IS THERE A RELATIONSHIP BETWEEN THE AXIS ORBITAL PLANE AND THE INCLINATION OF THE MAXILLARY CENTRAL INCISORS: AN IN VIVO STUDY

A Thesis

by

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ABSTRACT

The purpose of this investigation was to evaluate if a relationship exists between the maxillary central incisors and the axis orbital plane determined by the SAM® anatomic face-bow. The study evaluated the angle formed by the incisal half (IA) and the cervical half (CA) of the tooth to the axis orbital plane and if there is a difference in angles with respect to gender. A relationship was determined to exist if the mean CA and IA angles where within 1 Standard Deviation (SD) of $\pm 5^{o}$ for each angle.

An anatomical face-bow (SAM Präzisionstechnik , Munchen) was used to locate arbitrary transverse mandibular axis on fifteen males and fifteen females. Photos of cast models were taken in the sagittal view of each subject mounted in the SAM III articulator. The JPEG images were imported into an imaging-editing program (Photoshop CS6, Adobe Inc, San Jose CA) where a line was drawn representing the axis orbitale plane. Two more lines were drawn representing the incisal and cervical half of the maxillary central incisors producing the incisal angle (IA) and the cervical angle (CA). A statistical analysis of the CA and IA angles was performed using statistical software (SPSS 19.0; SPSS Inc., Chicago IL). A non-parametric t-test (Mann-Whitney U) was used to indicate significant differences between the genders ($p<0.05$).

The mean cervical angles (CA) for males was $104.2^{o} \pm 4.9$ and for females $96.8^{o} \pm 4.6$. The mean incisal angles (IA) for males was $75.8^{o} \pm 7.6$ and for females was $68.2^{o} \pm 6.6$. There is a statistically significant difference ($P \leq 0.001$) between genders for both angles tested.

The results and data analyzed suggest a relationship between the mean cervical

angle (CA) and the axis orbital plane for males (104.2) and females (96.8). There was no relationship shown between the mean incisal angle (IA) and the axis orbital plane for either gender.

DEDICATION

This thesis is dedicated to my beloved wife Shelly Marie Merrell who has been unwavering in her support for me throughout our marriage journey and my academic life, for almost a decade. She and my children have supported and encouraged me to continue to preserve in the pursuit of excellence, even when it consumed my time.

I would like to express immense gratitude to my mentor, Dr. William W. Nagy, Director of the Graduate Prosthodontics Program at Texas A&M University Baylor College of Dentistry. He has allowed me to have a successful learning experience and given me an opportunity to join him in the prosthodontic society.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE Page

1. INTRODUCTION AND LITERATURE REVIEW

Anatomical landmarks and reference planes are often used in dentistry in planning the reconstruction of partial dentate or edentulous patients. The Camper's and the Frankfort horizontal line have both been used to clinically determine the anterior-posterior occlusal plane of the maxillary teeth [1]. The bipupillary line is parallel to the incisal edge of the maxillary anterior teeth, giving the dentist a reference in the horizontal plane [2]. Andrews also used many anatomical landmarks, such as forehead inclination to measure the ideal anteroposterior jaw position, which in turn is used to position the inclination of the maxillary incisors [3]. The use of these guidelines provides clinicians with an initial esthetic reference to start reconstructing the patient.

The position and axial inclination of the upper incisor plays an important role in the functional and esthetic outcome of a restorative treatment. The maxillary incisal edge position is considered the starting point of all full mouth reconstructions [4]. The inclination of the anterior teeth affect the lip support for the facial profile, influence the personality of the dentition and the smile line, and determine the pronunciation of the fricative and sibilant sounds [5, 6]. McHorris discussed the importance of the disclusive angle of the anterior teeth and how the inclination effects the disclusion of the posterior teeth [7]. Kois reported that the location of the maxillary central incisors is on average 100mm from transverse horizontal axis regardless of sex or height [8]. Orthodontists have evaluated the inclination of the maxillary teeth to determine the most esthetic inclination for the maxillary incisors [9].

When evaluating the inclination of the maxillary incisors, one has to consider the variations in curvature within the tooth. When viewed in the sagittal plane there is a curved labial surface that is convex, while the lingual surface is concave [10]. The maxillary incisor was described as having two parts, the body and the blade [11]. Bryant described the variability of the maxillary incisor by three anatomical features: crown-root angulation, labial surface, and lingual surface [12]. Both studies describe the labial surface of the maxillary incisors, which consists of a plane above and below the height of contour. There are also differences in the inclination of the incisor with different skeletal relationships [13].

