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ORTHODONTICS

LINEAR PHOTOGRAMMETRIC ANALYSIS OF THE ADULT SOFT TISSUE FACIAL PROFILE

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ABSTRACT

The objective of this study was to assess the soft tissue profiles and determine gender dimorphism in the young adult population of Pakistani origin, working in the Children Hospital in different capacities.

This cross sectional descriptive study included 32 subjects including 16 males and 16 females. Age of these subjects ranged from 18-25 years. The sampling comprised random selection of the subjects. The method involved photogrammetric analysis with linear horizontal and vertical measurements made on standard photographic records taken in natural head position. Photocopies of the photographs with clearly identified landmarks were used for measurements. A total of 21 variables were used in the study comprising 11 horizontal and 10 vertical linear measurements.

Amongst horizontal linear measurements, gender dimorphism was seen in seven out of eleven variables. Out of the ten vertical variables only two variables showed sexual dimorphism.

Facial depth, nasal depth, labial and chin areas showed sexual dimorphism in most of horizontal measurements. However length of the mid face, nose, upper and lower lips as well as height of the chin and nasal tip were found greater in females, reflecting vertical growth tendency.

Key words: *Photogrammetric Profile analysis, standardized photographs, natural head position, linear measurements.*

INTRODUCTION

The human form has been measured since the ancient times for self-portrayal in sculpture, drawing, and painting. Another reason is to study normal relationship of the hard and soft tissue structures of the body. Portrayal of the human form demands not only artistic talent and technical ability but a disciplined and consistent style. Proportionate analyses and coordinate systems have been used since the very beginning with various motives and methods. Egypt, Greece, India, and Byzantium etc all applied the mathematics of measurement to the human face and form[1]. The ancient Egyptians developed an intricate quantitative system that defined the proportions ofthe human body. It was known as a canon[2]. The canon was drawn with the head, feet, and legs in profile and the torso in front view. The canon was then enclosed in a grid system of equal sized squares with 18 horizontal lines and was later on modified to a grid system of 22 horizontal lines. The proportions of the human body were determined with an "el" measuring ruler, established in 3,000 BC.

In the divine proportion, developed by Greek mathematicians, the length of a line is divided into two parts such that the minor part divided by the major part

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equals the major part divided by the total. In reverse, the relation of the total to the major part must be the same as that of the major part to the minor.3 In the divine proportion, or golden cut, the major part is 1.61803 times larger than the minor part. The Greek letter *phi,* the initial letter of Phidias Pythagoras' first name, has been adopted to designate the golden ratio. In addition to having mathematical applications, this golden section constitutes an ideal that informs esthetic assessments. The Roman architect Vitruvius[4] described dividing the face into three equal parts marked by the distance from the hairline to glabella, from the glabella to subnasale, and from subnasale to menton.

In Indian iconometry, face height was used as a module of both the Sariputra (1200AD) and Alekhyalaksana proportional systems that closely reflected the natural relation of parts of the body to each other5. The Byzantine art comprised three circle module system. Nose length was used as the radius for its construction; the inner circle outlined the brows and cheeks. The second circle with radius of two nose lengths defined the exterior measurements of the head including the hair and the lower limit of the face. The outermost circle cut through the pit of the throat and form a halo.

The fifteenth century's breakthrough in artistic thought, concept, and technique was accomplished by Leonardo da Vinci (1459-1519) and Albrecht Durer (1471-1528). Leonardo's drawing includes a study of facial prop ortions.[1]The Profile of man was divided into seven parts by eight horizontal lines (1490) in "natural head position".

Albrecht Durer[6], a brilliant and exuberant artist elaborated a study on human proportions that stands unequaled to date. Durer, using strictly geometric methods provided a proportionate analysis of the leptoprosopic (long) face and the euryprosopic (broad) face in a coordinate system, where the horizontal and vertical lines were drawn through the same landmarks or facial features. He devised the method of three-dimensional and proportionate analysis of the face. In addition to the coordinate system, Durer made use of two lines; one drawn from the forehead tangent to the nose, the other tangent to the chin and the upper lip that intersected to form the facial angle characterizing the profile outline. This angular measurement is particularly significant and stands as the key to the evolution of cephalometric analysis as it is known to date.

