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Changes in Integumental Dimensions of the Face Following Orthodontic Treatment: A Long-term Study

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Abstract

Most studies of facial growth in adults have relied on cross-sectional data. Longitudinal studies in this area are scarce because it is difficult to collect data on adults across time and because the changes are less dramatic than during childhood or adolescence. An interesting sample exists in the Charles H. Tweed collection, where orthodontic patients were recalled 10 or more years after treatment with an average time out of treatment of about 15 years. The availability of frontal facial photographs from this collection provided us with an uncommon opportunity to longitudinally quantify the changes in facial dimensions from adolescence into early adulthood. Frontal photographs were obtained from 101 subjects (41 males and 60 females) at posttreatment (x = 15.6 years) and long-term recall (x = 31.2 years) examinations. 7 transverse and 9 craniocaudal distances were measured to quantify facial growth and to assess the extents of sexual dimorphism of the face across the age span. Transverse dimensions generally increased significantly in both sexes with Lower face width (GoL-GoR) increasing more than any other measurement for both men (18%) and women (7%), which apparently is due to weight gain expressed in the cheeks. There also were unanticipated reductions in facial widths, namely in Inner canthus width (EnL-EnR), Outer canthus width (ExL-ExR), and Alar width (AlL-AlR). The transverse changes were sexually dimorphic, with men experiencing larger average changes. Craniocaudal changes were smaller than the transverse changes and not generally sexually dimorphic, except for Lower face height (Sn-Me) and its most influential component, Chin height (Li-Me). There was a fundamental difference in the development of Lower face height between men and women mainly because Chin height was significantly different in men and women (8% and 2%, respectively), suggesting that men have a considerably larger soft tissue addition to bony chin than women during this age interval. As a result of transverse and craniocaudal changes, the face becomes broader mediolaterally and, to a lesser degree, longer craniocaudally. Lower face width increased more than twice the amount of any craniocaudal distance. Orthodontists should be aware that continued growth alters facial sizes and proportionality in early adulthood, and treatment planning should be complementary to the anticipated facial growth in adolescent patients.

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CHANGES IN INTEGUMENTAL DIMENSIONS OF THE FACE FOLLOWING ORTHODONTIC TREATMENT: A LONG-TERM STUDY

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ABSTRACT

Most studies of facial growth in adults have relied on cross-sectional data. Longitudinal studies in this area are scarce because it is difficult to collect data on adults across time and because the changes are less dramatic than during childhood or adolescence. An interesting sample exists in the Charles H. Tweed collection, where orthodontic patients were recalled 10 or more years after treatment with an average time out of treatment of about 15 years. The availability of frontal facial photographs from this collection provided us with an uncommon opportunity to longitudinally quantify the changes in facial dimensions from adolescence into early adulthood. Frontal photographs were obtained from 101 subjects (41 males and 60 females) at posttreatment ($\bar{x}$ = 15.6 years) and long-term recall ($\bar{x}$ = 31.2 years) examinations. 7 transverse and 9 craniocaudal distances were measured to quantify facial growth and to assess the extents of sexual dimorphism of the face across the age span. Transverse dimensions generally increased significantly in both sexes with Lower face width (GoL-GoR) increasing more than any other measurement for both men (18%) and women (7%), which apparently is due to weight gain expressed in the cheeks. There also were unanticipated reductions in facial widths, namely in Inner canthus width (EnL-EnR), Outer canthus width (ExL-ExR), and Alar width (AlL-AlR). The transverse changes were sexually dimorphic, with men

experiencing larger average changes. Craniocaudal changes were smaller than the transverse changes and not generally sexually dimorphic, except for Lower face height (Sn-Me) and its most influential component, Chin height (Li-Me). There was a fundamental difference in the development of Lower face height between men and women mainly because Chin height was significantly different in men and women (8% and 2%, respectively), suggesting that men have a considerably larger soft tissue addition to bony chin than women during this age interval. As a result of transverse and craniocaudal changes, the face becomes broader mediolaterally and, to a lesser degree, longer craniocaudally. Lower face width increased more than twice the amount of any craniocaudal distance. Orthodontists should be aware that continued growth alters facial sizes and proportionality in early adulthood, and treatment planning should be complementary to the anticipated facial growth in adolescent patients.

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CHAPTER I

INTRODUCTION

Anthropometric data concerning the facial changes that occur in people throughout life provides useful information about the later phases of growth and development. The dynamics of facial growth during adolescence have been studied in appreciable detail (*e.g.,* Bishara *et al.* 1995; Athanasiou *et al.* 1992), but the changes occurring during adulthood are not well understood. This discrepancy is due in large part to the lack of available data. Still, cross-sectional studies show that slow but cumulative growth in the late teens and early adulthood alters the facial morphology and the frontal facial profile (*e.g.,* Behrents 1986; Bishara *et al.* 1994). The orthodontist needs to have some basis for anticipating the normative changes that occur as the posttreatment subject grows and ages.

Typical studies on facial growth in adults have relied on cross-sectional data, where it is assumed that the changes seen *among* people of different ages are representative of how individuals grow across time. Cross-sectional studies are, strictly, growth *surveys*; they contain no information about growth since each person is only seen once. While using cross-sectional measurements is informative, longitudinal studies are needed to estimate rates of change and at controlling for extraneous factors. Longitudinal studies in this area are scarce.

Orthodontic records are a valuable source of data that can be used to improve our understanding because of the extensive photographs and other quantifiable records that are taken before and after treatment. While these photographs are informative, they have primarily been used to assess the changes that take place during adolescence because this is the period when treatment typically occurs. An interesting sample exists in the Charles H. Tweed collection, in which orthodontic patients were recalled ten years or more following treatment. Orthodontic records are available from the pretreatment, posttreatment, and at the long-term recall examination. The orthodontic records included photographs, panoramic and cephalometric radiographs, and dental casts. The availability of the frontal facial photographs from the Charles H. Tweed study provided us with an uncommon opportunity to longitudinally measure the soft tissue changes that take place from the late adolescence to early adulthood, at about 30 years of age. The objectives of the present study were:

1. to quantify facial growth as seen in frontal view from adolescence (about 16 years) to early adulthood (about 30 years), and
2. to determine the extent of sexual dimorphism of facial dimensions as seen in frontal view.

CHAPTER II

REVIEW OF THE LITERATURE

Growth of the human craniofacial complexes is a dynamic process influenced by a variety of factors. Genetic and environmental factors serve to accelerate or retard this growth. An individual's genetic composition is basically predetermined, but environmental factors are more variable. Orthodontic treatment can be considered an environmental factor that serves to alter craniofacial growth and development. Orthodontic records are a valuable source for the data to evaluate facial growth because of the photographs and other quantifiable records that are taken before and after treatment. However, since most orthodontic treatment is performed in adolescence, considerable growth potential remains in the craniofacial complexes after treatment is completed. This continuation of growth may or may not alter the physical appearance of an individual. Consequently, the orthodontist is challenged to anticipate posttreatment growth in order to provide a stable functional occlusion and balanced facial esthetics. This chapter examines literature involving the effects of growth and development on the facial soft tissue during adolescence and early adulthood. Differences in rates of growth between males and females are discussed. Methods for evaluating the soft tissue profile in frontal view are reviewed as well as some concepts of facial proportionality.

General Growth and Development

Scammon (1930) described the postnatal growth patterns of the four major tissue systems (lymphoid, neural, somatic, and reproductive). As illustrated in Figure 1, neural tissue growth is approximately 90% complete by 6 to 8 years of age. Somatic tissue growth can be divided into four segments (Figure 2) namely, (1) an infant phase of rapid growth, (2) a juvenile phase of fairly uniform growth during early and middle childhood, (3) an adolescent phase of rapid parapubertal growth, and (4) an adult phase of slower growth during late adolescence and into adulthood. As seen in Figure 1, lymphoid tissues continue to proliferate until at least 10 years. Then a phase of involution begins resulting in their relatively small adult size. Significant changes in the dimensions of the cranium are assumed to take place until 20 years of age when 100% of adult size has been achieved.

Tanner (1990) and others have commented that growth, including that of the skeleton, continues after the parapubertal growth spurt. The bones of the limbs no longer increase as dramatically in length because of epiphyseal fusion, but the vertebral column continues to grow until approximately 30 years of age. Thus stature increases slightly, on average between 3 and 5 mm. From about 30

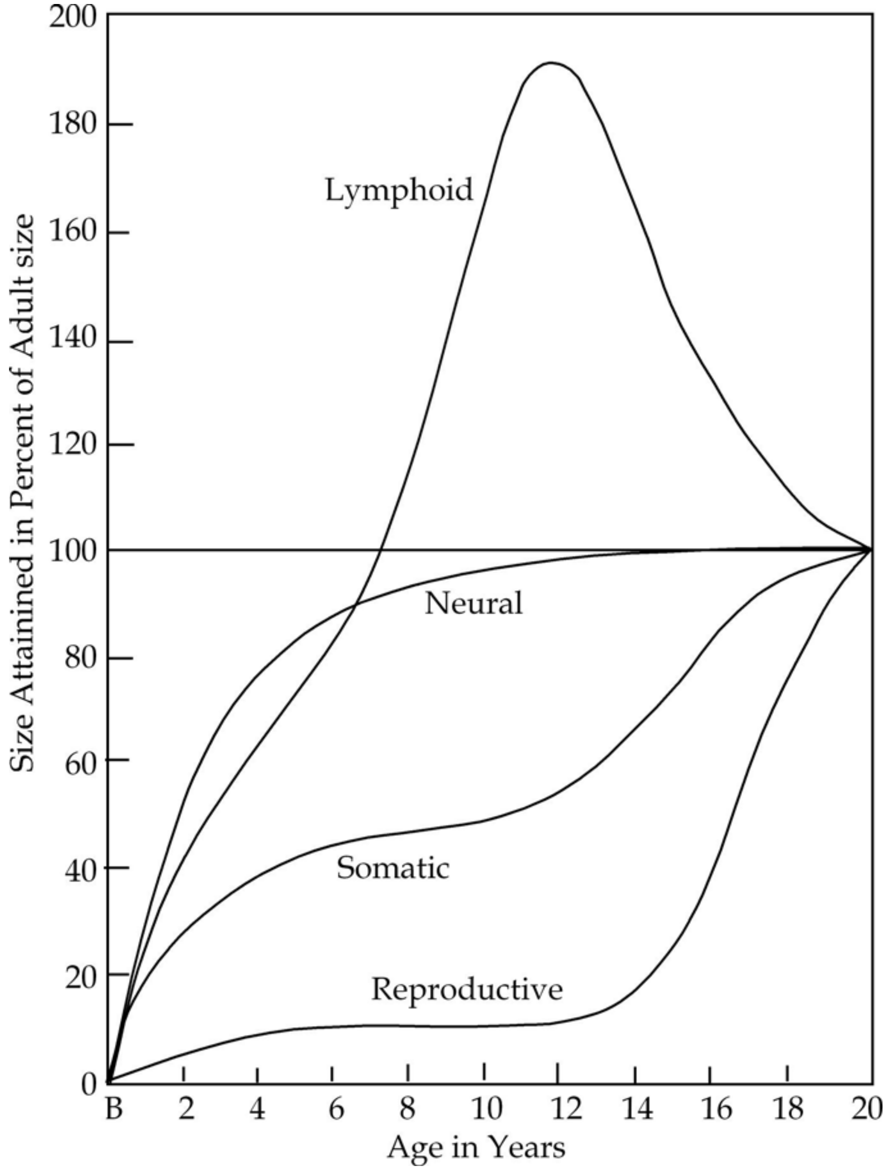


Figure 1. Scammon's four tissue-specific patterns of postnatal growth. The scheme is that postnatal size is set to 0% at birth and size is standardized (diagram provided by Dr. E. F. Harris).

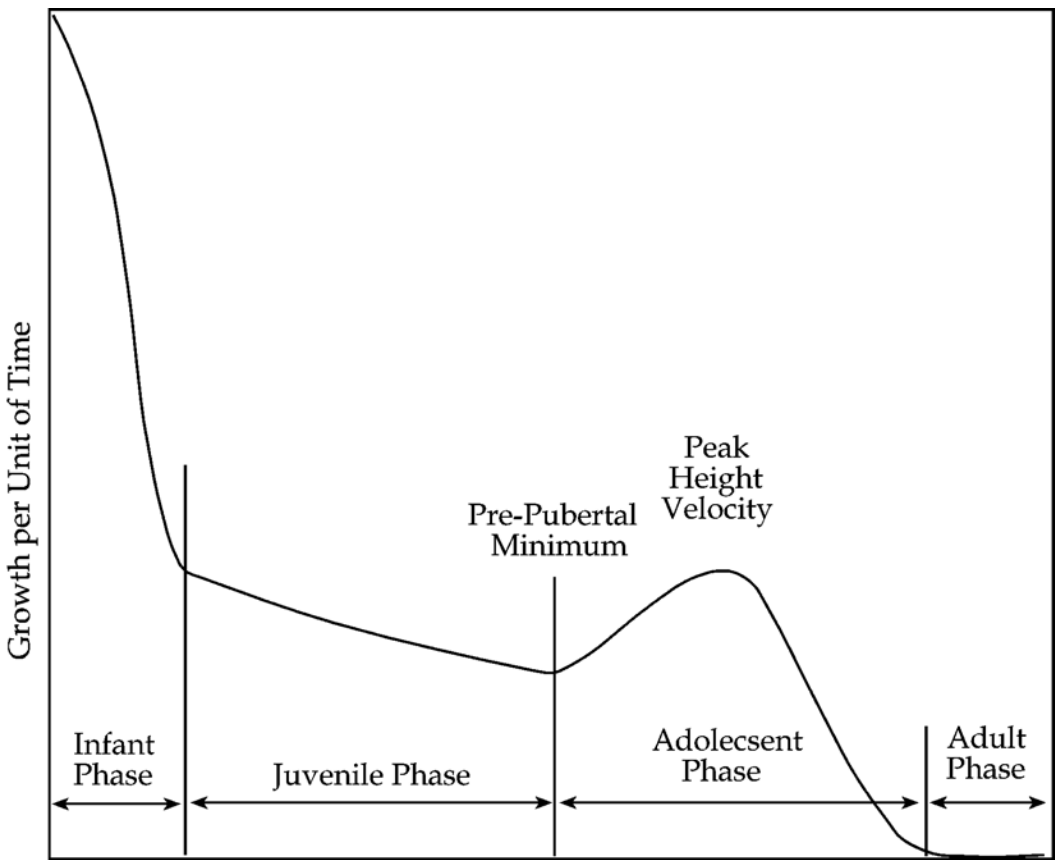


Figure 2. A generalized human growth velocity chart for somatic tissues partitioned into the four major intervals of postnatal growth (diagram provided by Dr. E. F. Harris).

to 45 years of age, stature remains constant, and then may begin to decline. Head vertical length and breadth and facial diameters continue to increase slightly throughout life. The widths in the bones of the legs and the hands also continually increase, for both sexes.

Longitudinal Growth Studies

This section focuses on longitudinal craniofacial growth studies that have been conducted in adults. The studies reviewed here mainly focused on skeletal dimensions per se. Soft-tissue changes are discussed in a later section.

Israel (1973) assessed changes in the cranium and face in adulthood. Records of 26 subjects were adequate for longitudinal assessment from age 14 to 28 years of age. Israel assessed 50 dimensions that he categorized into 10 craniofacial categories. These categories were (1) cranial thickness, (2) skull size, (3) cranial base length, (4) facial compartment, (5) paranasal sinuses, (6) sella turcica, (7) sella position, (8) mandible, (9) palate, and (10) cervical vertebrae. Israel concluded that this growth was not the result of sutural expansion, but due instead to remodeling. Israel (1973) also studied dried mandibles of 59 white males from the Terry skeletal collection and 31 specimens from the T. W. Todd Collection. He found that there was continued expansion and apposition of bone in the adult mandible with age. Israel also confirmed that sella turcica, frontal sinus, and the skull tables remodeled at a rate per unit time that is twice the amount of the anterior-posterior skull diameter.

Tallgren (1974) questioned the validity of Israel's study, suggesting that technique errors led to the perceived changes in the adult craniofacial skeleton. Her similar study failed to find significant changes in measurements of the craniofacial skeleton over her observation period. She studied lateral cephalometric radiographs of 32 Finnish women in the range of 20 and 73 years of age, with an interval of 15 years between the first and last radiograph. Measurements were computed from X- and Y-coordinates of 21 neurocranial reference points (Figure 3) obtained directly on the films. Her findings revealed no significant changes in the dimensions of the cranial vault or cranial base over the observation period. The constancy of the neurocranial structures (mean changes ranged from –0.14 to 0.20 mm) indicated no appreciable change in internal or external size of the calvaria had occurred with increasing age. Tallgren found no significant increase or decrease in skull thickness. She suggests that the symmetrical expansion demonstrated by Israel could be explained by an inconsistent radiographic distance from midsagittal plane of the head to the film. This object to film distance was controlled in her study with the use of a headholder.