The maxillary central incisor inclination has been a focus of investigations by orthodontists for many years. Downs, in 1948, first suggested the concept of a standard inclination for the upper incisors [14]. Anthropologists and orthodontists have used radiographs and cephalometric tracings to record the inclination of the maxillary anterior teeth [15]. The averages from these tracings are used to determine the inclination of the maxillary teeth to establish an esthetic profile. The Sella-nasion (SN) line and the Frankfort horizontal (FH) plane are often used as reference planes in the sagittal view. Daugaard and Jensen found that there is a 7° difference between the SN line and the FH plane[16]. Riedel found an angle between the SN plane to incisors of 103.9°± 5.75 and FH plane to incisors of 111.2°± 5.7 for adults with an Angles class 1 relationship [17]. These radiographic landmark averages allow orthodontists the ability to evaluate the patient's maxillary incisor inclination in order to make decisions to improve the esthetics, speech, and function.

These norms are based on radiographic anatomical landmarks and are different from clinical landmarks. Restorative dentists use the face-bow to transfer the spatial relationship of the maxillary dentition to anatomic reference points. The cephalometric radiograph uses an artificial machine porion with the ear rod [18], in contrast, the earbow uses the anatomical porion [19]. Sicher and Dubrul describe the differences in the machine porion, anthropologic porion and the anatomical porion. The anatomical porion is also known as the "cartilaginous porion". They discussed that the anthropologic porion cannot be determined in the living and that the cartilaginous porion is the midpoint on the upper border of the entrance into the external acoustic meatus [20].

The face-bow gives the restorative dentist the ability to capture the maxillary teeth in relation to the transverse mandiblular axis and then transfer that relationship to an articulator. To position the maxillary cast in the articulator there must be three reference points to establish a plane. The two posterior points are related to the transverse mandibular axis while a single anterior point, the orbitale, defines the plane. [1, 21] The axis orbital reference plane is the most commonly used [22].

A study by Gold and colleagues concluded that the face-bow transfer procedure has a high degree of accuracy [23]. When using the cephalometric radiograph, the tracings use the machine porion and the lowest point on the orbital rim as the anterior point. This plane is referred to as the Frankfort horizontal plane however; it is not related to the axis [24, 25]. With both methods, the anterior point is the orbitale. There are two ways the restorative dentist can locate the transverse mandibular axis point, kinematic and arbitrary.

The kinematic face-bow uses a clutch tray that is attached to the mandibular teeth. A hinge axis locator unit is attached to the clutch and the patient is instructed to open and close in terminal hinge relation, while the pin is adjusted in the X and Y axis until it only rotates around one point [26]. This procedure is lengthy and time consuming compared to the use of arbitrary axis points that use anatomical landmarks. There are many studies that looked at different locations of the arbitrary point and its relationship to the kinematic transverse horizontal axis [21, 27-30]. Locating an arbitrary axis point ± 5 mm anterior-posterior to the kinematic axis would result in a mathematically negligible error (0.2 mm) on the nonworking side when using a 3-mm–thick centric relation record [31]. Lauritzen used a Richey condyle marker to locate an arbitrary axis point that is 13mm anterior to the earpiece [29]. This arbitrary point was found to be within a 5mm radius of the kinematic axis point 33% of the time. One of the most common and widely used arbitrary points is the Bergström point. It is 11 mm anterior to the posterior margin of the tragus on a line parallel to and 7 mm below the Frankfort horizontal plane [27]. Beck reported that 83% of Bergström points were within 5mm of the kinematic axis [21]. More recently Nagy et al used an arbitrary face-bow that has a predetermined point 10mm anterior to the earpiece on the axis-orbital plane. They showed that this SAM® (prazisionstechnik) predetermined point is within 2mm of the kinematic axis 96.2% of the time [19]. The kinematic method is technique sensitive and time consuming, yet considered most accurate. The use of a time efficient arbitrary face-bow can be an acceptable method to locate the axis if the correct technique is used.

As orthodontists have used cephalometric tracings to relate the Frankfort horizontal plane to incisal inclination position, prosthodontists could use the face-bow to evaluate the axis-orbital to incisal inclination position. An incisal angle reference that relates to the axis orbital plane would allow clinicians the ability to position the maxillary incisors in an appropriate functional and esthetic relationship. There have been no clinical studies investigating the relationship of the incisal angle or cervical angle to the axis orbital plane. The purpose of this in vivo study is to determine if a relationship exists between the maxillary central incisors and the axis orbital plane as determined by the SAM® anatomic face-bow.