In 1509, Luca Pacioli[7], Professor of the Holy Theology made a publication that contained a drawing of the face in profile, oriented in natural head position and enclosed in a golden triangle and a golden rectangle.

Petrus Campers (1722-89) anatomist, physician and scientist made extensive studies to orient crania in space on a horizontal, from the middle of the porus acousticus to a point below the nose. Camper's horizontal became the reference line for the angular measurements used to characterize evolutionary trends in studies of facial morphology and aging. In the design of the human face, nature evidently translated the divine proportion into a pattern of harmonious relations between the soft and hard tissues. Paradies[9] demonstrated that the golden section is the key to determining the lower face height in the rehabilitation of the edentulous patients. Huntley10 rightfully considers that the divine proportion—the golden rectangle, triangle, cuboid, and ellipse—represents mathematical beauty and harmony.

At the end of the 19th century and the beginning of the 20th, the analysis of the soft tissue profile of the face became a concern for the pioneers of orthodontics such as Angle and Case. Angle11 took the sculpture of Apollo Belvedere as his canon of corporal and facial beauty. However, its straight, almost concave, profile would be difficult to attain orthodontically with Angle's non-extraction theory; he claimed that the correct occlusion of all teeth in both jaws was necessary to reach an optimum facial appearance.

Case[12], a contemporary of Angle, did not try to follow a single canon representing the ideal of beauty and thus the treatment objective. He tried to individualize the facial esthetic goal of treatment. He looked for the best facial appearance of each person, according to his or her own morphological features and tried to integrate the occlusal and facial objectives into the orthodontic treatment plan. After the standardization of the radiographic technique in 1931 by Broadbent and Hofrath, the importance of soft tissue facial analysis was downplayed, and dentoskeletal relationships became the deciding factor in diagnosis and treatment planning. However, some authors such as Downs" began to incorporate measurements of the soft tissue

facial profile into their cephalometric analyses, to obtain information about the relationship between the soft tissue facial profile and the underlying dentoskeletal structure, as soft tissues did not always follow the underlying dentoskeletal profile.

In a longitudinal growth study, Subtelny[14] used linear measurements of the soft tissue facial profile, such as nasal length, length of the upper lip, thickness of the upper lip and the chin. Steiner[15] described the S-line as tangent to the upper and lower lips.

Ricketts[16] established what he called the law of the labial relationship according to the esthetic E-plane (nasal tip-pogonion). Burstone17" carried out an exhaustive esthetic analysis of the facial profile.

In the 1980s, Ricketts[18]used the golden divider in his morphologic dentofacial analysis; Ricketts was the first in the recent history to establish divine or golden proportions (0 = 1.618) among the different parts of the face in front view and the profile. Holdaway[19] defined the H-line with which he evaluated the nasal, labial and chin positions.

Canut[20°] introduced esthetic analysis in 1996. He studied the interrelationship of nasal, labial, and chin prominences with regard to Sn-Sm line (facial esthetic triad) and depth of the nasolabial sulcus that he called the nasolabial esthetic sigma. Parallel to the development of radiographic cephalometrics, the linear analysis of the soft tissue facial profile on photographic records was developed. In 1981, Farkas,[21] using a sample of young people (6-18 years old) of both sexes, standardized the photographic technique and the taking of records in natural head position The surgeons Powell and Humphreys[22] defined their esthetic triangle, the position of the lips and exposure of the incis al edge.

Epker[23] took his records in natural head position, using the true vertical (TV) as the reference line on which he defined proportional measures of the facial profile.

Arnett and Bergman[24] described an analysis of the soft tissue facial profile on photographic records in natural head position using SN-PG reference line previously used by Burstone.

Riveiro, Quintanilla, Chamosa and Cunqueiro[25] conducted a study on soft tissue profile of a Europeans white population of young adults by means of linear measurements made on Standard photographic records taken in natural head position. They reported sexual dimorphism in most parameters of the labial, nasal and chin areas. The males had greater heights and lengths as well as greater prominence of these three areas. The nasal depth and facial depth was also found greater in the male subjects.