With the benefit of subsequent studies, it is evident that Israel's findings were largely correct (though he indeed did not have have good control over

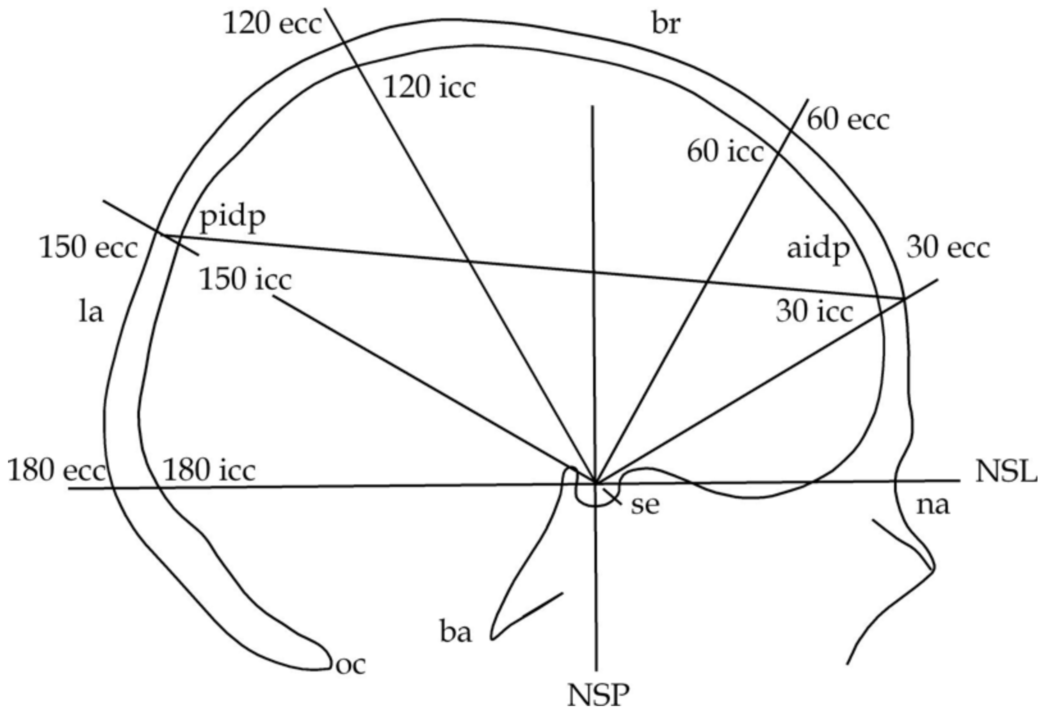


Figure 3. Cephalometric reference points and lines used by Tallgren (1974) to measure neurocranial dimensional changes with aging in females. The majority of variables measured calvarial bone thicknesses (obliquely), but she also measured distances between the conventional landmarks of Sella (se), Nasion (na), Basion (ba), Bregma (br), and Lambda (la). (Diagram provided by Dr. E. F. Harris.)

radiographic enlargement). The discrepancy with his and Tallgren's findings seems to revolve on differences in the nature of their studies. Israel studied changes throughout the skull in both sexes, while Tallgren examined just calvarial changes in women (because most of her subjects were edentulous in at least one arch so facial changes could not be assessed). Calvarial changes are indeed much more subtle than those in the face, especially so in slower-remodeling women.

A longitudinal cephalometric craniofacial study by Susanne (1977) revealed measurable increases in skull size during adulthood in males. Men (n = 44) between the ages of 25 and 60 years were measured at two different times. On average, 22 years elapsed between examinations. Susanne found statistically significant increases in facial height, bizygomatic width, head breadth, nose breadth and ear height. Decreases in upper and lower lip length and frontal breadth were also reported. Susanne concluded that facial growth continued into the fourth and even the sixth decade of life.

Longitudinal Studies of Craniofacial and Dental Landmarks

Forsberg (1979) conducted a longitudinal cephalometric study of changes in the adult face from 24 to 34 years of age. Former male (n = 25) and female (n = 24) students at the Faculty of Odontology in Stockholm participated in the study. None had tooth loss or facial injuries during the 10-year interval. In a few cases orthodontic treatment had been carried out but this was not considered to be significant to the investigation, as treatment had taken place in childhood. Twenty-seven hard tissue variables and 6 soft tissue variables were studied. In the parasagittal plane, a significant increase in facial height occurred during the 10-year period. More specifically, this increase was in lower facial height as measured from anterior nasal spine (ANS) to Gnathion. An increased horizontal distance (measured from Sella parallel to Frankfort Horizontal) was significant for Nasion in females only and decreased horizontal distances were significant for B Point and Pogonion in both sexes. All other variables showed no statistically significant change. Angular measurements revealed that the upper incisors became more upright ($\Delta = 0.69°$ male; $\Delta = 0.79°$ female), the mandibular plane to Sella-Nasion angle increased ($\Delta = 0.26°$ male; $\Delta = 0.52°$ female), and the ANB angle increased ($\Delta = 0.26°$ male and female). Forsberg concluded that a major part of the changes of the bony profile were due to a downward-backward rotation of the mandible and adjustment of the upper incisors in both sexes.

Behrents (1985) reported on 113 orthodontically untreated participants of the Bolton-Brush Growth Study at Case Western Reserve University in Cleveland, Ohio. These subjects had been evaluated extensively as children in the 1930s and 1940s using both anthropometry and cephalometry. Behrents subjects were reexamined in the 1980s to quantify the craniofacial changes that had occurred during adulthood. Behrents found that adults continued to grow in almost all of the craniofacial complexes. Behrents' results showed that adults tend to experience more vertical changes rather than anteroposterior or transverse changes. In other words, facial height increased more than facial width. Behrents also found that the nature of adult growth was different between the two sexes. Females were smaller at all ages, grew less, and grew in a more vertical direction than males. Menton moved downward throughout all chronological age intervals in both males and females. Only females showed a change in the angulation of mandibular plane, which rotated downward in the front (clockwise) with age. Males exhibited movement of Pogonion anteriorly, away from Nasion-perpendicular, while females did not. In females, the mandible apparently moved posteriorly or, perhaps more correctly, did not move forward with Nasion with increasing age. The maxillary incisors became more upright in both sexes. In females the lower incisors tended to become more proclined in relation to upper facial structures, but in relation to the mandibular plane they were more upright than in males.

Bishara, Treder and Jakobsen (1994) evaluated postadolescent changes in 30 subjects (15 male, 15 female) followed longitudinally between 25 and 46 years of age. None of the subjects had undergone orthodontic treatment. Their findings were that growth in the craniofacial dimension did not cease with the onset of adulthood, but continued at a significantly slower rate, perhaps throughout adult life. In female and male subjects, skeletal anteroposterior and vertical linear dimensions continued to change between 26 and 46 years of age. In males, skeletal profile continued to increase in convexity because of greater prominence of the maxilla. Both upper and lower lips tended to become relatively more retruded in relation to the nose and chin. In female subjects, the skeletal profile increased in convexity because of a tendency for the mandible to rotate downward and backward. As in the male subjects, the soft tissue profile flattened and the lips became relatively more retruded.

Harris, Gardener and Vaden (1999) conducted a longitudinal cephalometric study of postorthodontic craniofacial changes. Former patients (n = 36) were recalled an average of 5.5 years and again an average of 14.4 years after posttreatment records had been taken. Most skeletal linear measurements exhibited significant growth after the first recall, but most of the growth observed between 13 and 30 years had occurred between the ages of 13 and 16 years. The midface (Condylion-A Point) remained statistically unchanged during treatment but increased significantly from the posttreatment examination to the first recall examination (3.0 mm) and from the first recall examination to the second recall examination (1.1 mm). The increase up to the first recall examination was due to the downward and forward growth of the midface during late adolescence.

Facial Changes Associated with Orthodontic Treatment

Bishara *et al*. (1995) investigated the soft tissue changes concurrent with orthodontic treatment. The subjects exhibited Class II, division 1 malocclusions. A total of 91 patients (47 extraction and 44 nonextraction cases) were evaluated with standardized facial photographs, at pretreatment, posttreatment, and 2 years after the posttreatment examination. The average age of the subjects at pretreatment, posttreatment, and 2 years after the posttreatment examinations were about 12, 15, and 17 years of age, respectively. From the photographs 38 landmarks were located (18 frontal shown in Figure 4 and 20 lateral shown in Figure 5). These landmarks where used to construct 29 linear dimensions (Figures 6 and 7). Bishara's group found that the face increased in anteroposterior length about two times its increase in mediolateral width. Similarly, the nose grew in vertical length and sagittal depth twice as much as it grew in lateral width. The upper lip length in males and the upper and lower lip lengths in females increased among subjects who were treated without premolar extractions and decreased among those who were treated with extractions in both sexes. The decreased upper and lower lip lengths were assumed to be associated with the retrusion of the upper and lower incisors in the subjects that were treated with extractions.

Figure 4. Craniometric landmarks located in the study by Bishara *et al.* (1995) from frontal facial photographs.

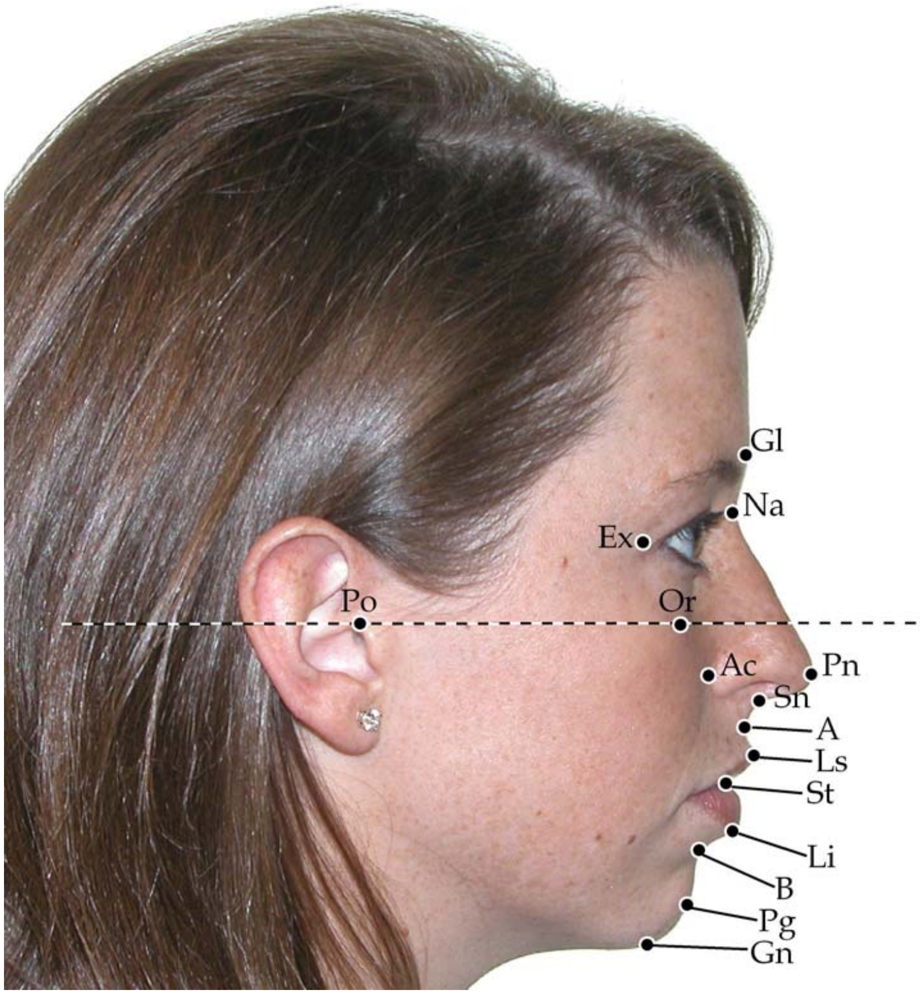


Figure 5. Craniometric landmarks located by Bishara *et al.* (1995) from lateral facial photographs.

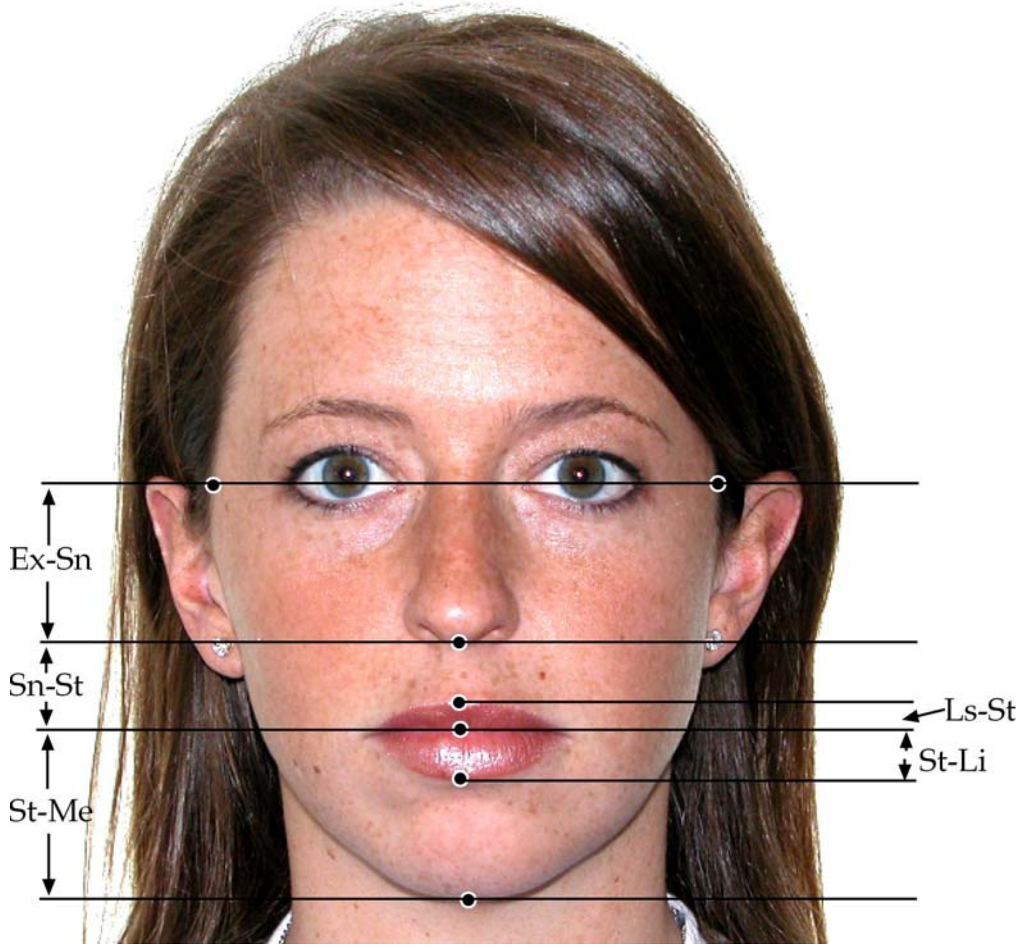


Figure 6. Craniocaudal distances measured by Bishara *et al.* (1995) from frontal facial photographs.

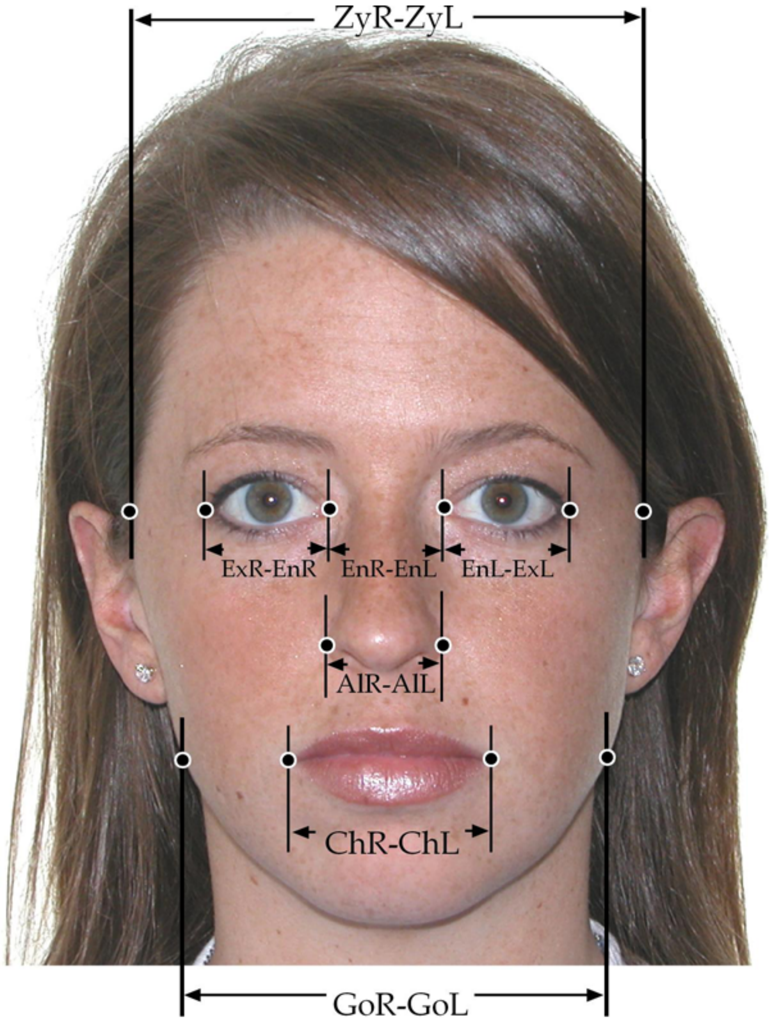


Figure 7. Transverse distances measured by Bishara *et al.* (1995) from frontal facial photographs.

Facial Changes in Adulthood

Bishara *et al.* (1984) quantified the changes in facial dimensions and relationships along with standing height. The sample included subjects from the ages of 5.0 years to 25.5 years. The total changes were split up into three age intervals: (1) 5 to 10 years; (2) 10 to 15 years; and (3) 15 to 25.5 years of age. The magnitude and timing of growth differed among subjects within the same chronological age intervals as well as between the sexes. The growth of males was evenly distributed over the three periods, whereas the females tended to have the most growth change within the first two growth periods. During the third growth period, there was no significant difference in the magnitude of change between 15 and 17 years of age and the change after 17 years of age.

