Hönn M, Göz G. The ideal of facial beauty: a review. J Orofac Orthop. 2007 Jan;68(1):6-16. English, German. doi: 10.1007/s00056-007-0604-6. PMID: 17238049.

[5] Zaidel, Dahlia W., and Marjan Hessamian. “Asymmetry and Symmetry in the Beauty of Human Faces.” *Symmetry (Basel)* 2.1 (2010): 136–149. Web.

[6] Alam MK, Mohd Noor NF, Basri R, Yew TF, Wen TH (2015) Multiracial Facial Golden Ratio and Evaluation of Facial Appearance. PLoS ONE 10(11): e0142914. https://doi.org/10.1371/journal.pone.0142914

[7] Ercan I, Ozdemir ST, Etoz A, et al. Facial asymmetry in young healthy subjects evaluated by statistical shape analysis. *J Anat*. 2008;213(6):663–669. doi:10.1111/j.1469-7580.2008.01002.x

[8] Thiesen, Guilherme et al. “Facial asymmetry: a current review.” *Dental press journal of orthodontics* vol. 20,6 (2015): 110-25. doi:10.1590/2177-6709.20.6.110-125.sar

[9] Graber, L. W., Vanardsdall, R.L., Vig, K. W. & Huang, G.J. (2016) Orthodontics-E-Book: Current Principles and Techniques Elsevier Health Science’s.

Karatas O.H. & Toy, E. (2014) Three-dimensional imaging techniques: A literature review. European Journal of Dentistry, 8(1), 132-140

[10] Proffit, W.R. Fields Jr., H.W. & Sarver, D. M. (2006) Contemporary orthodontics Elsevier Health Sciences

[11] Joseph, Arun et al. "Effect of Sagittal Dentoskeletal Discrepancies on the Vermilion Height and Lip Area." *Turkish journal of orthodontics* vol. 32,2 (2019): 79-86. doi:10.5152/TurkJOrthod.2019.18037

[12] Ishizaki, Kyoko et al. "Morphologic, functional, and occlusal characterization of mandibular lateral displacement malocclusion." *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics* vol. 137,4 (2010): 454.e1-9; discussion 454-5. doi:10.1016/j.ajodo.2009.10.031

[13] Duran, Gökhan Serhat, Fahir Özer Taşdelen, and Furkan Dindaroğlu. "Effect of Facial Profile Convexity on the Perception of Mandibular Asymmetry Using Three-dimensional Stereophotogrammetric Images." *Orthodontics & craniofacial research* 23.1 (2020): 110–117. Web.

[14] Brook, PH, Shaw, WC (1989) The development of an index of orthodontic treatment priority. European Journal of Orthodontics 11: 309–320.

[15] Nazgol Zamanian, and Alireza Jafari-Naeimi. "The Perception of the Severity of Facial Asymmetry Among Laypersons, General Practitioners, Orthodontists, and Maxillofacial Surgeons." *Journal of dentistry (Shiraz)* 22.2 (2021): 102–108. Web.

[16] Kim, Da In, and Manuel O Lagravère. "Assessing the Correlation between Skeletal and Corresponding Soft-Tissue Equivalents to Determine the Relationship between CBCT Skeletal/Dental Dimensions and 3D Radiographic Soft-Tissue Equivalents." *International journal of dentistry* vol. 2018 8926314. 3 Jul. 2018, doi:10.1155/2018/8926314

[17] Alam, Mohammad Khursheed et al. “Multiracial Facial Golden Ratio and Evaluation of Facial Appearance.” *PloS one* vol. 10,11 e0142914. 12 Nov. 2015, doi:10.1371/journal.pone.0142914

[18] Ricketts, R M. “The golden divider.” *Journal of clinical orthodontics : JCO* vol. 15,11 (1981): 752-9.

[19] Veerala, Gopi et al. “Marquardt's Facial Golden Decagon Mask and Its Fitness with South Indian Facial Traits.” *Journal of clinical and diagnostic research : JCDR* vol. 10,4 (2016): ZC49-52. doi:10.7860/JCDR/2016/16791.7593

[20] Choi, Kang Young. “Analysis of Facial Asymmetry.” *Archives of craniofacial surgery* vol. 16,1 (2015): 1-10. doi:10.7181/acfs.2015.16.1.1

[21] Zaidel, Dahlia W, and Choi Deblieck. “Attractiveness of natural faces compared to computer constructed perfectly symmetrical faces.” *The International journal of neuroscience* vol. 117,4 (2007): 423-31. doi:10.1080/00207450600581928

[22] Qamaruddin, Irfan et al. “Comparison of popular sagittal cephalometric analyses for validity and reliability.” *The Saudi dental journal* vol. 30,1 (2018): 43-46. doi:10.1016/j.sdentj.2017.10.002

[23] Farhad B. Naini, James P. Moss, Daljit S. Gill The enigma of facial beauty: Esthetics, proportions, deformity, and controversy,American Journal of Orthodontics and Dentofacial Orthopedics,Volume 130, Issue 3,2006,Pages 277-282.

[24] Phillips, C et al. “The effect of treatment on facial attractiveness.” *Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons* vol. 50,6 (1992): 590-4. doi:10.1016/0278-2391(92)90439-7

[25] Little AC, Jones BC, DeBruine LM. Facial attractiveness: evolutionary based research. *Philos Trans R Soc Lond B Biol Sci*. 2011;366(1571):1638–1659. doi:10.1098/rstb.2010.0404

[26] Langlois, J. H., Roggman, L. A., Casey, R. J., Ritter, J. M., Rieser-Danner, L. A., & Jenkins, V. Y. (1987). Infant preferences for attractive faces: Rudiments of a stereotype? *Developmental Psychology, 23*(3), 363–369. https://doi.org/10.1037/0012-1649.23.3.363

[27] Cunningham, M. R., Roberts, A. R., Barbee, A. P., Druen, P. B., & Wu, C.-H. (1995). "Their ideas of beauty are, on the whole, the same as ours": Consistency and variability in the cross-cultural perception of female physical attractiveness. *Journal of Personality and Social Psychology, 68*(2), 261–279. https://doi.org/10.1037/0022-3514.68.2.261

[28] Rhodes, G., Proffitt, F., Grady, J. M., & Sumich, A. (1998). Facial symmetry and the perception of beauty. *Psychonomic Bulletin & Review*, *5*(4), 659-669. https://doi.org/10.3758/BF03208842

[30] Schabel, Brian J et al. "Q-sort assessment vs visual analog scale in the evaluation of smile esthetics." American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics vol. 135,4 Suppl (2009): S61-71. doi:10.1016/j.ajodo.2007.08.019

[31] Decoste, Janick. Three Dimensional Shape Correlates of Facial Attractiveness in Patients with Sagittal Skeletal Discrepancy

[32] *OED Online*. Oxford University Press, March 2022. Web. 14 May 2022.

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