All the factors that influence the normality criteria when making a facial analysis should be taken into account, including age, sex, and race. In this study, we tried to determine the linear measurements that define the average soft tissue profile of a young adult from the study sample. We used a standardized photogrammetric analysis of the profile in natural head position to assess the soft tissue profiles and to determine the gender dimorphism in the proposed sample.

MATERIALS AND METHODS

This cross sectional descriptive study was conducted in the Orthodontic Department of Dental Section of Children Hospital and Institute of Child health, Lahore. The sample consisted of 32 subjects of age range 18-25 years. Out of this sample size, 16 subjects were males and 16 were females. The sampling comprised random selection of subjects

Inclusion criteria

The inclusion criteria of this study comprised

- Healthy subjects of age range 18-25 years.
- Subjects of Pakistani origin.
- Subjects with fully developed adult dentition and facial profile.

Exclusion criteria

The exclusion criteria included

- Subjects who were previously orthodontically treated.
- Subjects with facial deformities.
- Subjects having congenital and dentofacial anomalies.

DATA COLLECTION PROCEDURE

The study sample was collected from the Allied Health Sciences, the Nursing School, Para medical/

Para dental staff and professional colleagues from the dental section of the Children Hospital. The photographic setup consisted of a tripod that holds a 35 mm camera (Yaschica-S-35) with 100 mm macro lens and a micro ring flash. Stability and easy adjustment of the Tripod enabled the Optic axis of the lens to be kept horizontal during recording. The camera was used in manual position, with a shutter speed of 60. The film used was Konica —VX100 developed with color negative film by Konica processing at the same laboratory to ensure identical results.

Thirty two 4 x 6 inches photographs were selected. Photocopies of the photographs with clearly identified landmarks were used for measurements. Two separate sets of measurements were taken at two different time intervals by the same operator and the mean values were used for further data analysis (Table 1 and 2).

The landmarks were located on the photographs to obtain all the measurements manually.

The following landmarks are shown in Figs 1, 2 and 3.

- Trichion (Tri), the sagittal midpoint of the forehead that borders the hairline
- Glabella (G), the most anterior point of the middle line of the forehead
- Nasion (N), the point in the midline located at the nasal root
- Pronasal (Prn), the most prominent point of the tip of the nose
- Columella (Cm), the most inferior and anterior point of the nose
- Subnasal (Sn), the point where the upper lip joins the Columella.
- Labial superior (Ls), the point that indicates the mucocutaneous limit of the upper lip
- Stomion superior (Sts), the most inferior point of the upper lip
- Stomion inferior (Sti), the most superior point of the lower lip
- Labial inferior (Li), the point that indicates the mucocutaneous limit of the lower lip
- Supramental (Sm), the deepest point of the inferior sublabial concavity
- Pogonion (Pg), the most anterior point of the chin
- Menton (Me), the most inferior point of the inferior edge of the chin
- Tragus (Trg), the most posterior point of the auricular tragus
- Alar (Al), the most lateral point of the alar contour of the nose
- Superior point of the TV (sTV)
- Inferior point of the TV (iTV)
- Ort, the point joining the TV and the TH
- TV, sTV-iTV
- TV in N (N-Ort), parallel to TV through N
- TH, Trg-Ort, perpendicular to TV through Trg
- Canut line (Juanita Line), Sn-Sm

The following vertical linear measurements (parallel to TV) are shown in Fig 3:

- Superior facial third, Tri-G
- Middle facial third, G-Sn
- Inferior facial third, Sn-Me
- Nasal length, N-Sn
- Length of upper lip, Sn-Sts
- Length of lower lip, Sti-Sm
- Vermilion of upper lip, Ls-Sts
- Vermilion of lower lip, Li-Sti
- Height of chin, Sm-Me
- Height of nasal tip, Sn-Prn

The following linear horizontal measurements (parallel to TH) are shown in Figure 1:

- Facial depth, Trg-Sn
- Nasal depth, Al-Prn
- Nasal prominence, Pm to N-Ort line
- Subnasal depth, Sn to N-Ort line
- Mentolabial depth, Sm to N-Ort line
- Prominence of upper lip, Ls to N-Ort line
- Prominence of lower lip, Li to N-Ort line
- Prominence of chin, Pg to N-Ort line