Akgul and Toygar (2002) longitudinally evaluated the craniofacial changes that occurred in their sample of 30 subjects (14 women and 16 men) into the third decade of life. Their subjects were examined twice, with a mean age of 22 years at the first observation and 32 years at the second observation. Lateral cephalometric films were evaluated using a traditional evaluation to measure skeletodental and soft tissue changes. The total anterior face height increased in both sexes, while the lower face height increased significantly only in the female group. The upper lip position, measured from labrale superius (Ls) to a vertical reference plane, retruded significantly in women. Upper lip thickness, measured from labrale superius to the tip of the upper central incisor, decreased in both sexes.

Frontal Facial Differences in Males and Females

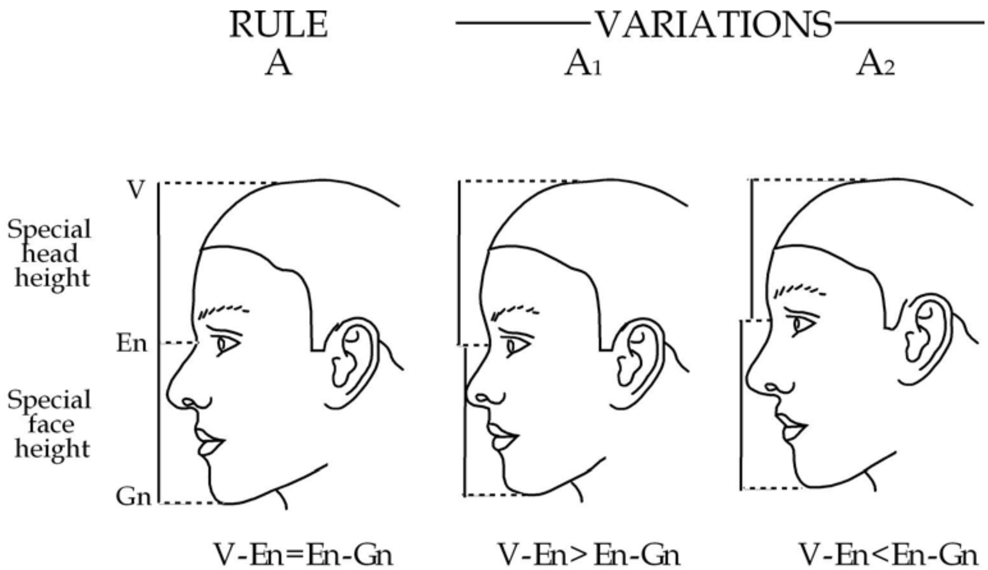
Ferrario *et al.* (2001) examined the growth changes associated with the orbital region in a cross-sectional study. Three-dimensional coordinates of several soft-tissue landmarks of the orbits and face were obtained with an electromagnetic digitizer. The subjects consisted of 40 male and 33 female adolescents aged 12 to 15 years, 73 female and 89 male young adults aged 19 to 30 years, and 41 male and 38 female adults aged 31 to 56 years. Length and inclination of the eye fissure and the orbital height to eye fissure length ratios were calculated for age and sex using the following landmarks: biocular width, intercanthal widths, and height and inclination of the orbit relative to both the true horizontal (natural head position) and Frankfort horizontal. Both the linear dimensions and the angular values were significantly larger in males than in females of corresponding age ($P < 0.05$). A significant effect of age was found ($P < 0.05$): while the linear distances and the orbital height-to-length ratio were greater in older people of the same sex, the inclination of the eye fissure decreased as a function of age. The changes in the inclinations of the eye fissures led to downward-and-medial movements of the outer canthi. Orbital inclinations were larger in the young adult group than in the adolescent and middle-aged groups.

Farkas *et al*. (1992) measured the intercanthal width (bi-Endocanthion) and biocular width (bi-Exocanthion) of 1,594 North American Caucasians. The subjects were between the ages of 1 year and 18 years, and equally divided between males and females. Total growth achieved between ages 1 and 18 years was 5.2 mm in intercanthal width and 12.5 mm in biocular width. At 1 year of age, the degree of development of the intercanthal width reached 84.1%, and that of the biocular width 85.9% of adult dimensions in both sexes. The levels of growth achieved by 5 years of age rose to 93.3% in the intercanthal width and 88.1% in the biocular width in both sexes. The intercanthal width showed little growth after 1 year of age; in contrast, the biocular width showed significantly greater growth increments both before and after 5 years of age. Rapid growth was observed between 3 and 4 years in the intercanthal width of both sexes in these cross-sectional data. The growth observed in the biocular width was small but continuous up to mid-adolescence. The intercanthal width reached adult size at 8 years in females and 11 years in males, and the biocular width at 13 years in females and 15 years in males.

Perceptions of Balanced Facial Proportions

Rules defining facial proportions were mainly formulated by scholars and artists of the Renaissance based on classical Greek proportions. An understanding of the basic proportions of the head and neck is fundamental to artistic renditions of the human face as well as reconstructive plastic surgery. Farkas *et al.* (1985) examined the validity of nine neoclassical rules of facial proportion using normative data obtained by measurement of a North American Caucasian sample. Farkas and colleagues used 103 young adults (eighteen year olds) to calculate the variations of the neoclassical proportions and determine their frequency in seven of the aforementioned rules.

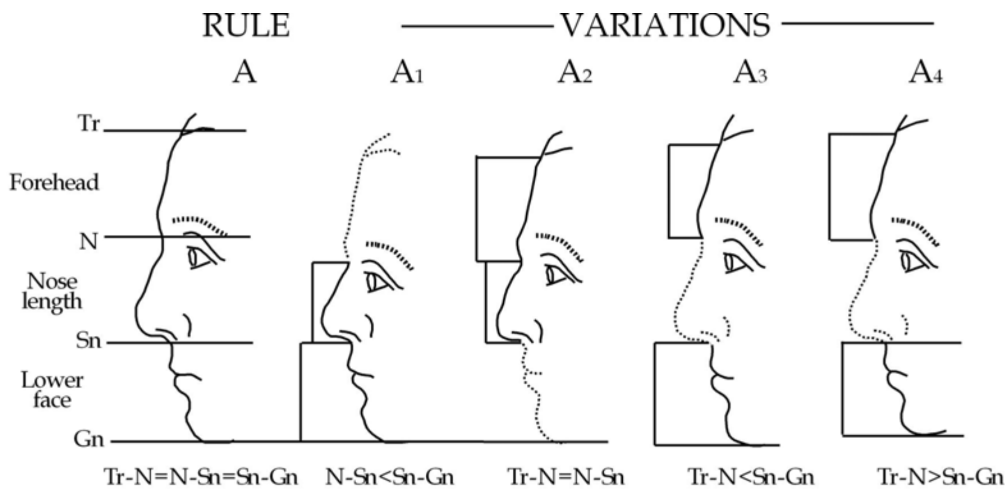
As illustrated in Figure 8, when the facial profile was divided into two vertical measurements, the special head height (Vertex-Endocanthion, V-En) and the special face height (Endocanthion-Gnathion, En-Gn), only 10% of the sample met the rule that states that these two measurements should be equivalent. Another rule (Figure 9) states that when the facial profile is divided into three equal parts—the forehead (Trichion-Nasion), the nose (Nasion-Subnasale), and the lower half of the face (Subnasale-Gnathion). None of the subjects displayed three equal distances. In the four-section facial profile rule, the head-face is divided into four equal parts—the height of the calva (Vertex-Trichion), the height of the forehead (Trichion-Glabella), the special upper face height (Glabella-Subnasale), and the height of the lower face (Subnasale-Gnathion).



n = 103	10%	80%	10%
Mean difference from rule	---	12.3 mm	5.8 mm
Minimum-maximum difference	---	2 - 29 mm	4 - 9mm

Figure 8. Two-section facial profile rule (A) and two proportion alternatives (A_1 and A_2). Rule: The combined head-face height is divided into two equal parts-the special head height (Vertex-Endocanthion, V-En) and the special face height (Endocanthion-Gnathion, En-Gn).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.



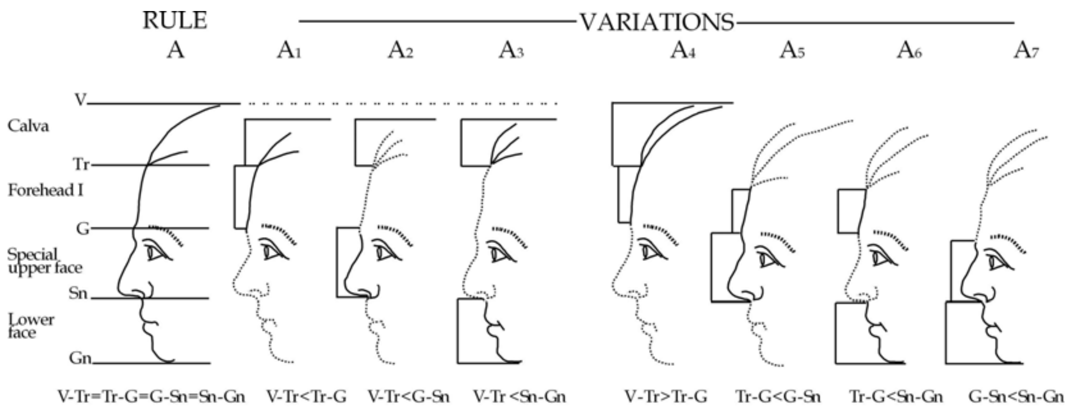
n = 103	0%	100%	95%	49.5%	35%
Mean difference from rule	---	17.8 mm	16.7 mm	8.1 mm	6.1 mm
Minimum-maximum difference	---	4 - 31 mm	4 - 34 mm	2 - 19 mm	2 - 12 mm

Figure 9. Three-section facial profile rule (A) and four proportion alternatives (A_1 to A_4). Rule: The combined forehead-face height is divided into three equal parts-the forehead (Trichion-Nasion, Tr-N), the nose (Nasion-Subnasale, N-Sn), and the lower half of the face (Subnasale-Gnathion, Sn-Gn).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

None of the subjects in the sample possessed this proportion (Figure 10). In the nasoaural proportion rule (Figure 11), the length of the nose (Nasion-Subnasale) equals the length of the ear (Supraaurale-Subaurale, Sa-Sb). The length of the ear was greater than the length of the nose in 95.1% of the sample. In the orbitonasal proportion rule Figure 12, interocular distance (Endocanthion left-Endocanthion right) equals the width of the nose (Alare left-Alare right). This was true 40.8% of the time. In the orbital proportion rule (Figure 13), the interocular distance (bi-Endocanthion) equals the length of the right or left eye fissure (Exocanthion-Endocanthion). In Farkas' sample, 51.5% of the subjects had an interocular distance that was greater than the length of the left or right eye fissure. In the naso-oral proportion rule the width of the mouth (bi-Cheilion) equals 1½ the width of the nose (bi-Alare). As in Figure 14, 20.4% of the sample had this relationship. The nasofacial proportion rule supposes that the width of the nose (bi-Alare) equals ¼ the width of the face (bi-Zygomatic). This was true 36.9% of the time (Figure 15).

Lee and Lee (1979) used various facial proportions that may be applied to most people. Along with these proportions, they described simply ways to draw faces to facilitate medical record keeping and communication between surgeons. The adult face can be divided into three equal parts by four lines drawn through Trichion, Nasion, Subnasale, and Gnathion (Figure 16). This simple rule does not apply to an infant or child. The forehead makes up the greatest portion of



	A	A_1	A_2	A_3	A_4	A_5	A_6	A_7
n = 103	0%	40%	87%	100%	52.5%	92.5%	100%	68%
Mean difference from rule	---	12.2 mm	15.2 mm	19.1 mm	11.0 mm	15.5 mm	17.6 mm	9.4 mm
Minimum-maximum difference	---	2 - 29 mm	3 - 37mm	2 - 42 mm	2 - 25 mm	4 - 35 mm	3 - 42 mm	2 - 21 mm

Figure 10. Four-section facial profile rule (A) and the seven proportion alternativess (A_1 to A_7). Rule: The combined head-face height is divided into four equal parts-the height of the calva (Vertex-Trichion, V-Tr), the height of the forehead (Trichion-Glabella, Tr-G), the special upper face height (Glabella-Subnasale, G-Sn), and the height of the lower face (Subnasale-Gnathion, Sn-Gn).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

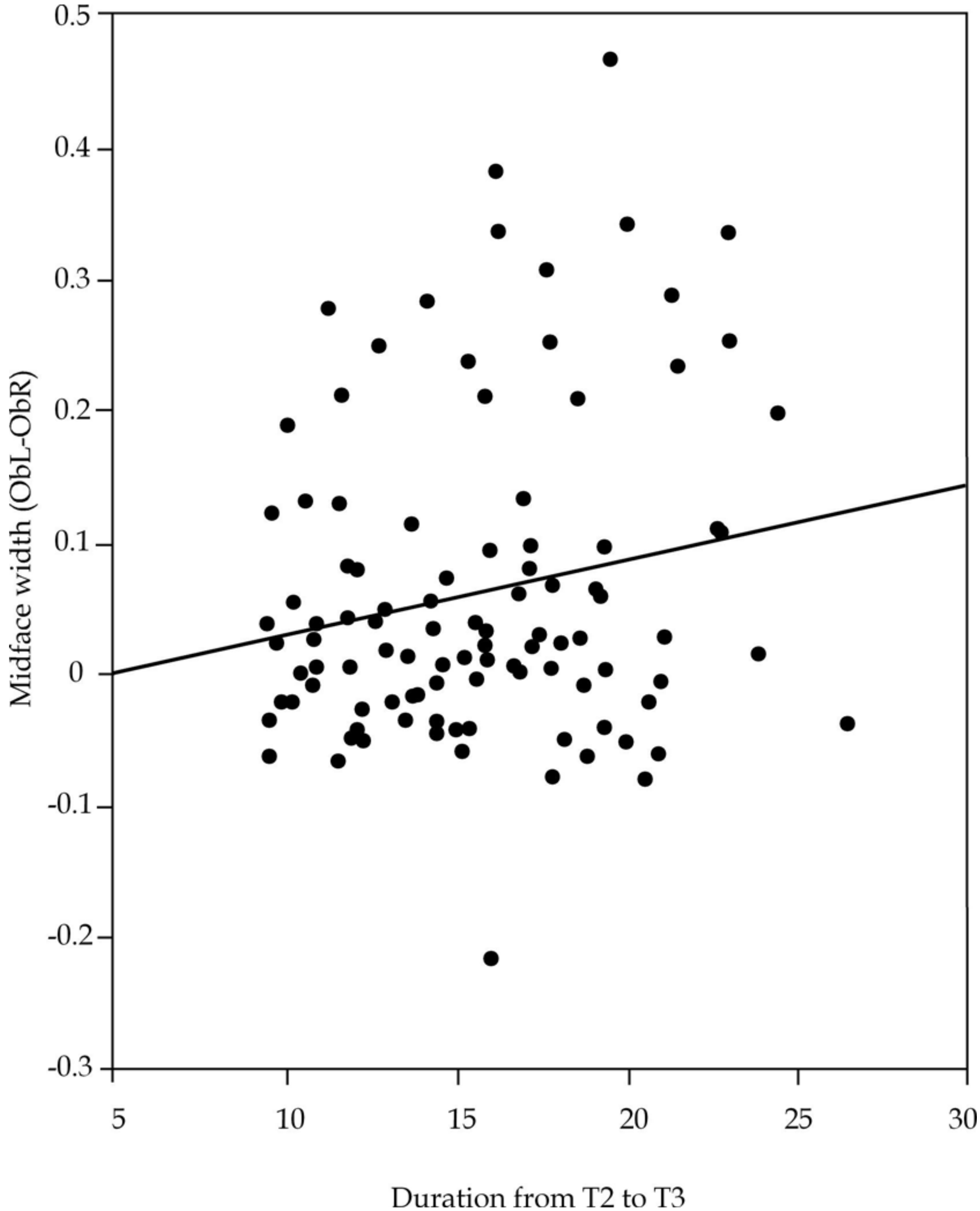
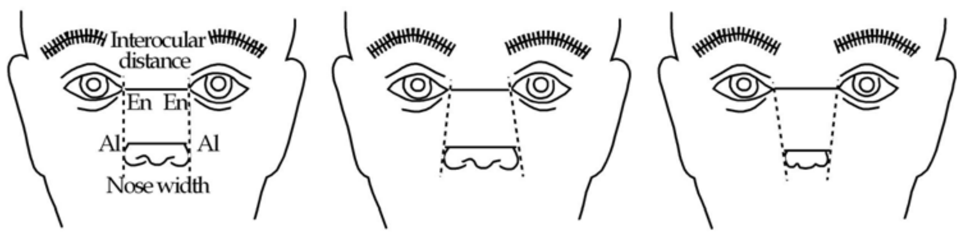


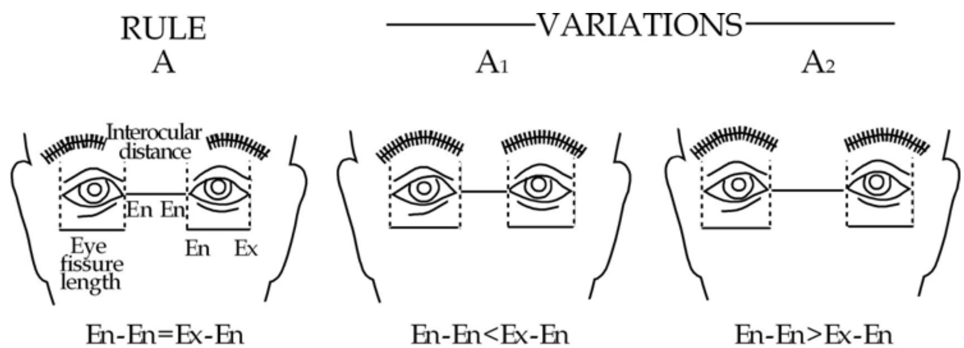
Figure 27. Scattergram between duration from T2 to T3 (X-axis) and the amount of change in Midface width (ObL-ObR).