The hypothesis is that the angle formed by the incisal half of maxillary central incisors with the axis-orbital plane and the angle formed by the cervical half of maxillary central incisors with the axis-orbital plane will fall within 1 Standard Deviation (SD) of $\pm 5^{o}$ for each angle. The null hypothesis is that there will be no statistical difference between males and females in the angles formed by the incisal half of maxillary central incisors with the axis-orbital plane and the angle formed by the cervical half of maxillary central incisors with the axis-orbital plane.

2. MATERIALS AND METHODS

All facets of this in vivo study were approved by the Texas A&M University, Baylor College of Dentistry Institutional Review Board. Participants were selected based on the following inclusion and exclusion criteria. Fifteen males and fifteen females between ages 21 to 41years (mean: M-27, F-29).

Inclusion criteria:

1. Class 1 dentate patient
2. Permanent dentition in maxillary arch

Exclusion criteria:

1. History of orthodontic treatment
2. Restoration of labial surface of maxillary anterior teeth
3. Patients who were edentulous in the anterior segment of either arch

2.1 Preliminary Procedures

An anatomical face-bow (SAM Präzisionstechnik, Munchen) was used to locate each participants arbitrary transverse mandibular axis. The face-bow device was positioned using the blue earpiece inserts and nasion support bar. The maxillary face-bow anterior crossbar was oriented parallel to the interpupilary line. During orientation of the blue earpieces the participant hummed to verify the equal horizontal placement in the external auditory meatus. Three self-adhesive modeling plastic recording tabs were placed on the face-bow transfer fork at the maxillary left, right molar and the central incisor region to create 3 points of contact. The intraoral end of the face-bow fork was placed in 40C water for 1 min to soften the modeling plastic tabs. The fork was placed in the subjects' mouth and light finger pressure was applied to create maxillary cusp tip impressions in the modeling plastic tabs. The face-bow was attached to the transfer fork using the SAM non-torsion clamp. The face-bow was then visually inspected on the participant to insure that the anterior face-bow crossbar was oriented to the interpupilary line at the orbitale level. (Figure 1) The face-bow was carefully removed to eliminate any errors in the record and transferred to the articulator.

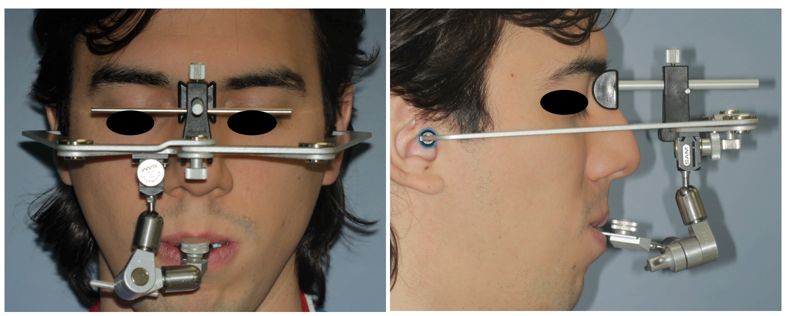

Figure 1: A, B, Face-bow attached by using anatomic landmarks of nasion and external auditory meati.

Maxillary dental arch impressions were made using stock impression trays (3M, Coltene President) and irreversible hydrocolloid impression material (Densply Caulk, Jeltrate). Water/powder ratio was used according to manufacture instructions. The stone casts were obtained using ADA type III dental stone (Whip Mix, Microstone). Each stone cast was mounted using an Axiosplit mounting plate (SAM) and ADA type III dental stone (Whip Mix, Mounting stone) in the SAM III articulator. (Figure 2)

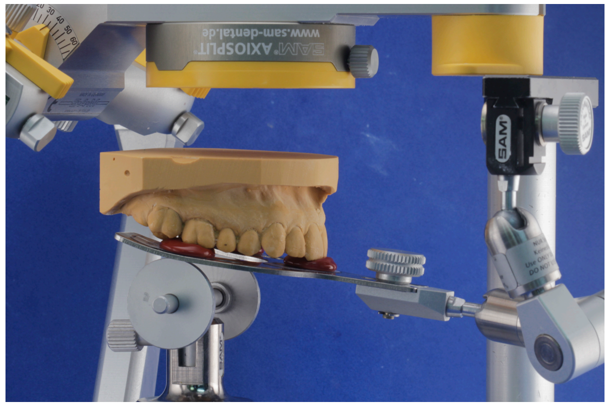

Figure 2: Stone cast stabilized for mounting using SAM non-torsion clamp with three self-adhesive modeling plastic recording tabs (SAM) on the SAM III articulator