The following Canut's linear measurements (perpendicular to Sn-Sm Line) are shown in Figure 2:

- Canut's nasal prominence, Pm to Sn-Sm
- Canut's prominence of upper lip, Ls to Sn-Sm
- Canut's prominence of lower lip, Li to Sn-Sm

DATA ANALYSIS PROCEDURE

The study included ten vertical linear variables namely the superior, middle and inferior facial thirds, nasal length, length of the upper and lower lip vermilion and height of chin and nasal tip. The eight horizontal variables included facial, nasal, subnasal and mentolabial depth and prominence of the nose, upper lip, lower lip and chin. The three variables with respect to Canut's line were prominence of the nose, lower lip and upper lip respectively. The results were analyzed by using the SPSS 10. Descriptive analysis was used for finding the norms, means and standard deviations of both male and female groups (Table 1 and 2) as well as to evaluate gender dimorphism.

RESULTS

In this study a total of 21 variables were used comprising 11 horizontal linear measurement and 10 vertical linear measurements (Fig 1, 2 and 3 and Table **1** and 2).

Amongst the horizontal measurements, facial depth (Trg-Sn) was greater in male subjects i.e. 58.4 mm ± 4.17 (table 1) than that of the females, 57.25 mm ± 3.64 (table 2). Similarly, nasal depth (Al-Prn) was measured greater in males i.e. 14.06 mm ± 1.74 compared to 13.56 mm ± 1.25 in the females. The nasal prominence (Prn to N-Ort) and sub nasal depth (Sn to N-Ort) were found lesser in males as compared to female subjects. (Nasal prominence; males 11.50 ± 2.38 , females 11.68 ± 1.45; subnasal depth , males 2.84 ± 2.24 , females 3.62 ± 2.82) .The four horizontal measurements mentolabial depth, prominence of the upper lip, prominence of the lower lip and prominence of the chin were also found greater in the male subjects. Sm to N-Ort in males was measured 2.56 ± 3.75, whereas in the females it was 1.90 ± 3.30 ,Ls to N-Ort males was 3.56 ± 2.59 and in females was 3.50 ± 2.22; Li to N-Ort males 2.78 ± 2.30, females 2.18 ± 2.44 ; Pog- N-Ort males 5.68 ± 10.48, females 3.71 ± 10.97.

From the Canut's esthetic analysis one out of three variables i.e. nasal prominence (Prn-Sn Sm) was found