	RULE A	VARIATIONS A_1	VARIATIONS A_2
	En-En=Al-Al	En-En<Al-Al	En-En>Al-Al
n = 103	40.8%	37.9%	21.4%
Mean difference from rule	---	3.6 mm	3.0 mm
Minimum-maximum difference	---	2 - 8 mm	2 - 6 mm

Figure 12. Orbitonasal proportion rule (A) and two alternatives (A_1 and A_2). Rule: The interocular distance (Endocanthion left-Endocanthion right, EnL-EnR) equals the width of the nose (Alare left-Alare right, AlL-AlR).

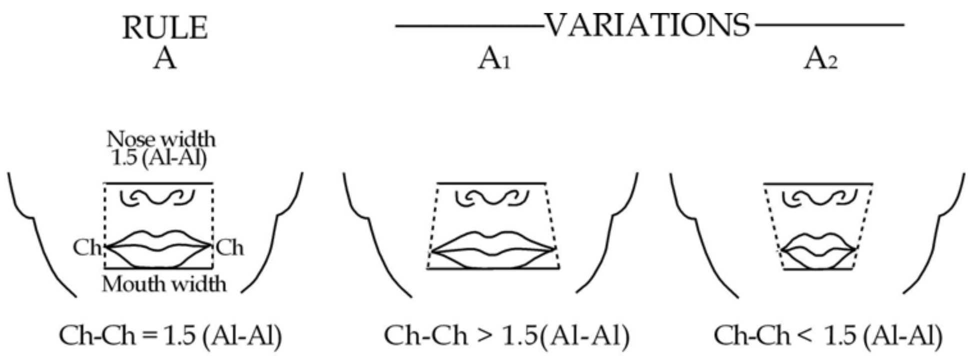
Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.



n = 103	33%	15.5%	51.5%
Mean difference from rule	---	2.8 mm	3.5 mm
Minimum-maximum difference	---	2 - 5 mm	2 - 6 mm

Figure 13. Orbital proportion rule (A) and two alternatives (A_1 and A_2). Rule: The interocular distance (Endocanthion left-Endocanthion right, EnL-EnR) equals the length of the right or left eye fissure (Exocanthion-Endocanthion, Ex-En).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

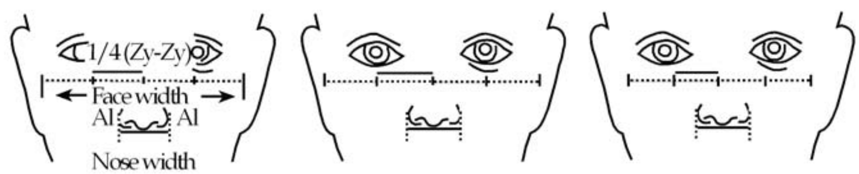


n = 103	20.4%	60.2%	19.4%
Mean difference from rule	---	4.5 mm	4.2 mm
Minimum-maximum difference	---	1.5 - 9 mm	1.5 - 8.5 mm

Figure 14. Naso-oral proportion rule (A) and two alternatives (A_1 and A_2). Rule: The width of the mouth (Cheilion left-Cheilion right, ChL-ChR) equals 1 ½ the width of the nose (Alare left-Alare right, AlL-AlR).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

	RULE A	VARIATIONS A1	VARIATIONS A2



	Al - Al = 1/4(Zy - Zy)	Al - Al < 1/4(Zy - Zy)	Al - Al > 1/4(Zy - Zy)
n = 103	36.9%	38.8%	21.4%
Mean difference from rule	---	3.6 mm	3.0 mm
Minimum-maximum difference	---	2 - 8 mm	2 - 6 mm

Figure 15. Nasofacial proportion rule (A) and two alternatives (A_1 and A_2). Rule: The width of the nose (Alare left-Alare right, AlL-AlR) equals ¼ the width of the face (Zygion left-Zygion right, ZyL-ZyR).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

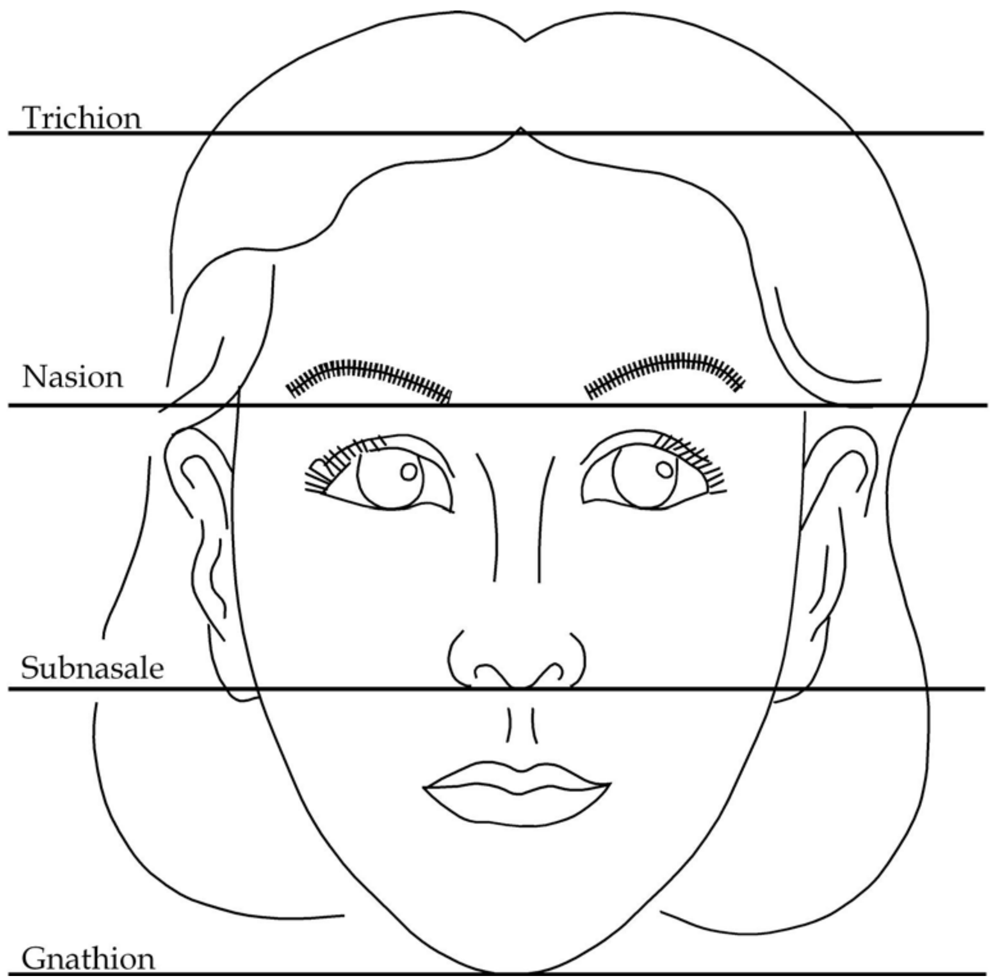


Figure 16. Lines drawn through the Trichion, Nasion, Subnasale, and Gnathion divide the face into three equal parts.

Source: Lee L, Lee KJ. A study of facial proportions and sketching of facial contours. Ear Nose Throat J 1979;58:150-8.

the face of the infant (Figure 17), but the divisions in adolescence (Figure 18) are closer to that of the adult. The width of each eye is equal to the distance between the eyes, which is also the distance between the alar rims of the nose (Figure 19A and C). The length of the nose, from the bridge to the anterior nasal spine, is approximately 1½ times the interalar distance (Figure 19B).

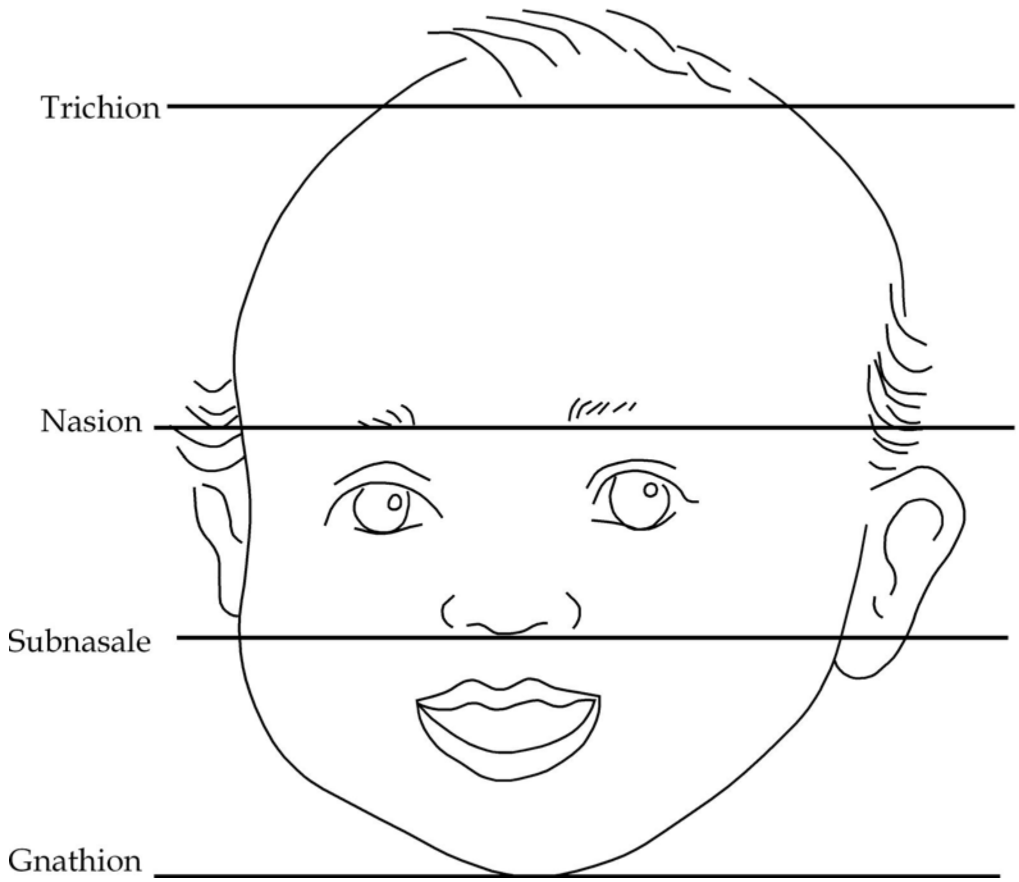


Figure 17. In the infant, the forehead occupies the greatest portion of the face.

Source: Lee L, Lee KJ. A study of facial proportions and sketching of facial contours. Ear Nose Throat J 1979;58:150-8.

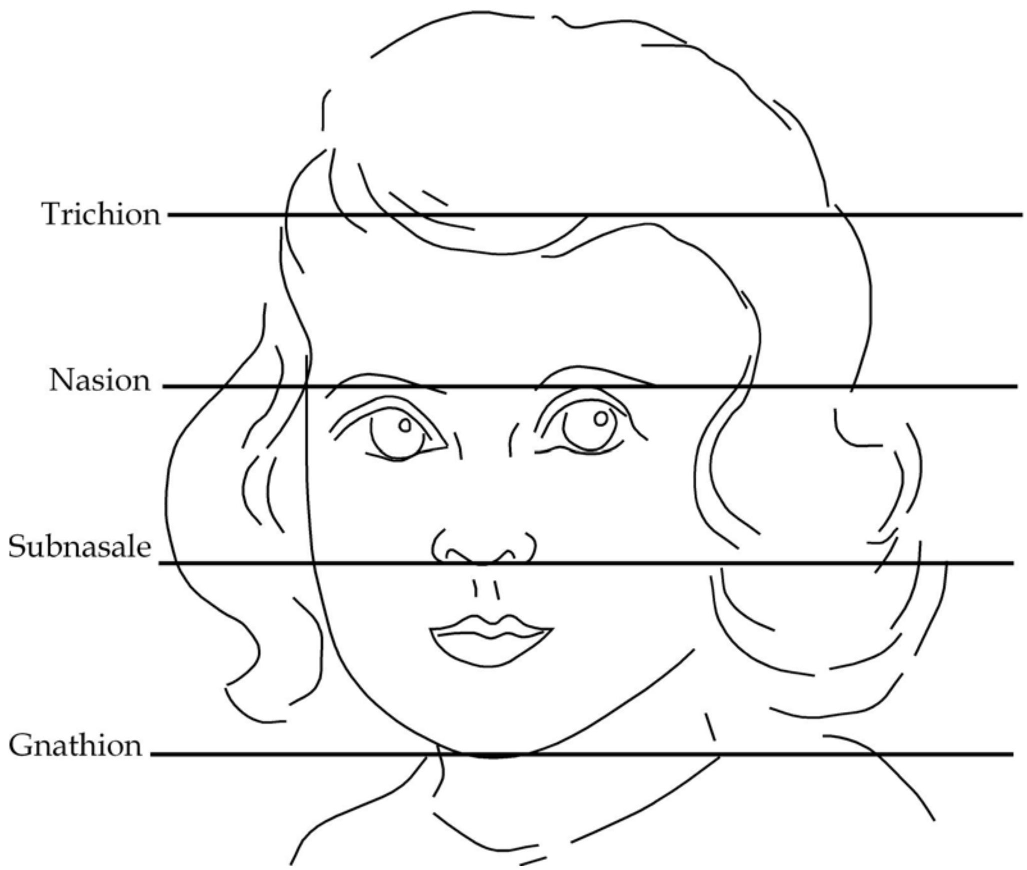


Figure 18. In the older child, the face can begin to be divided into the three equal parts characteristic of the adult face.

Source: Lee L, Lee KJ. A study of facial proportions and sketching of facial contours. Ear Nose Throat J 1979;58:150-8.

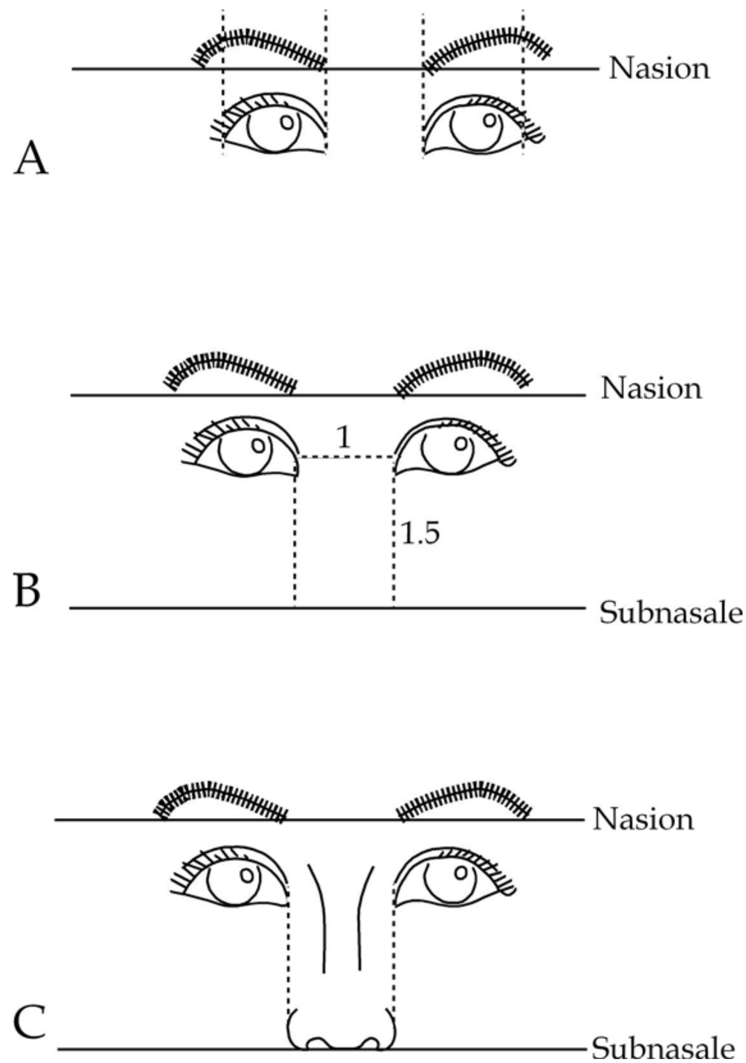


Figure 19. The width of each eye equals the distance between the inner canthi, which is the same as that between the alar rims of the nose.

Source: Lee L, Lee KJ. A study of facial proportions and sketching of facial contours. Ear Nose Throat J 1979;58:150-8.

CHAPTER III

MATERIALS AND METHODS

In the present study, frontal facial photographs of 133 orthodontic patients were analyzed to assess the changes in facial dimensions in frontal view from adolescence to adulthood. Frontal facial photographs were obtained after orthodontic treatment and at a long-term recall examination. The long-term interval was defined as 10 years or more following the end of the active phase of orthodontic treatment. The photographs were obtained from the orthodontic records collected by the Charles H. Tweed Foundation from several private practices. The photographs were taken by orthodontic assistants, in each of the private practices, then compiled and stored using Dentofacial Planner Plus® (Dentofacial Software Inc., Monterey, CA). The photographs were converted to JPEG format and measured using SigmaScan® Pro 5.0 (LEAD technologies Inc., Chicago, IL) software.

Although most of the subjects were positioned in head holders, an exact focal length was not used for the frontal photographs. Various magnifications were inevitable due to the lack of a fixed focal distance within or among subjects. On the frontal photographs, vertical head orientation was deemed to be acceptable when the estimated points of Orbitale and Porion formed a line that was approximately parallel to a line connecting the left and right Exocanthions. Transverse head orientation was deemed acceptable when the ears were visible and approximately equal in size. The posttreatment ages of the patients were selected to be between 14 and 18 years. The patients in this sample of convenience were all treated with conventional edgewise mechanics.