2.2 Data Collection

A photo jig was fabricated to accommodate the articulator in a stationary reproducible position with a tripod ball head (Dolica, Los Angeles CA) attached 3 feet away from the center of the articulator. (Figure 3) A camera (Rebel T3i Canon, Canon U.S.A. Inc, Melville NY) with a Macro lens (Canon, Canon U.S.A. Inc, Melville NY) EF 100mm 1:2.8 USM with a focus of 1:1 was used to capture the image of the stone model in the articulator in the sagittal view. The camera f-stop was set to 14, the shutter speed to 1/40th of a second, and the aperture priority exposure program was selected. Images were stored in joint photographic experts group (JPEG) format. The settings on the camera and articulator were the same for all mounted specimens and taken at the same time.

Figure 3: Photo jig with articulator in a stationary reproducible position and Dolica tripod ball head attached 3 feet away.

2.3 Data Preparation and Analysis

The JPEG images were imported into an imaging-editing program (Photoshop CS6, Adobe Inc, San Jose CA) where a line was drawn parallel to the upper member of the articulator, representing the axis orbital plane. Another line was drawn 90 degree from the axis orbit plane to mark the height of contour. This point was used as break point of the incisal half vs. the cervical half of the tooth. Lines where drawn from the incisal edge to the height of contour along the labial surface of maxillary left central until it intersected the upper member of the articulator. This represented the incisal angle (IA). Another line from the height of contour point to gingival margin along the labial surface of maxillary left central until it intersected the upper member of the articulator. This represented the cervical angle (CA). This allowed imaging-editing program (Photoshop CS6, Adobe Inc, San Jose CA) to produce an angle. (Figure 4)

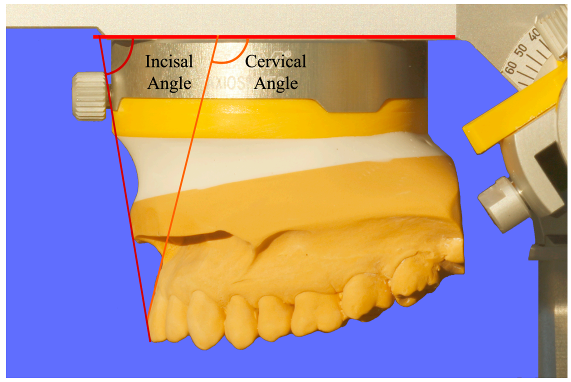

Figure 4: Maxillary cast showing the two different angles measured, incisal angle (IA) and the cervical angle (CA).

This procedure was performed three times to determine the incisal angle (IA) and three for the cervical angle (CA) per participant. The three incisal angles (IA) and cervical angles (CA) for each participant were averaged to produce a single angle for both (IA) and (CA).

A single operator performed all measurements. After collection of the data for all thirty participants, a statistical analysis was performed using statistical software (SPSS 19.0; SPSS Inc., Chicago IL). A non-parametric t-test (Mann-Whitney U) was used to indicate significant differences between the genders ($p<0.05$).

3. RESULTS

The basic research question was to determine if a relationship (± 5°) existed between the maxillary central incisors and the axis orbital plane determined by the SAM® anatomic face-bow. The data suggest there is a relationship between the mean cervical angle (CA) and the axis orbital plane for males and for females. However, there is not a relationship between the mean incisal angle (IA) and the axis orbital plane. The descriptive statistics for both genders and the two angles measured are shown in Table 1.

Table 1. Descriptive Statistics for Cervical and Incisal Angle according to Gender.

	Cervical Angle (CA)		Incisal Angle (IA)	
	Male	**Female**	**Male**	**Female**
Mean ± SD*	104.2°± 4.9	96.8°± 4.6	75.8°± 7.6	68.2°± 6.6
Median	103.2°	97.4°	74.5°	68.4°
IR**	7.6°	6.3°	9.4°	10.3°
Minimum	96.1°	87.1°	63.0°	57.7°
Maximum	114.8°	105.8°	93.6°	80.2°

* Standard Deviation (SD)
** Interquartile Range (IR)

A non-parametric t-test (Mann-Whitney U) was used to evaluate the CA and IA angle gender differences ($p<0.05$). Table 2 shows that the CA and IA angles were significantly different ($P \leq 0.001$).