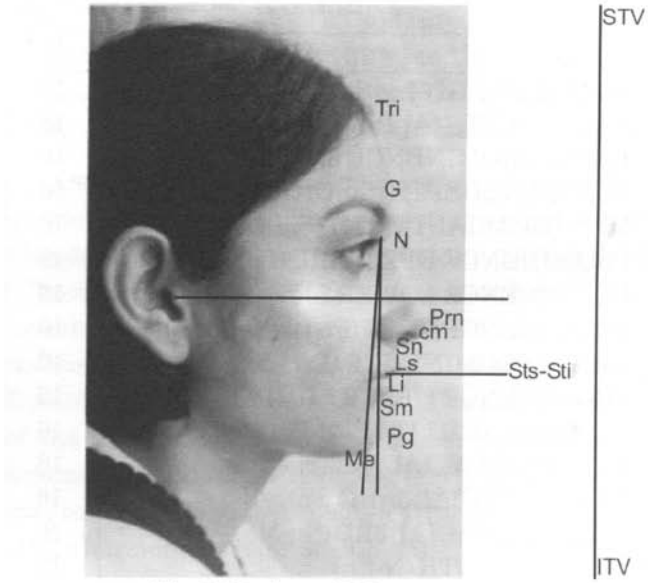

Fig. 1. Horizontal Measurements

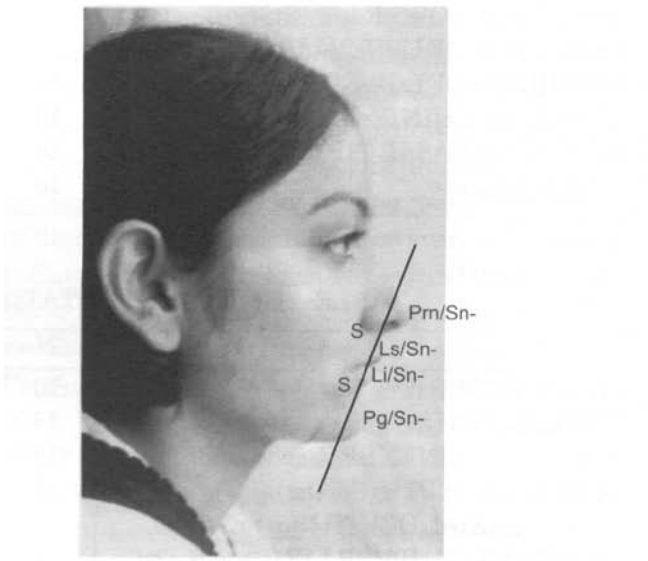

Fig. 2. Canut's analysis (related to Sn-Sm Line)

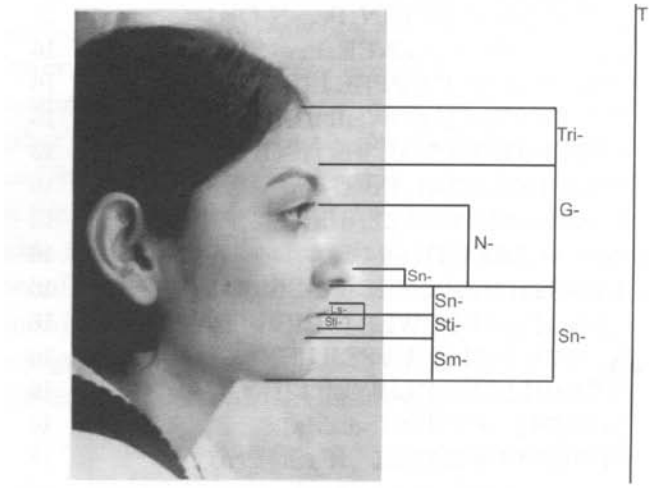

Fig. 3. Vertical measurements (Measured Parallel to TV)

TABLE 1: DESCRIPTIVE STATISTICS OF THE MALE SUBJECTS

	N	Minimum	Maximum	Mean	Std. Deviation
FACIAL DEPTH (Trg-Sn)	16	51.00	66.00	58.4375	4.17882
NASAL DEPTH (Al-Pm)	16	9.00	16.00	14.0625	1.74045
NASAL PROMINENCE (Prn to N-Ort)	16	7.50	16.00	11.5000	2.38048
SUBNASAL DEPTH (Sn-Ort)	16	.00	9.00	2.8437	2.24884
MENTOLABIAL DEPTH (Sm to N-Ort)	16	-5.00	7.00	2.5625	3.75000
PROMINENCE UPPER LIP (Ls to N-Ort)	16	.00	10.50	3.5625	2.59406
PROMINENCE LOWER LIP (Li to N-Ort)	16	.00	8.50	2.781.3	2.30195
PROMINENCE CHIN (Pog to N-Ort)	16	-3.00	43.2.7813	5.6875	10.48471
NASAL PROMINENCE (Prn- Sn Sm)	16	3.00	9.00	6.6563	1.70018
PROMINENCE UPPER LIP (Ls to Sn Sm)	16	1.00	4.00	2.2500	.79582
PROMINENCE LOWER LIP (Li to Sn Sm)	16	1.00	4.00	2.2813	.72958
SUPERIOR FACIAL 3rd(Tri-G)	16	14.00	25.50	19.0625	3.12983
MIDDLE FACIAL 3rd (G-Sn)	16	32.00	45.00	38.3438	3.94850
INFERIOR FACIAL 3RD (Sn-Me)	16	22.00	36.00	30.8125	3.86383
NASAL LENGTH (N-Sn)	16	20.50	34.00	25.1563	3.21827
LENGTH UPPER LIP (Sn-Sts)	16	7.00	12.00	9.5938	1.47443
LENGTH OF LOWER LIP (Sti-Sm)	16	5.50	10.00	7.3125	1.19548
VERMILION OF UPPER LIP (Ls-Sts)	16	2.50	5.00	3.7187	.85574
VERMILION OF LOWER LIP (Li-Sts)	16	2.00	5.50	3.7812	1.07964
HEIGHT OF CHIN (Sm-Me)	16	1.00	15.00	11.6250	3.34415
HEIGHT OF NASAL TIP (Sn-Prn)	16	3.50	9.00	5.8750	1.64823
Valid N (listwise)	16				