The Sample

Cases for the present study were drawn from the database accumulated by Dr. George S. Harris and Dr. James L. Ferguson, from patient records submitted by members of the Charles H. Tweed Foundation. The Foundation's plan was to assess the very long-term orthodontic stability of people treated with the conventional edgewise mechanics. Individuals who had been patients treated by members of the Tweed Foundation were recalled several years after treatment, recall records (T3) were taken, and the cases (records at T1, T2, and T3) were sent to Dr. George Harris (Menominee, Michigan). He took standardized photographs of the casts, scanned the intra- and extra-oral photographs and radiographs, and recorded the treatment plans. Cephalometric analysis and cast analysis were also performed.

For the present study, we focused on analyzing the frontal extra-oral photographs from the end of the active phase of treatment (T2) to the long-term recall examination (T3). The nature of the malocclusion (*e.g.*, Angle's molar classification) was not considered.

Horowitz and Hixon (1969) contended that orthodontic treatment has a finite, limited effect on a person's growth and development. Certainly mechanotherapy alters tooth positions and, depending on the treatment, it can also influence vectors of bone growth. Once treatment is complete, however, the specialist's control of the person's subsequent growth and development (and relapse) is limited and transient. Our perspective is that changes in size and shape of the facial structures, especially over the long term, primarily reflect the outplaying of the person's intrinsic growth and aging potential.

There were a total of 133 patient records available for this study. The selection criteria for inclusion were (1) usable frontal extra-oral photographs at T2 and T3 and (2) that T3 needed to be a minimum of 10 years from T2. The usable sample was 101 cases (41 males, 60 females). This preponderance of women suggests that girls more frequently seek orthodontic treatment than boys in most orthodontic practices and that a common means of locating participants for this long-term recall study was to get T3 records on the mother (who had been a patient) when she brought one of her own offspring to the same orthodontist for treatment.

Interpupillary Width as a Stable Reference

The material studied here consists of frontal facial photographs of people who had been treated orthodontically. There was no metric scale in the photographs, so it was not possible to provide millimetric dimensions of the variables measured. Instead, the facial dimensions are presented as a ratio of the person's interpupillary width (IPW). Other studies have expressed facial measurements as a ratio of ocular measurements (*e.g.*, Pitanguy 1998; Bisson and Grobbelaar 2004). Based on previous studies (*e.g.*, Pryor 1969; Fledelius and Stubgaard 1986; Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003), it is highly suggestive that IPW is stable after adolescence.

Bisson and Grobbelaar (2004) expressed measurements of the lips as a ratio of intercanthal distance. They determined that in order to correct for the inevitable variation of image size, distances in their study would be expressed as a ratio of the intercanthal distance (bi-Endocanthion) in each image, which was given a nominal value of 10 units. Pitanguy *et al. (*1998) used IPW to calculate ratios for several facial measurements. The aim of their study was to determine a pattern of change in facial dimensions during the aging process.

Pryor's (1969) data suggest that IPW increases with age from birth to about 24 years of age. Fledelius and Stubgaard (1986) analyzed the association between eye position and age. Their sample comprised 267 subjects between the ages of 5 and 20 years and 187 subjects between the ages of 21 and 80 years. The study was prompted by a previous longitudinal finding of a 3 mm increase in exophthalmometry value from age of 10 to 18 years. An adult mean value of 16.0 mm in females and 16.6 mm in males was achieved in late teen-age years, the dimension being stable after that. Lakshminarayana *et al*. (1991) found that IPW increases from birth to 5 years of age, with negligible changes thereafter. Farkas *et al.* (1992) measured the intercanthal width (bi-Endocanthion) and biocular width (bi-Exocanthion) of 1,594 North American Caucasians. The subjects in this cross-sectional appraisal were between the ages of 1 year and 18 years. Intercanthal width reached adult size by 8 years in females and 11 years in males, and the biocular width by 13 years in females and 15 years in males. Filipovic (2003) found a mean IPW of 5.1 cm in 5-year old children, with an increase to 6.3 cm in adults (20 years of age). According to Filipovic, IPW remains the same (*i.e.* 6.3 cm) after 20 years of age.

Many of the studies regarding interpupillary width (IPW) were cross-sectional in nature (*e.g.*, Pryor 1969; Fledelius and Stubgaard 1986; Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003). Few longitudinal studies have been performed to measure IPW and other related ocular dimensions. It is highly suggestive that IPW is stable after adolescence based on the available cross-sectional data (*e.g.*, Pryor 1969; Fledelius and Stubgaard 1986; Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003). Again, there was no millimetric scale in the photographs in the present study. Measurements in the present study were expressed as a ratio of IPW.

Age Distribution

This sample was treated with conventional edgewise orthodontic treatment that commences when all of the permanent teeth have emerged, which is around 12 to 13 years of age (Hurme 1949). Active treatment lasted an average of about 2.5 years, so the adolescents were about 15.5 years of age at the posttreatment examination (Table 1). Again, there were 41 males and 60 females in the usable sample. There was no missing data in this study, so sample sizes are invariably 60 for females and 41 for males. Average duration from T2 to T3 was 15 years, so the people were about 30 years of age ($\bar{x}$ = 31.2 years) at the long-term recall examination. Statistically, there was no difference between the sexes for age at T2 or T3 or for the duration from T2 to T3.

The gist of the present study is to investigate the changes in facial size and shape from T2 (mid-adolescence) to T3 (adulthood), a span of 15 years, on the average. This span incorporates biological changes that occurred late in adolescence in combination with those changes characteristic of young adulthood. The changes should, however, stop well short of the degradative changes associated with maturity (Finch and Hayflick 1985).

Table 1. Age distributions of the sample (years).

Statistic	Total	Males	Females
	End of Treatment (T2)		
Mean	15.57	15.66	15.52
SD	1.99	1.61	2.23
SEM	0.20	0.25	0.29
n	101	41	60
	Recall Examination (T3)		
Mean	31.23	31.26	31.21
SD	4.57	4.56	4.61
SEM	0.45	0.71	0.60
n	101	41	60
	T2 to T3 Age Interval		
Mean	15.66	15.60	15.69
SD	3.96	4.01	3.96
SEM	0.39	0.63	0.51
n	101	41	60

Mean indicates the average age (in years); SD, the standard deviation; SEM, the standard error of mean; n, the number of subjects.

Variables

The facial landmarks (Figure 20), transverse distances (Figure 21 and Figure 22), and craniocaudal distances (Figure 23) evaluated in the present study are defined below. These are adopted primarily from the work of Bishara *et al.* (1995).

Facial Landmarks

Integumental Facial Landmarks

Zygion left and right (ZyL and ZyR). The most lateral point of each zygomatic arch. Operationally, it is the point formed by the intersection of the lateral border of the face and a line extended down from Exocanthion on each side of the face.

Gonion left and right (GoL and GoR). The most lateral point on the mandibular angle close to the bony Gonion. Operationally, it is the point formed by the intersection of the lateral border of the face and a continuation of a line from Cheilion left and right.

Menton (Me). The lowest median landmark on the lower border of the mandible. Operationally, it is the lowest point of the chin in the frontal photograph.

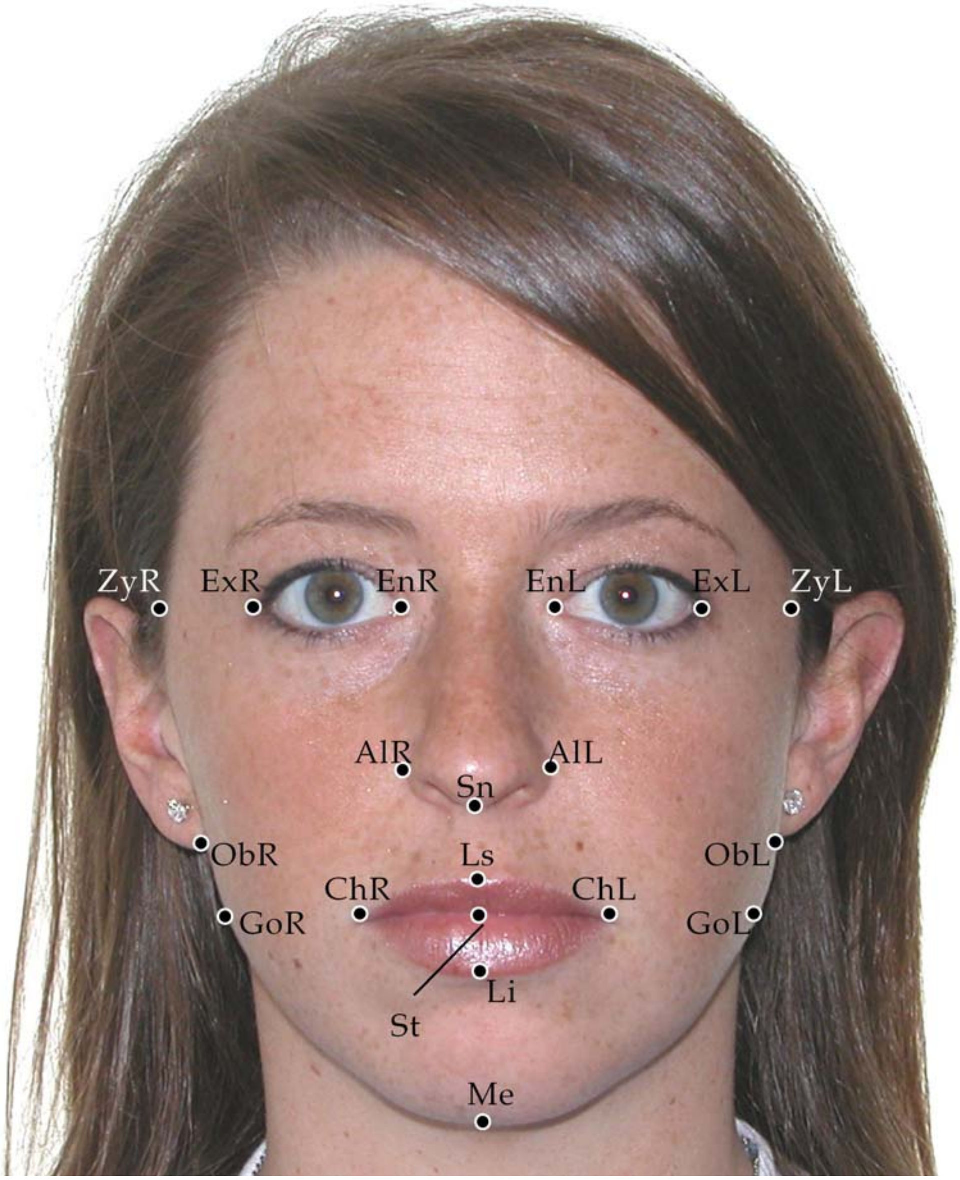


Figure 20. Facial landmarks located on the frontal photographs in the present study.

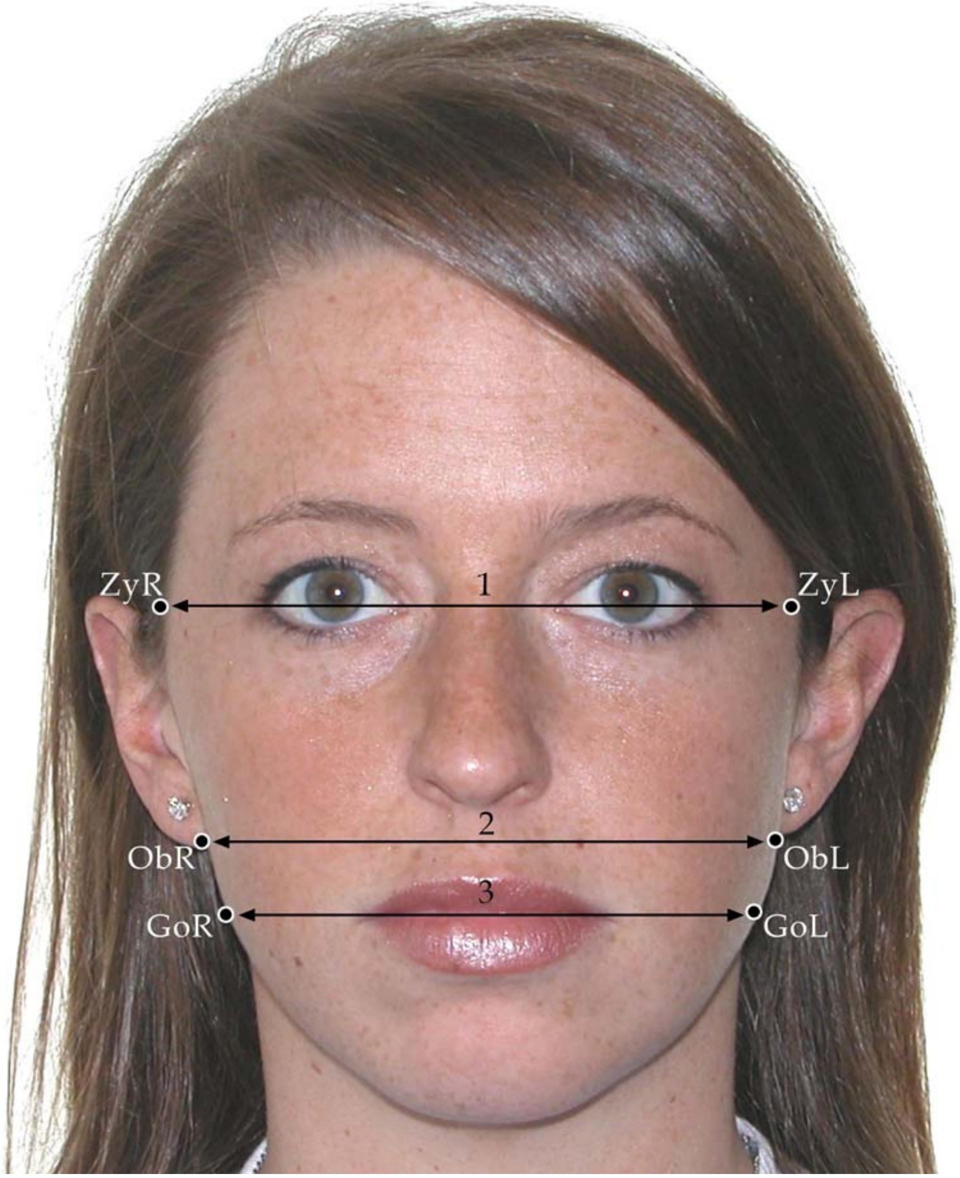


Figure 21. Transverse distances measured from the frontal photographs in the present study: (1) Upper face width, (2) Midface width, and (3) Lower face width.

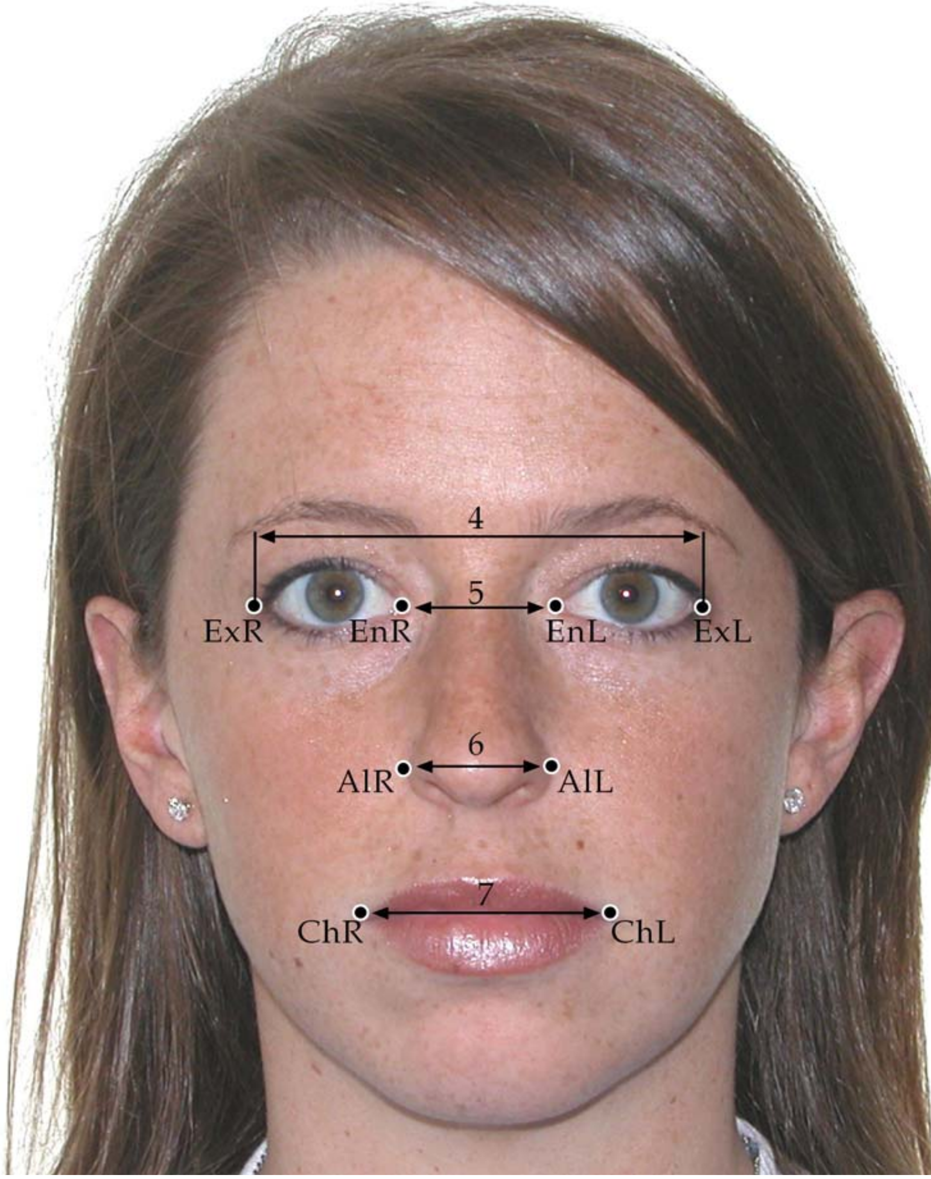


Figure 22. Transverse distances measured from the frontal photographs in the present study: (4) Outer canthus width, (5) Inner canthus width, (6) Alar width, and (7) Mouth width.