Table 2. Non-parametric tests exploring differences according to Gender (Male vs. Female)

	Cervical Angle	Incisal Angle
Mann-Whitney U	256	436.5
Wilcoxon W	1291	1471.5
Z	-5.853	-4.319
Significance (2-tailed)	*P*≤0.001	*P*≤0.001

4. DISCUSSION

The purpose of this investigation was to evaluate if a relationship exists between the maxillary central incisors and the axis orbital plane determined by the SAM® anatomic face-bow. The study evaluated the angle formed by the incisal half (IA) and the cervical half (CA) of the tooth to the axis orbital plane. The study also investigated the difference in the IA and CA angle compared by gender.

The results strongly suggest a relationship between the cervical angle (CA) and the axis orbital plane determined by the SAM® anatomic face-bow for both males and females. A mean angle variation of 1SD $\pm 5^{o}$ was used and is supported by other studies that have evaluated the inclination of the anterior teeth [17, 32]. Therefore, the hypothesis that the angle formed by the cervical half of maxillary central incisors with the axis-orbital plane will fall within 1SD for males and females is accepted. This relationship is statistically different for gender, resulting in rejection of the null hypothesis that there is no significant difference between genders in the angle formed by the cervical half of maxillary central incisors with the axis-orbital plane. The males have a greater mean cervical angles (CA) of $104.2^{o} \pm 4.9$, while the females is less with a mean of $96.8^{o} \pm 4.6$.

The Riedel study evaluated comparable radiographic landmarks and reported similar means [17]. However, his study reported different mean inclination angles that could be due to the difference between radiographic landmarks and clinical landmarks [20].

Other studies have also evaluated the difference between radiographic and clinical landmarks. A study by Ferrario and colleagues evaluated the changes in the Frankfort horizontal plane that occurs with different posterior endpoints. They concluded that the machine porion (hard) and tragus (soft) tissue did not coincide, as there was a $7.29^{o} \pm 3.7^{o}$ difference between the two points[25]. Ferrario and Pitchford concluded that lack of parallelism of the radiographic and anatomical landmarks would result in inaccuracies with prosthetic reconstructions and esthetics [25, 33]. The present clinical study used the axis orbital plane that was located with the SAM face-bow and is an accurate reproduction of this plane [19]. Therefore, the mean CA angle found in this study should be useful to the restorative dentist when restoring the anterior teeth.

Another recent in vivo study evaluated the importance of the incisor inclination on aesthetics using photographs with reference lines drawn horizontally through orbitale and clinical porion [9]. Their estheticly determined angle of 93^{o} for all female subjects and is close to our results with the female CA group. However, they used a technique to position the head described by Bass [34], where an aesthetic horizontal line is drawn using angles made from the e-plane, while our study used the predetermined SAM axis orbital points.

In our study, there was no relationship with the mean incisal angle (IA), even though there was a difference between males and females. A study by Kois found that there is an average distance of 100mm from the arbitrary transverse horizontal axis to the maxillary central incisal edge regardless of gender [8]. Even though the Kois and our study were evaluating different aspects of the central incisors to the axis, the Kois study reported a relationship with the incisal edge, while our study had no relationship with the incisal angle. It is also worth noting that our study found a difference between genders while the Kois study stated no gender difference. Both studies used different face-bows, which have different arbitrary hinge axis points. It would be interesting to utilize the SAM anatomic face-bow to evaluate the distance to the incisal edge providing clinicians the ability to know the incisal edge position. This position in conjunction with the mean cervical angle would give the dentist information needed to restore the maxillary teeth.

The most predictable angle and surface of the maxillary tooth is the cervical half of the tooth. It was an interesting observation in all of the photos (figure 4), the cervical half of the tooth followed the maxillary alveolar process contour as discussed by Dawson [10] and the CA may also predict the alveolar process contour. On the other hand, the incisal angle was the least predictable. This could be due to the wear that occurs in the incisal half of the teeth as Smith reports tooth wear in all ages [35].

Using the SAM anatomic face-bow the clinician has an inclination reference to start the reconstruction of partially dentate or edentulous patients. As reported by Pound and Frush, the inclination of the anterior teeth affect the lip support for the facial profile, influence the personality of the dentition and the smile line, and determine the pronunciation of the fricative and sibilant sounds [5, 6]. These cervical angles (CA) of the upper incisors play an important role in the functional and esthetic outcome of a restorative treatment. The use of the cervical angles according to gender allows for better predictability when clinicians are replacing the anterior teeth. Once the incisal edge is located, the use of the cervical angle (CA) mean provides clinicians with an initial esthetic reference to start dental reconstruction.