TABLE 2: DESCRIPTIVE STATISTICS OF THE FEMALE SUBJECTS

	N	Minimum	Maximum	Mean	Std. Deviation
FACIAL DEPTH (Trg-Sn)	16	51.00	64.00	57.1333	3.64234
NASAL DEPTH (Al-Prn)	16	11.00	16.00	13.5625	1.25000
NASAL PROMINENCE (Pm to N-Ort)	16	9.00	14.00	11.6875	1.45917
SUBNASAL DEPTH (Sn-Ort)	16	.00	12.00	3.6250	2.82548
MENTOLABIAL DEPTH (Sm to N-Ort)	16	-6.00	5.50	1.9062	3.30262
PROMINENCE UPPER LIP (Ls to N-Ort)	16	.00	8.00	3.5000	2.22111
PROMINENCE LOWER LIP (Li to N-Ort)	16	-2.00	7.00	2.1875	2.44864
PROMINENCE CHIN (Pog- N-Ort)	16	-5.00	43.00	3.7188	10.97416
NASAL PROMINENCE (Prn- Sn Sm)	16	4.00	8.00	6.3125	1.13835
PROMINENCE UPPER LIP (Ls to Sn Sm)	16	.00	7.00	2.3750	1.59687
PROMINENCE LOWER LIP (Li to Sn Sm)	16	1.00	5.00	2.3438	1.13606
SUPERIOR FACIAL 3rd(Tri-G)	16	13.00	26.00	18.5313	3.93052
MIDDLE FACIAL 3rd (G-Sn)	16	34.00	44.50	39.7500	2.67706
INFERIOR FACIAL 3rd (Sn-Me)	16	28.00	40.00	31.7813	2.97192
NASAL LENGTH (N-Sn)	16	21.50	32.00	26.4063	2.71550
LENGTH UPPER LIP (Sn-Sts)	16	8.00	18.00	10.3125	2.44182
LENGTH OF LOWER LIP (Sti-Sm)	16	6.00	12.50	8.0000	1.80739
VERMILION OF UPPER LIP (Ls-Sts)	16	2.50	5.00	3.5938	.80039
VERMILION OF LOWER LIP (Li-Sts)	16	2.00	6.00	4.1875	1.31498
HEIGHT OF CHIN (Sm-Me)	16	11.00	15.00	12.8438	1.19330
HEIGHT OF NASAL TIP (Sn-Prn)	16	5.00	9.00	6.4062	1.24122
Valid N (listwise)	15				

greater in the males (6.65 ± 1.70) than that of the females (6.31 ± 1.13). The remainder two variables i.e. the prominence of the upper and lower lips were measured greater in the female subjects. LS to Sn Sm in male subjects was 2.25 ± 0.79, females was 2.37 ± 1.59. Li to Sn-Sm in males was 2.28 ± 0.72, whereas in the females was 2.34 ± 1.13.

In the vertical photogrammetric analysis, amongst the facial thirds, the superior facial third was larger in the males (19.06 ± 3.12) than that of the females (18.53 ± 3.93). The middle third was the largest in both sexes (males 38.34 ± 3.94), female 39.75 ± 2.67). The inferior facial third in the males was 30.81 ± 3.86 and that in the females 31.78 ± 2.97. The nasal length (N-Sn) was 26.40 ± 2.71 in females and 25.15 ± 3.21 in males. Similarly, the lengths of the upper and lower lips were slightly greater in the female sample (Sn-Sts male 9.5 ± 1.47 , female 10.3 ± 2.44 ; Sti-Sm male 7.3 ± 1.19 , female 8.00 ± 1.80). Vermillion of the upper lip was slightly greater in the males (3.71 ± 0.85) than females (3.59 ± 0.80). The lower lip vermillion Li -Sts was slightly greater in the female subjects (males 3.78 ± 1.07, females 4.18 ± 1.31) .The height of the chin and that of the nasal tip was also slightly greater in the females. Sm -Me in males was 11.62 ± 3.34 and in the females was 12.84 ± 1.19; Sn-Prn male 5.87 ± 1.64, female 6.40 ± 1.24.