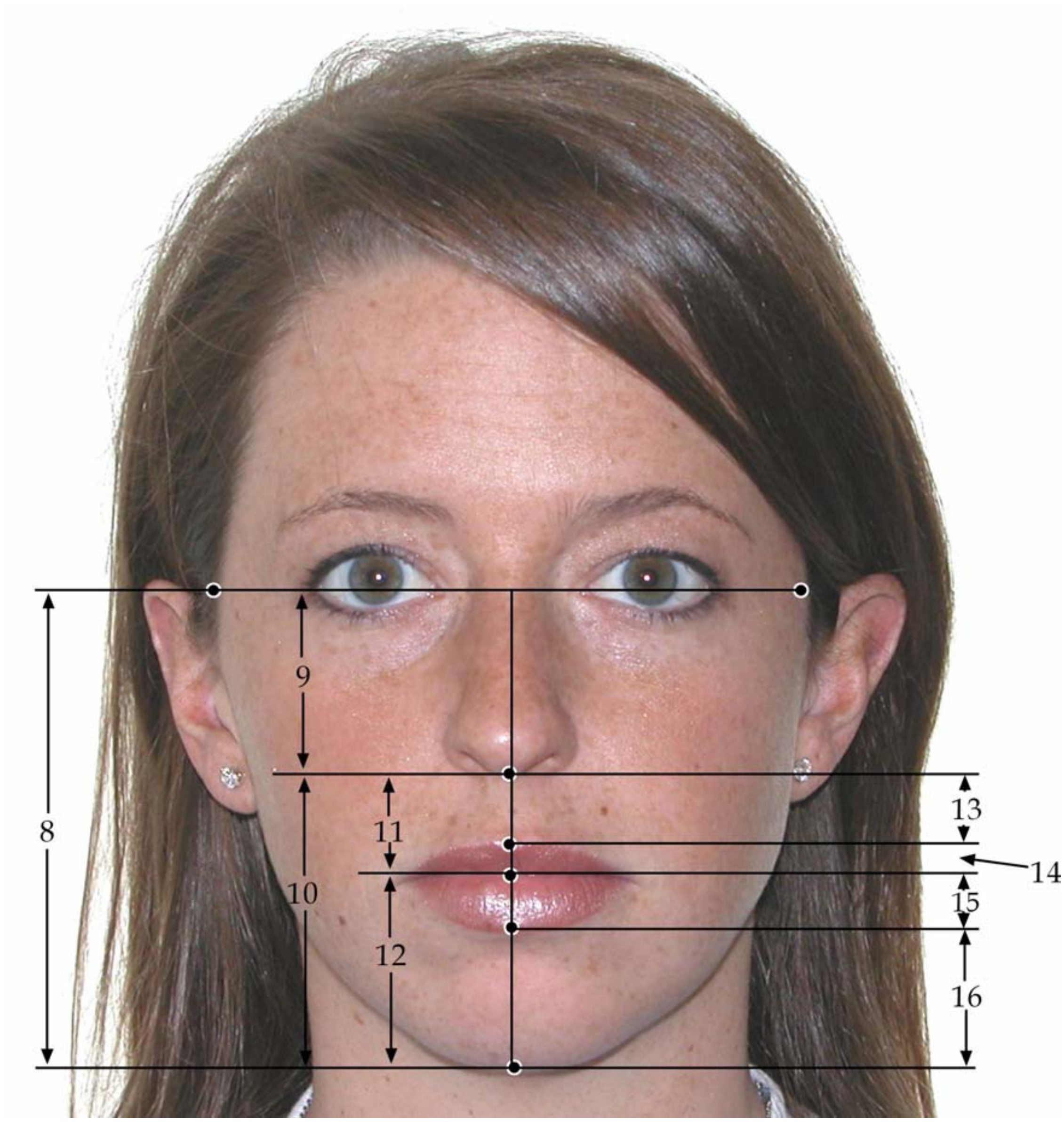


Figure 23. Craniocaudal distances measured from the frontal photographs in the present study: (8) Total face height, (9) Upper face height, (10) Lower face height, (11) Stomion height, (12) Lower lip height, (13) Upper lip height, (14) Upper lip exposure, (15) Lower lip exposure, and (16) Chin height.

Landmarks of the Eyes

Endocanthion left and right (EnL and EnR). The point at the inner commissure of the palpebral fissures

Exocanthion left and right (ExL and ExR). The point at the outer commissure of the palpebral fissures.

Exocanthion midpoint (Ex). The constructed midpoint of the line connecting Exocantion left and Exocanthion right.

Landmarks of the Nose

Alare left and right (AlL and AlR). The most lateral point on the left and the right alar contour.

Subnasale (Sn). The mediolateral midpoint at the angle at the columella base where the lower border of the nasal septum and the surface of the upper lip meet.

Landmarks of the Lips and Mouth

Cheilion left and right (ChL and ChR). The lateral-most point located at the left and the right labial commissure.

Labrale superius (Ls). The most superior point of the upper vermilion contour in the mediolateral midline of the mouth.

Stomion (St). The point at the crossing of the vertical facial midline and the horizontal labial fissure between gently closed lips, with the upper and lower teeth together.

Labrale inferius (Li). The midpoint of the lower vermilion contour in the mediolateral midline of the mouth.

Landmarks of the Ears

Otobasion left and right (ObL and ObR). The point of attachment of the ear lobe to the cheek. It is the caudal border of the ear attachment.

Distances

Transverse Facial Distances

1. Upper face width (ZyL to ZyR). The linear measurement from Zygion left to Zygion right.
2. Midface width (ObL to ObR). The linear measurement from Otobasion left to Otobasion right.
3. Lower face width (GoL to GoR). The linear measurement from Gonion left to Gonion right.
4. Outer canthus width (ExL to ExR). The linear measurement from Exocanthion left to Exocanthion right.

5. Inner canthus width (EnL to EnR). The linear measurement from Endocanthion left to Endocanthion right.

6. Alar width (AlL to AlR). The linear measurement from Alare left to Alare right.

7. Mouth width (ChL to ChR). The linear measurement from Cheilion left to Cheilion right.

<u>Craniocaudal Facial Distances</u>

8. Total face height (Ex to Me). The linear distance from the midpoint of the line connecting Exocantion left and Exocanthion right with Menton.

9. Upper face height (Ex to Sn). The linear distance from the midpoint of a line connecting Exocanthion left and Exocanthion right with Subnasale.

10. Lower face height (Sn to Me). The linear distance for Subnasale to Menton.

11. Stomion height (Sn to St). The linear distance from Subnasale to Stomion.

12. Lower lip height (St to Me). The linear distance from Stomion to Menton.

13. Upper lip height (Sn to Ls). The linear distance from Subnasale to Labrale Superius.

14. Upper lip exposure (Ls to St). The linear distance from Labrale Superius to Stomion.

15. Lower lip exposure (St to Li). The linear distance from Stomion to Labrale Inferius.

16. Chin height (Li to Me). The linear distance from Labrale Inferius to Menton.

Statistical Analysis

There are two broad aspects of the analysis, (1) data description, by sex and by examination (T2 or T3) and (2) inferential tests for changes due to growth—differences between the sexes at T2 and/or at T3 and differences within individuals between examinations (*i.e.,* changes from T2 to T3).

A person's sex is a fixed effect, but following the same individuals from T2 to T3 produces repeated measures (Winer *et al*. 1991; Sokal and Rohlf 1995). Consequently, a mixed-model analysis of variance is appropriate to account for these two sorts of data, since the error mean square is different for these two effects.

When significant sex-by-age interactions were encountered (as is common since circumpubertal growth is appreciably greater in males), the design needed to be simplified by testing each sex separately. One-sample t-tests were be used to test for systematic changes across time (T2 to T3). Unpaired t-tests (group comparison tests) were used to test for sexual dimorphism at T2 and at T3. All tests will be evaluated as two-tail with alpha set at the conventional level of 0.05.

CHAPTER IV

RESULTS

The material studied here consisted of frontal photographs of people who had been treated orthodontically. The purpose in this chapter is to describe the changes from T2 (mid-adolescence) to T3 (adulthood). As described in the Methods chapter, there was no metric scale in these photographs, so it was not possible to provide millimetric dimensions of the variables measured. Instead the facial dimensions are presented as a ratio of the person's interpupillary width (IPW), which does not change after childhood (Pryor 1969; Fledelius and Stubgaard 1986; Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003).

Presenting the data in terms of interpupillary width (IPW) means that some of the natural variation in facial dimensions is altered because the inter-individual variation in IPW is not known. It was assumed that IPW does not change with time within an individual, but there is, of course, variation among individuals. Because the photographs are unstandardized, the present analysis necessarily ignores variation in IPW. Specifically, each dimension was expressed in relation to IPW, so, if the ratio is 0.6 (as for Alar width, Figure 24), it means that the width of the nose is 60% as wide as IPW. Likewise, if the ratio is

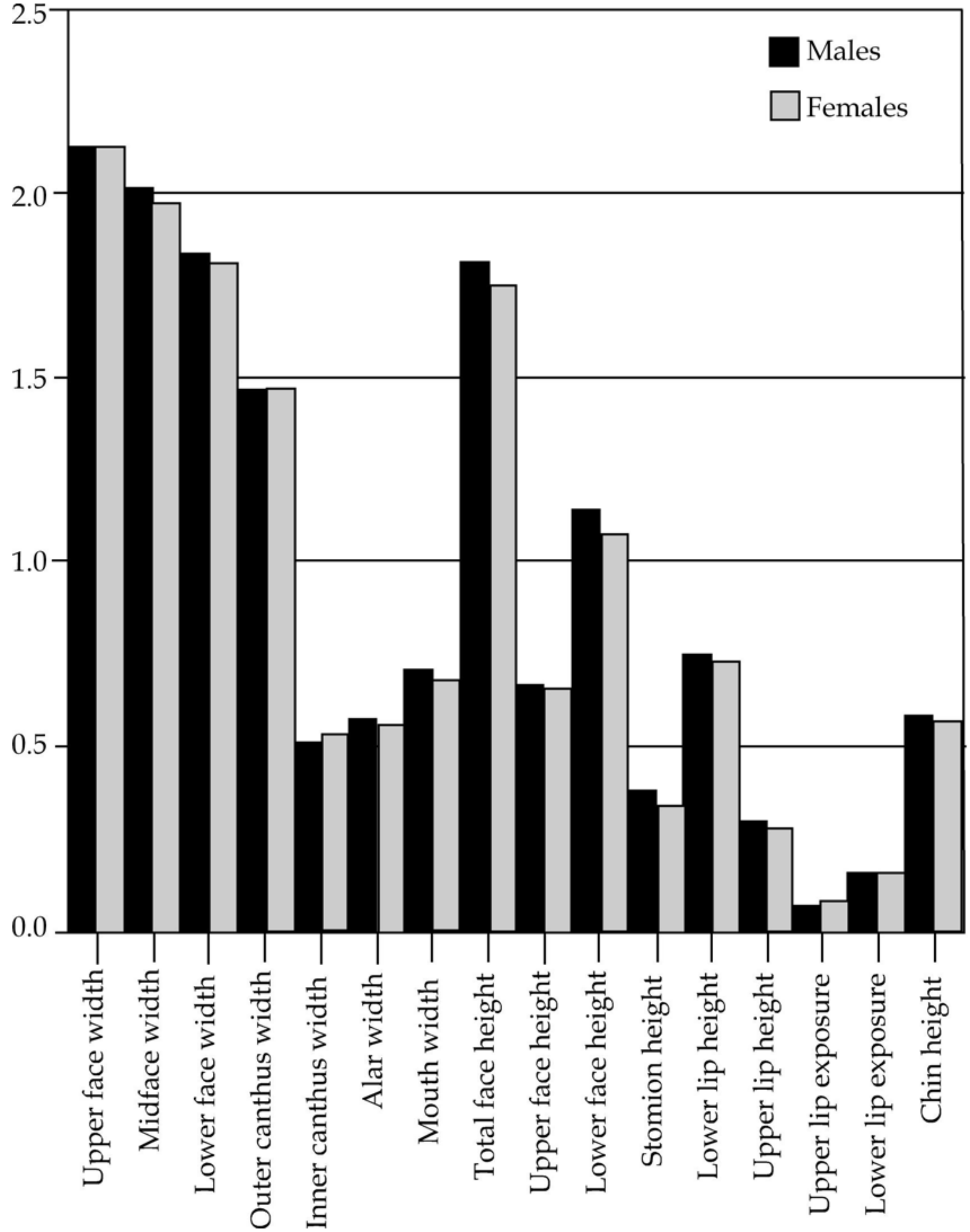


Figure 24. Mean ratios, by sex, at the posttreatment examination (T2).

1.8 (as for Lower face width, Figure 24), it means that Lower face width (GoL-GoR) is 1.8 times wider than IPW (*i.e.*, 180% of IPW).

This frame of reference can be further clarified with an example. Figure 24 shows that, on the average, Upper face width (ZyL-ZyR) was 2.1 times broader than IPW at T2 (with no apparent sexual dimorphism). This means that relative to each individual's IPW, Upper face width was about twice as broad. There is, of course, variation in IPW but because there was no scale in the photographs, we cannot say what IPW was millimetrically. At T3, Upper face width had increased relative to IPW, and more so in men than women (Figure 25). The mean at T3 was close to 2.2 times IPW (while it was about 2.1 times IPW at T2). Testing the T2-to-T3 change due to growth (Figure 26), we see that in both sexes Upper face width grew somewhat relative to IPW, but the increase for women was trivial ($\bar{x}_d$ = 0.01) whereas it was appreciably greater ($\bar{x}_d$ = 0.05) and highly significant in men. In other words, there was an increase of 0.05 *(i.e.*, 5% or 5 percentage points) in the ratio of upper face width to IPW from T2 to T3 in men. (Recall that ratios are unit-less.)

Prior work suggests that IPW is about 66.9 mm in men of western European descent and 62.6 mm in women (Farkas 1994). For the present sample, then, Upper face width would have been about 133.5 mm at T2 for men and 129.7 mm for women and 139.1 mm for men at T3 and 130.0 mm for women at T3. The increases in width for men would have been 5.6 mm, a 4.2% increase

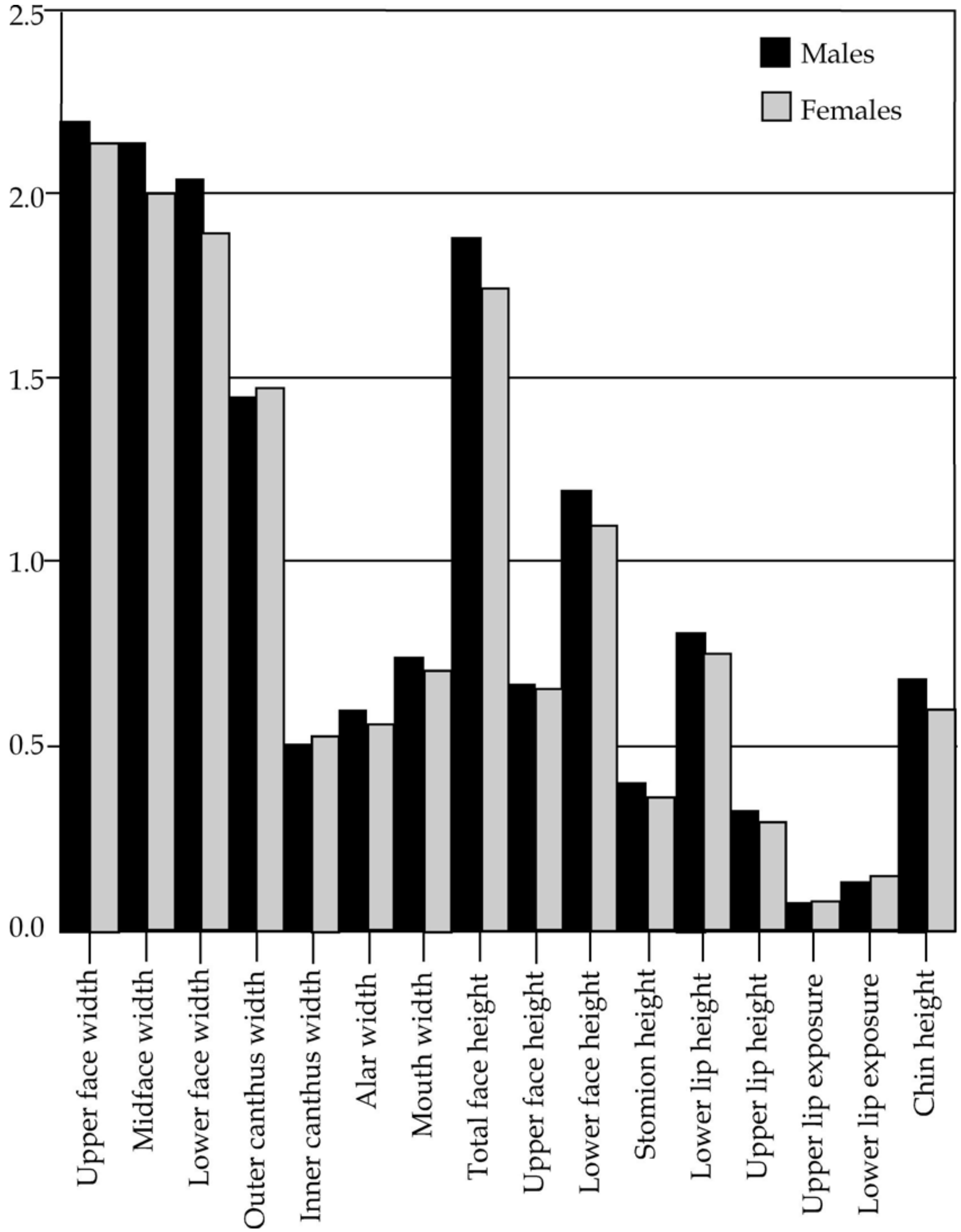


Figure 25. Mean ratios, by sex, at the recall examination (T3).