This study has suggested the importance of using clinical averages instead of the radiographic averages, and has also illustrated a statistically significant and clinically relevant difference between males and females with respect to cervical angle. However, one should apply these guidelines with caution and in conjunction with sound clinical judgment.

Our study population size was determined by an analysis of similar studies. However, the sample size of 30 Class I subjects with an age range of 21-41 is a limitation when generalizing to the overall population. Future studies should examine the difference between Angles Class II and Class III patients as well as the distance of the incisal edge from the hinge axis.

5. CONCLUSIONS

Within the limitations of this in vivo study, the following conclusions can be drawn:

1. The data suggests a relationship exist between the mean cervical angle (CA) of the maxillary anterior teeth and the axis orbital plane determined by the SAM anatomic face-bow for males and for females.
2. The mean CA angle for males was 104.2 degrees and for females 96.8 degrees.
3. There was no relationship shown between the mean incisal angle (IA) and the face-bow determined axis orbital plane for males and females.

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APPENDIX

Angle Data for each subject			
Subject	Gender	Cervical_Angle (CA)	Incisal_Angle (IA)
22	Male	106.6	73.2
22	Male	108.1	73.5
22	Male	107.8	73.1
20	Male	97.4	76.1
20	Male	97.2	77.2
20	Male	98	76.6
12	Male	100.1	74.9
12	Male	101.1	73.5
12	Male	102.8	74
11	Male	111.2	73.1
11	Male	110.2	72.4
11	Male	107.4	69.9
9	Male	105.4	50.8
9	Male	106	50.4
9	Male	105.7	56.4
4	Male	100.1	81.7
4	Male	101.9	80

Subject	Gender	Cervical_Angle (CA)	Incisal_Angle (IA)
4	Male	102.8	79.3
2	Male	96.1	71.2
2	Male	96.5	70.9
2	Male	99.5	69.4
24	Male	114.8	87.8
24	Male	113.4	86.1
24	Male	112.1	89.7
36	Male	102.5	75.2
36	Male	103.6	75.9
36	Male	102.5	75
34	Male	107.3	93.6
34	Male	105.3	91.7
34	Male	106.6	91.1
33	Male	108.4	83.1
33	Male	111.7	80.1
33	Male	109.7	83.6
27	Male	98.8	67.3
27	Male	98.9	67.3
27	Male	99.6	67.2

Subject	Gender	Cervical_Angle (CA)	Incisal_Angle (IA)
39	Male	101	70.2
39	Male	101.9	70.8
39	Male	101.7	68.4
1	Male	106.8	64.1
1	Male	107.7	63
1	Male	106.8	65.7
40	Male	103.8	74.9
40	Male	104.6	73.5
40	Male	102.5	76.3
8	Female	97.2	58.4
8	Female	98.4	60.7
8	Female	98.2	59.2
19	Female	94.1	59.8
19	Female	94.8	57.7
19	Female	96.5	59.6
17	Female	101.1	69.1
17	Female	101.9	68.5
17	Female	101.3	69
15	Female	99.6	70.7

Subject	Gender	Cervical_Angle (CA)	Incisal_Angle (IA)
15	Female	100.3	70
15	Female	99.5	70.9
14	Female	102.5	63.7
14	Female	102.4	60.7
14	Female	101.3	62.2
10	Female	88	64
10	Female	87.1	67.6
10	Female	89	64.8
5	Female	98.3	80.2
5	Female	96.9	79.9
5	Female	99.2	79.5
23	Female	88.5	63.4
23	Female	89.1	61.1
23	Female	90.3	62.8
38	Female	97.1	68.4
38	Female	100.2	66.9
38	Female	98.1	71.1
35	Female	103.2	71.5
35	Female	103.8	69.8

Subject	Gender	Cervical_Angle (CA)	Incisal_Angle (IA)
35	Female	105.8	69.1
31	Female	98	66.4
31	Female	97.4	67.5
31	Female	97	64.7
29	Female	90.6	61.7
29	Female	92.5	61.4
29	Female	92.4	62.4
28	Female	98.1	79.6
28	Female	95.1	79.7
28	Female	96	77.5
26	Female	94.1	76
26	Female	92.7	75.3
26	Female	93.2	76.1
25	Female	98.5	72.5
25	Female	97.3	72.7
25	Female	98	74.4