DISCUSSION

In the study of the horizontal linear measurements, gender dimorphism was seen in seven out of eleven variables whereas amongst the ten vertical variables, only two variables showed gender dimorphism. From the study of the facial thirds, the middle facial third was found the largest in both sexes; whereas superior facial third was smallest in both sexes. The inferior facial third was almost midway between these two extremes. These findings of our study were unlike the descriptions of traditional vertical equal facial thirds (Vitruvius[4], Ricketts[16], Arnett and Bergman[24]). Sexual dimorphism was seen in case of superior facial thirds (males 19.06 ± 3.12, females 18.53 ± 3.93). Middle facial third in the females (39.75 ± 2.67) was however larger than the male subjects (38.34 ± 3.94) reflecting increased tendency towards vertical growth pattern in the female sample. Measurements of the inferior facial thirds were also found greater in females (31.78 ± 2.97) compared to the male subjects (30.81 ± 3.86). The findings of Powell and Humphreys[22], Epker [23](inferior 38%, middle third 32 %) and Riveiro[25], too did not match the results of our study. The study of the facial depth (Trg-Sn) also showed sexual dimorphism.

On analyzing the nose the nasal depth was found greater in the male sample indicating sexual dimorphism as reported by many other researchers (Chaconas[26], Riveiro etc). The nose length and nasal prominence however, were greater in female subjects unlike the findings of other researchers like Farkas", Burstone[17], Chaconas and Riveiro . The size and shape of the nose plays an important role in orthodontic treatment planning. An excessively prominent nose may contraindicate therapeutic extractions in order to attain harmonious relationship of the nose, lip and soft tissue chin.

The labial area needs thorough evaluation because the appearance of the lips and the smile may be improved by orthodontic treatment. On analyzing lip prominence with regards to TV in N, it was observed that both the upper and lower lip prominences showed gender dimorphism. This finding coincides with those of Riveiro and Quintanilla. However, with reference to Canut's[20]° Sn-Sm line, both upper and lower lips were found more prominent in female subjects. These results of our study support the findings of Sarver, Proffit and Ackerman". On comparison with Riveiro's study, our findings are contrary to their results. The upper lip vermillion height showed sexual dimorphism in our study. This result was contrary to the findings of Riveiro. The lower lip vermillion was however greater in females. Comparing upper and lower lip vermillion in the same gender, in the male subjects the lower lip showed a nominal increase, whereas in the females the lower lip vermillion was fairly prominent in the vertical dimension. This finding of our study was similar to other studies, such as Legan and Burstone[28], Riveiro and Sarver. The size of lip vermillion causes exposure of the mucocutaneous lip. Its volume is also responsible for muscular tension of that lip. The more the vermillion, the lesser the muscular tension of that lip and vise versa. The length of both upper and lower lips was greater in female unlike the findings of Park and Burstone[29], Yuen and Hiranaka30 and Riveiro.

The chin prominence was greater in males, reflecting sexual dimorphism. This finding of our study was supported by most of other studies. The chin height on

the other hand was found greater in the females like most other vertical measurements of the study that are contrary to other studies like Park and Burstone, Farkas, Chaconas and Riveiro . The greater lengths of the midface and that of the nose, upper and lower lip and chin heights in the female subjects corresponded with the increased vertical trends of the face form in the female study sample. [9]

CONCLUSIONS

On the basis of the results of this study, following conclusions may be drawn:

- Facial depth, nasal depth, labial and chin areas showed sexual dimorphism in most of the horizontal measurements.
- The length of the midface, nose length, upper and lower lip lengths, height of the chin and height of the nasal tip were found greater in the females, reflecting increased vertical growth pattern of the face.

Further studies are suggested in this area involving different centers on community basis to establish norms of the adult soft tissue profile based on photogrammetric analysis for the Pakistani population.

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