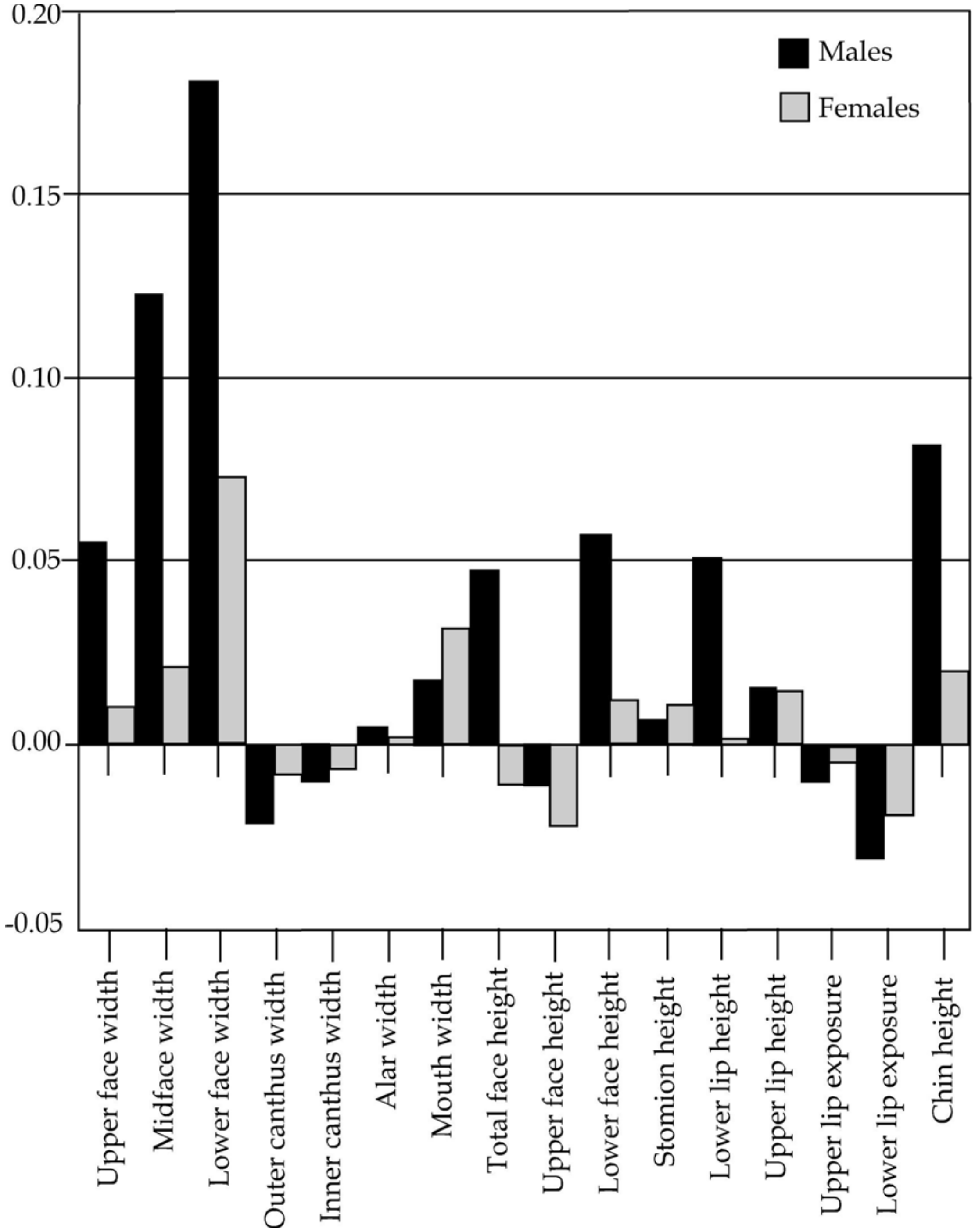


Figure 26. Mean sizes, by sex, from the posttreatment to the recall examination (T3-T2).

over the 15-year span from T2 to T3. The increases in width for women would have been negligible at 0.3 mm, a 0.2% increase over the 15-year span from T2 to T3.

End of Treatment

Descriptive statistics for the facial ratios at T2 are listed in Table 2 and graphed in Figure 24. T2 averaged 15.6 years of age in the sample, which is the mid-teens, and most of the cases would have completed their adolescent growth spurt (Tanner 1962; Nanda 1971). Some of the variables in Figure 24 have equivalent proportions between the sexes (*e.g.*, Upper face width, ZyL-ZyR; Outer canthus width, ExL-ExR) while others (*e.g.*, Mouth width, ChL-ChR; Total face height, Ex-Me) appear to be sexually dimorphic relative to IPW.

One-way analysis of variance was used to test for sexual dimorphism at the posttreatment (T2) examination (Table 3). (One could use group comparison t-tests, but with the JMP statistics package it was more informative to use the ANOVA platform. Results are identical, recalling that $F = t^2$ for two-sample comparisons.) Table 3 shows that six of the 16 variables are significantly sexually dimorphic when assessed in the mid-teens. These are:

1. Lower face width (GoL-GoR)
2. Mouth width (ChL-ChR)
3. Total face height (Ex-Me)

Table 2. Descriptive statistics at the posttreatment (T2) examination.

	Sexes Pooled	Males	Females
	Upper face width (ZyL-ZyR)		
Mean	2.13	2.13	2.13
SD	0.10	0.11	0.10
SEM	0.01	0.02	0.01
n	101	41	60
	Midface width (ObL-ObR)		
Mean	2.00	2.02	1.98
SD	0.11	0.13	0.10
SEM	0.01	0.02	0.01
n	101	41	60
	Lower face width (GoL-GoR)		
Mean	1.83	1.85	1.82
SD	0.13	0.14	0.11
SEM	0.01	0.02	0.01
n	101	41	60
	Outer canthus width (ExL-ExR)		
Mean	1.47	1.47	1.48
SD	0.04	0.04	0.04
SEM	0.00	0.01	0.01
n	101	41	60
	Inner canthus width (EnL-EnR)		
Mean	0.53	0.52	0.53
SD	0.04	0.03	0.04
SEM	0.00	0.01	0.01
n	101	41	60
	Alare width (AlL-AlR)		
Mean	0.57	0.58	0.57
SD	0.04	0.03	0.04
SEM	0.00	0.01	0.01
n	101	41	60

Continued

Table 2. *Continued.*

	Sexes Pooled	Males	Females
	Mouth width (ChL-ChR)		
Mean	0.69	0.71	0.68
SD	0.06	0.06	0.06
SEM	0.01	0.01	0.01
n	101	41	60
	Total face height (Ex-Me)		
Mean	1.78	1.82	1.75
SD	0.12	0.11	0.11
SEM	0.01	0.02	0.01
n	101	41	60
	Upper face height (Ex-Sn)		
Mean	0.68	0.68	0.67
SD	0.08	0.07	0.08
SEM	0.01	0.01	0.01
n	101	41	60
	Lower face height (Sn-Me)		
Mean	1.10	1.14	1.08
SD	0.10	0.09	0.10
SEM	0.01	0.01	0.01
n	101	41	60
	Stomion height (Sn-St)		
Mean	0.36	0.38	0.35
SD	0.04	0.04	0.04
SEM	0.00	0.01	0.01
n	101	41	60
	Lower lip height (St-Me)		
Mean	0.74	0.75	0.73
SD	0.07	0.06	0.07
SEM	0.01	0.01	0.01
n	101	41	60

Continued

Table 2. *Continued.*

	Sexes Pooled	Males	Females
	Upper lip height (Sn-Ls)		
Mean	0.28	0.30	0.27
SD	0.04	0.03	0.04
SEM	0.00	0.01	0.00
n	101	41	60
	Upper lip exposure (Ls-St)		
Mean	0.08	0.08	0.08
SD	0.02	0.03	0.02
SEM	0.00	0.00	0.00
n	101	41	60
	Lower lip exposure (St-Li)		
Mean	0.16	0.16	0.16
SD	0.03	0.03	0.03
SEM	0.00	0.00	0.00
n	101	41	60
	Chin height (Li-Me)		
Mean	0.58	0.59	0.57
SD	0.07	0.06	0.07
SEM	0.01	0.01	0.01
n	101	41	60

Table 3. Results of testing for sexual dimorphism at the end of treatment (T2).

Variable	Males			Females			F Ratio	P Value
	n	$\bar{x}$	SEM	n	$\bar{x}$	SEM		
ZyL-ZyR	41	2.134	0.016	60	2.133	0.013	0.00	0.9620
ObL-ObR	41	2.020	0.018	60	1.981	0.015	2.86	0.0941
GoL-GoR	41	1.847	0.020	60	1.820	0.016	1.14	0.0144
ExL-ExR	41	1.472	0.007	60	1.476	0.006	0.22	0.6383
EnL-EnR	41	0.524	0.006	60	0.533	0.005	1.40	0.2391
AlL-AlR	41	0.584	0.006	60	0.565	0.005	6.20	0.2873
ChL-ChR	41	0.711	0.010	60	0.679	0.008	6.29	0.0138
Ex-Me	41	1.819	0.018	60	1.746	0.015	10.03	0.0020
Ex-Sn	41	0.684	0.012	60	0.669	0.010	0.95	0.3325
Sn-Me	41	1.135	0.014	60	1.078	0.012	9.34	0.0029
Sn-St	41	0.384	0.006	60	0.349	0.005	18.30	<0.0001
St-Me	41	0.751	0.011	60	0.728	0.009	2.55	0.1133
Sn-Ls	41	0.302	0.005	60	0.270	0.004	20.89	<0.0001
Ls-St	41	0.082	0.003	60	0.079	0.003	0.44	0.5067
St-Li	41	0.161	0.004	60	0.159	0.004	0.16	0.6936
Li-Me	41	0.589	0.010	60	0.569	0.009	2.29	0.1334

4. Lower face height (Sn-Me)
5. Upper lip height (Sn-St)
6. Lower lip exposure (St-Ls)

In each of these instances, the proportion of face size to IPW was greater in males than in females. The largest differences were for the vertical dimensions, such as Total face height (Ex-Me).

At full adulthood (T3), the degree and extent of sexual dimorphism had increased (Table 4; Figure 26). At T3 (about 30 years of age) 9 of the 16 variables are significantly different between the sexes, and three other variables are "close" to significance ($0.10 > P > 0.05$). Descriptive statistics for the T3 examination are listed in Table 5. Several statistical changes occur from T2 to T3—reflecting the biological size and shape changes in the faces of men and women: variables that had not been significantly dimorphic at T2 are dimorphic at T3 (*e.g.*, Alar width, AlL-AlR; Chin height, Li-Me; Lower lip height, St-Me), and for the same degrees of freedom, several variables are "more significant" as the degree of dimporphism increased (*e.g.*, Lower face width, GoL-GoR; Total face height, Ex-Me). These changes occur primarily because of the greater-but-later adolescent growth spurt in boys than girls (*e.g.*, Largo *et al*. 1978) and because of the longer post-adolescent growth in boys (*e.g.*, Bishara *et al.* 1998).

Table 4. Results of testing for sexual dimorphism at the recall (T3) examination.

	Males			Females				
Variable	n	$\bar{x}$	SEM	n	$\bar{x}$	SEM	F Ratio	P Value
ZyL-ZyR	41	2.188	0.019	60	2.141	0.016	3.59	0.0610
ObL-ObR	41	2.143	0.022	0	2.002	0.019	23.23	<0.0001
GoL-GoR	41	2.027	0.024	60	1.891	0.020	18.99	<0.0001
ExL-ExR	41	1.451	0.007	0	1.468	0.006	3.24	0.0750
EnL-EnR	41	0.514	0.006	0	0.527	0.005	2.58	0.1113
AlL-AlR	41	0.588	0.006	60	0.563	0.005	9.42	0.0028
ChL-ChR	41	0.729	0.009	0	0.710	0.008	2.34	0.1295
Ex-Me	41	1.866	0.020	60	1.735	0.016	25.81	<0.0001
Ex-Sn	41	0.674	0.012	60	0.647	0.010	2.95	0.0889
Sn-Me	41	1.192	0.016	60	1.089	0.014	23.50	<0.0001
Sn-St	41	0.390	0.008	60	0.360	0.006	9.17	0.0031
St-Me	41	0.802	0.012	60	0.729	0.010	23.62	<0.0001
Sn-Ls	41	0.318	0.007	60	0.285	0.005	15.02	0.0002
Ls-St	41	0.072	0.003	60	0.075	0.003	0.30	0.5841
St-Li	41	0.131	0.005	60	0.140	0.004	1.65	0.2015
Li-Me	41	0.671	0.011	60	0.589	0.009	31.98	<0.0001

Table 5. Descriptive statistics at the recall examination (T3).

	Sexes Pooled	Males	Females
	Upper face width (ZyL-ZyR)		
Mean	2.16	2.19	2.14
SD	0.12	0.13	0.12
SEM	0.01	0.02	0.02
n	101	41	60
	Midface width (ObL-ObR)		
Mean	2.06	2.14	2.00
SD	0.16	0.17	0.12
SEM	0.02	0.03	0.02
n	101	41	60
	Lower face width (GoL-GoR)		
Mean	1.95	2.03	1.89
SD	0.17	0.18	0.14
SEM	0.02	0.03	0.02
n	101	41	60
	Outer canthus width (ExL-ExR)		
Mean	1.46	1.45	1.47
SD	0.05	0.05	0.05
SEM	0.00	0.01	0.01
n	101	41	60
	Inner canthus width (EnL-EnR)		
Mean	0.52	0.51	0.53
SD	0.04	0.03	0.04
SEM	0.00	0.01	0.01
n	101	41	60
	Alar width (AlL-AlR)		
Mean	0.57	0.59	0.56
SD	0.04	0.04	0.04
SEM	0.00	0.01	0.01
n	101	41	60

Continued

Table 5. *Continued.*

	Sexes Pooled	Males	Females
	Mouth width (ChL-ChR)		
Mean	0.72	0.73	0.71
SD	0.06	0.06	0.06
SEM	0.01	0.01	0.01
n	101	41	60
	Total face height (Ex-Me)		
Mean	1.79	1.87	1.74
SD	0.14	0.14	0.12
SEM	0.01	0.02	0.02
n	101	41	60
	Upper face height (Ex-Sn)		
Mean	0.66	0.67	0.65
SD	0.08	0.07	0.08
SEM	0.01	0.01	0.01
n	101	41	60
	Lower face height (Sn-Me)		
Mean	1.13	1.19	1.09
SD	0.12	0.11	0.10
SEM	0.01	0.02	0.01
n	101	41	60
	Stomion height (Sn-St)		
Mean	0.37	0.39	0.36
SD	0.05	0.05	0.05
SEM	0.01	0.01	0.01
n	101	41	60
	Lower lip height (St-Me)		
Mean	0.76	0.80	0.73
SD	0.08	0.08	0.07
SEM	0.01	0.01	0.01
n	101	41	60

Continued

Table 5. *Continued.*

	Sexes Pooled	Males	Females
	Upper lip height (Sn-ls)		
Mean	0.30	0.32	0.28
SD	0.04	0.04	0.04
SEM	0.00	0.01	0.01
n	101	41	60
	Upper lip exposure (Ls-St)		
Mean	0.07	0.07	0.07
SD	0.02	0.02	0.02
SEM	0.00	0.00	0.00
n	101	41	60
	Lower lip exposure (St-Li)		
Mean	0.14	0.13	0.14
SD	0.03	0.03	0.03
SEM	0.00	0.01	0.00
n	101	41	60
	Chin height (Li-Me)		
Mean	0.62	0.67	0.59
SD	0.08	0.07	0.07
SEM	0.01	0.01	0.01
n	101	41	60

Changes with Growth

Descriptive changes are listed in Table 6, and the mean T3-minus-T2 changes are graphed in Figure 26. This graph discloses the substantially larger changes in males for several of the variables, notably Midface width (bi-Otobasion) and Lower face width (bi-Gonion).

Table 7 lists the results of sex-specific one-sample t-tests. The purpose here was to assess whether the T2-to-T3 changes were systematic (*i.e.*, changed significantly between the two examinations) or, alternatively, the observed T2 versus T3 differences were likely attributable to chance. As described below, there were substantial differences in the amounts of change—both among variables and between the sexes. By adulthood (T3), facial physiognomy (as well as sexual dimorphism) changed appreciably vis-à-vis the situation at adolescence. This early aging process involves more and greater changes in men than woman.

Upper face width increased significantly in men ($\bar{x}_d = 0.05$) but not in women ($\bar{x}_d = 0.01$). We suppose that this increase involves the combined effects of some increase in the bony elements of the midface via surface apposition (*e.g.*, Isreal 1977) but primarily increases in muscle mass and the deposition of subcutaneous fat.

Midface width was measured here as the distance between left and right Otobasion, the intersection of the ear's tragus with the cheek when viewing the

Table 6. Descriptive statistics for posttreatment changes (T3-T2).

	Sexes Pooled	Males	Females
	Upper face width (ZyL-ZyR)		
Mean	0.027	0.055	0.009
SD	0.098	0.105	0.089
SEM	0.010	0.016	0.011
n	101	41	60
	Midface width (ObL-ObR)		
Mean	0.062	0.122	0.021
SD	0.120	0.125	0.098
SEM	0.012	0.020	0.013
n	101	41	60
	Lower face width (GoL-GoR)		
Mean	0.116	0.180	0.072
SD	0.146	0.156	0.121
SEM	0.014	0.024	0.016
n	101	41	60
	Outer canthus width (ExL-ExR)		
Mean	-0.013	-0.021	-0.008
SD	0.045	0.046	0.044
SEM	0.004	0.007	0.006
n	101	41	60
	Inner canthus width (EnL-EnR)		
Mean	-0.007	-0.010	-0.006
SD	0.027	0.026	0.028
SEM	0.003	0.004	0.004
n	101	41	60
	Alar width (AlL-AlR)		
Mean	0.000	0.004	-0.002
SD	0.027	0.028	0.026
SEM	0.003	0.004	0.003
n	101	41	60

Continued

Table 6. *Continued*.

	Sexes Pooled	Males	Females
	Mouth width (ChL-ChR)		
Mean	0.025	0.017	0.031
SD	0.059	0.061	0.058
SEM	0.006	0.009	0.007
n	101	41	60
	Total face height (Ex-Me)		
Mean	0.012	0.047	-0.011
SD	0.079	0.090	0.059
SEM	0.008	0.014	0.008
n	101	41	60
	Upper face height (Ex-Sn)		
Mean	-0.017	-0.010	-0.022
SD	0.065	0.069	0.062
SEM	0.006	0.011	0.008
n	101	41	60
	Lower face height (Sn-Me)		
Mean	0.030	0.057	0.011
SD	0.082	0.094	0.069
SEM	0.008	0.015	0.009
n	101	41	60
	Stomion height (Sn-St)		
Mean	0.008	0.006	0.010
SD	0.037	0.038	0.036
SEM	0.004	0.006	0.005
n	101	41	60
	Lower lip height (St-Me)		
Mean	0.021	0.051	0.001
SD	0.067	0.075	0.052
SEM	0.007	0.012	0.007
n	101	41	60

Continued

Table 6. *Continued.*

	Sexes Pooled	Males	Females
	Upper lip height (Sn-Ls)		
Mean	0.015	0.015	0.015
SD	0.032	0.031	0.033
SEM	0.003	0.005	0.004
n	101	41	60
	Upper lip exposure (Ls-St)		
Mean	-0.006	-0.010	-0.004
SD	0.022	0.027	0.017
SEM	0.002	0.004	0.002
n	101	41	60
	Lower lip exposure (St-Li)		
Mean	-0.024	-0.030	-0.019
SD	0.031	0.029	0.031
SEM	0.003	0.005	0.004
n	101	41	60
	Chin height (Li-Me)		
Mean	0.045	0.082	0.020
SD	0.075	0.080	0.060
SEM	0.007	0.013	0.008
n	101	41	60

Table 7. Results of one-sample t-tests assessing whether the posttreatment changes were statistically significant.

Statistic	Sexes Pooled	Males	Females
	Total face height (ZyL-ZyR)		
Mean	0.027	0.055	0.009
SD	0.098	0.105	0.089
n	101	41	60
t-test	2.82	3.36	0.75
P Value	0.0058	0.0017	0.4547
	Midface width (ObL-ObR)		
Mean	0.062	0.122	0.021
SD	0.120	0.125	0.098
n	101	41	60
t-test	5.20	6.26	1.67
P Value	<0.0001	<0.0001	0.0997
	Lower face width (GoL-GoR)		
Mean	0.116	0.180	0.072
SD	0.146	0.156	0.121
n	101	41	60
t-test	7.99	7.41	4.59
P Value	<0.0001	<0.0001	<0.0001
	Outer canthus width (ExL-ExR)		
Mean	-0.013	-0.021	-0.008
SD	0.045	0.046	0.044
n	101	41	60
t-test	-2.94	-2.87	-1.41
P Value	0.0041	0.0065	0.1635

Continued

Table 7. *Continued.*

Statistic	Sexes Pooled	Males	Females
	Inner canthus width (EnL-EnR)		
Mean	-0.007	-0.010	-0.006
SD	0.027	0.026	0.028
n	101	41	60
t-test	-2.80	-2.37	-1.70
P Value	0.0061	0.0228	0.0941
	Alar width (AlL-AlR)		
Mean	0.000	0.004	-0.002
SD	0.027	0.028	0.026
n	101	41	60
t-test	0.18	0.92	-0.58
P Value	0.8585	0.3625	0.5646
	Mouth width (ChL-ChR)		
Mean	0.025	0.017	0.031
SD	0.059	0.061	0.058
n	101	41	60
t-test	4.3264	1.8433	4.1393
P Value	<0.0001	0.0727	0.0001
	Total face height (Ex-Me)		
Mean	0.012	0.047	-0.011
SD	0.079	0.090	0.059
n	101	41	60
t-test	1.60	3.32	-1.44
P Value	0.1132	0.0019	0.1548
	Upper face height (Ex-Sn)		
Mean	-0.017	-0.010	-0.022
SD	0.065	0.069	0.062
n	101	41	60
t-test	-2.68	-0.95	-2.76
P Value	0.0086	0.3473	0.0077

Continued

Table 7. *Continued.*

Statistic	Sexes Pooled	Males	Females
	Lower face height (Sn-Me)		
Mean	0.030	0.057	0.011
SD	0.082	0.094	0.069
n	101	41	60
t-test	3.64	3.91	1.26
P Value	0.0004	0.0003	0.2131
	Stomion height (Sn-St)		
Mean	0.008	0.006	0.010
SD	0.037	0.038	0.036
n	101	41	60
t-test	2.32	0.97	2.21
P Value	0.0225	0.3356	0.0308
	Lower lip height (St-Me)		
Mean	0.021	0.051	0.001
SD	0.067	0.075	0.052
n	101	41	60
t-test	3.20	4.37	0.12
P Value	0.0018	<0.0001	0.9059
	Upper lip height (Sn-Ls)		
Mean	0.015	0.015	0.015
SD	0.032	0.031	0.033
n	101	41	60
t-test	4.68	3.13	3.46
P Value	<0.0001	0.0033	0.001
	Upper lip exposure (Ls-St)		
Mean	-0.006	-0.010	-0.004
SD	0.022	0.027	0.017
n	101	41	60
t-test	-2.96	-2.29	-1.89
P Value	0.0038	0.0277	0.0638

Continued

Table 7. *Continued*.

Statistic	Sexes Pooled	Males	Females
	Lower lip exposure (St-Li)		
Mean	-0.024	-0.030	-0.019
SD	0.031	0.029	0.031
n	101	41	60
t-test	-7.73	-6.73	-4.71
P Value	<0.0001	<0.0001	<0.0001
	Chin height (Li-Me)		
Mean	0.045	0.082	0.020
SD	0.075	0.080	0.060
n	101	41	60
t-test	6.01	6.53	2.55
P Value	<0.0001	<0.0001	0.0133

face frontally (Farkas 1994). As with Lower face width described above, the increases in Midface width probably reflects primarily the deposition of muscle mass and subcutaneous fat with age. The increase was substantially larger in men (12%) compared to women (2%).

Lower face width was of interest because this dimension changed more in both sexes than any of the 15 other dimensions studied. There was, on the average, an 18% increase in this width in men and a 7% increase in women. Both of these increases are highly significant statistically ($P < 0.0001$), but the increase was more than twice as great in men *relative* to IPW (which is itself greater in men than women). The effect of these considerable increases in facial width in men (bi-Gonial and bi-Otobasion) was to round-out the face, increasing its width-to-height ratio.

Outer canthus width (ExL to ExR) *decreased* with age, probably in parallel—but to greater extents—with Inner canthus width, EnL-EnR (Figure 26). As with Inner canthus width, males exhibited a significantly greater decrease than females. Mean change was 2% relative to IPW in males ($P < 0.01$) but just 1% in females ($P = 0.16$). We assume that this horizontal decrease actually reflects an oblique (downward-and-medial) "sagging" of the outer canthus with age.

Inner canthus width (EnL to EnR) *decreased* significantly in men ($\bar{x}_d = -0.01$; $P = 0.02$) but the reduction was comparable but nonsignificant in women ($\bar{x}_d$ = -0.01; P = 0.09) because of greater inter-individual variation. We attribute this small decrease to the progressive "drooping" of the eyelids with age (*e.g.*, Ferrario *et al.* 2001).

Alar width (bi-Alare) did not change systematically in either sex. At the T2 and at the T3 examination, Alar width averaged 57% of IPW (with no sexual dimorphism).

Mouth width (ChL-ChR) increased with age in both sexes relative to IPW, but relatively more so in women ($\bar{x}_d$ = 0.03) than men ($\bar{x}_d$ = 0.02). Indeed, the smaller mean change in men, in combination with greater inter-individual variability, caused the change in males to be nonsignificant (P = 0.07) at the conventional level of alpha. The increases in mouth width occurs in combination with the lowering of Stomion (*e.g.*, Forsberg 1979) and results from the age-progressive decrease in muscle tone, here of the perioral muscles of facial expression.

Total face height was the summary of the craniocaudal distance from Exocanthion down to Menton. The two sexes grew quite differently with respect to this dimension. There was a substantial (5%; P = 0.002) *increase* in Total face height in males. Females, in contrast, exhibited no systematic change ($\bar{x}_d$ = 1%; P = 0.15). This increase of 5% in males may be attributable to the increase in soft tissue at Menton. The reason for the absence of an increase in females is not apparent, other than the obvious inference that they experienced less weight gain than men.

Upper face height is the craniocaudal distance from Exocanthion down to Subnasale. This is, in effect, height of the nose, excluding just the nose's cranial root. In these data, nose height *diminished* in each sex, but more so in females; the change was just 1% of IPW in men ($P = 0.35$) but 2% of IPW in women ($P = 0.01$). This may not reflect an actual shortening of the nose height, but rather a drooping of the outer canthus. This in turn may have made nose height decrease when the change could be attributed to a change in the references used to make the measurements.

Lower face height was measured as the craniocaudal distance from Subnasale down to Menton. Both sexes exhibited an increase in this vertical distance over time, but the change was trivial in women ($\bar{x}_d = 1\%$; $P = 0.21$) whereas it was much greater in men ($\bar{x}_d = 6\%$; $P < 0.001$). Again, we attribute the majority of this change to the vertical increase in the soft tissue chin region, over Menton.

Upper lip height (Sn to Ls) increased significantly with age in both sexes (Figure 26). This was in concert with prior observations (*e.g.*, Bishara *et al.* 1995) that the age-progressive decrease in muscle tone and in tautness of the integument causes the lip line to descend so that, with aging, more of the lower incisors (and less of the upper incisors) are exposed during oral functions like speaking and smiling (Dong *et al.* 1999).

Upper lip exposure was the craniocaudal height of the vermilion border (from Ls to St) with the person at repose. This was one of the smaller variables measured, but there was statistical confirmation in both sexes that this dimension thins with age. The decrease was only about 1% of IPW—one would not expect marked changes in this small dimension—and, statistically, the decreases hover on either side of alpha, being $P = 0.03$ in males and $P = 0.06$ in females. The orthodontic literature makes it clear that lip protrusion is tied to support of the underlying incisors (*e.g.*, Behrents 1985, 1986). Behrents found that the maxillary incisors upright with age, which would be in concert with the decrease in eversion of the vermilion border documented here.

Comparably, Lower lip exposure (St to Li) also diminished with age—actually to a greater extent than changes in the Upper lip exposure. The vermilion in males decreased 3% of IPW in men ($P < 0.001$) and decreased 2% in women ($P = 0.01$). Likewise, the decrease in lip support by the incisors may be important here.

Chin height was measured as the craniocaudal distance from Labrale inferius down to Menton, so it was largely composed of the lower lip—but also the soft tissue mass between the bony chin and the soft tissue landmark, Menton. This dimension increased to highly significant extents in both sexes

(P < 0.01), but considerably more in men ($\bar{x}_d$ = 0.08) than women ($\bar{x}_d$ = 0.02). Given the modest change in upper lip length (Sn-St), we ascribe most of the change seen here between Li and Menton to the addition of soft-tissue bulk beneath the bony chin. This claim is supported by prior cephalometric studies of these same cases (Bradshaw 2002), where the vertical distance from skeletal Menton to soft tissue Menton increased substantially and more so in males, between T2 and T3.

Sex Differences Controlled for Duration

Prior sections of this chapter tested for sexual dimorphism using group comparison t-tests (Sokal and Rohlf 1995). There was, however, an obvious covariate that is not taken into account in such tests, namely the time relative to treatment. That is, while we truncated the T2-to-T3 duration at a minimum of 10 years, this still leaves a good deal of variation. One might suppose that the longer the duration between T2 and T3, the older the person would be at T3 *and* the more growth (aging) would have occurred.

Table 8 presents the results of testing for sexual dimorphism in the amount of change between the T2 and T3 examinations, using the duration of time between examinations (T2 to T3) as the covariate. The design also tested for any sex-by-duration interaction.

Table 8. Results of ANCOVA tests assessing whether duration from T2 to T3 affects the amount of change in facial dimensions.

Variable: Upper face width (ZyL-ZyR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0093	1.01	0.3177
Sex	1	0.0526	5.73	0.0186
Sex-x-Duration	1	0.0008	0.09	0.7667

Variable: Midface width (ObL-ObR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0556	4.72	0.0323
Sex	1	0.2526	21.44	<.0001
Sex-x-Duration	1	0.0063	0.53	0.4678

Variable: Lower face width (GoL-GoR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0491	2.68	0.1048
Sex	1	0.2895	15.81	0.0001
Sex-x-Duration	1	0.0203	1.11	0.2951

Variable: Outer canthus width (ExL-ExR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0033	1.77	0.1865
Sex	1	0.0040	2.17	0.1443
Sex-x-Duration	1	0.0123	6.62	0.0116

Continued

Table 8. *Continued.*

Variable: Inner canthus width (EnL-EnR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0003	0.46	0.4975
Sex	1	0.0003	0.42	0.5191
Sex-x-Duration	1	0.0006	0.87	0.3545

Variable: Alar width (AlL-AlR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0004	0.54	0.4655
Sex	1	0.0009	1.21	0.2745
Sex-x-Duration	1	0.0000	0.00	0.9803

Variable: Mouth width (ChL-ChR)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0013	0.36	0.5498
Sex	1	0.0042	1.20	0.2756
Sex-x-Duration	1	0.0000	0.00	0.9944

Variable: Total face height (Ex-Me)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0050	0.92	0.3406
Sex	1	0.0816	14.97	0.0002
Sex-x-Duration	1	0.0012	0.22	0.6379

Continued

Table 8. *Continued.*

Variable: Upper face height (Ex-Sn)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0004	0.09	0.7615
Sex	1	0.0034	0.79	0.3754
Sex-x-Duration	1	0.0004	0.08	0.7730

Variable: Lower face height (Sn-Me)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0026	0.40	0.5283
Sex	1	0.0515	8.04	0.0056
Sex-x-Duration	1	0.0029	0.45	0.5027

Variable: Stomion height (Sn-St)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0000	0.01	0.9343
Sex	1	0.0005	0.36	0.5473
Sex-x-Duration	1	0.0006	0.41	0.5226

Variable: Lower lip height (St-Me)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0029	0.73	0.3947
Sex	1	0.0623	15.75	0.0001
Sex-x-Duration	1	0.0009	0.23	0.6342

Continued

Table 8. *Continued.*

Variable: Upper lip height (Sn-Ls)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0007	0.67	0.4167
Sex	1	0.0000	0.02	0.8988
Sex-x-Duration	1	0.0028	2.76	0.0998

Variable: Upper lip exposure (Ls-St)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0005	1.14	0.2892
Sex	1	0.0007	1.52	0.2205
Sex-x-Duration	1	0.0008	1.83	0.1793

Variable: Lower lip exposure (St-Li)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0044	4.94	0.0286
Sex	1	0.0031	3.50	0.0644
Sex-x-Duration	1	0.0001	0.17	0.6835

Variable: Chin height (Li-Me)

Source	df	Sum of Squares	F Ratio	P Value
Duration (T3-T2)	1	0.0002	0.03	0.8569
Sex	1	0.0933	19.15	<.0001
Sex-x-Duration	1	0.0003	0.07	0.7993

Specifically, these tests assessed whether the amount of change from T2 to T3 was statistically equivalent in men and women. Fully half of the 16 variables did, in fact, exhibit significant sex differences. There were eight statistically significant variables:

1. Upper face width
2. Midface width
3. Alar width
4. Total face height
5. Lower face height
6. Lower lip height
7. Lower lip exposure
8. Chin height

Most of these sex differences were achieved in the “conventional” way, where there was substantially more growth in males than females. This pattern holds for Upper face width, Midface width (bi-Otobasion), Lower face width, Total face height (Ex to Me), Chin height (Li to Me), and Lower lip exposure (St to Li). Lower lip exposure achieved significance because the distance got smaller in both sexes, but significantly more so in men (Figure 26).

Of equal interest in these ANCOVA tests was where the covariate was statistically significant. There were two such instances among the 16 tests (Table 8), namely Midface width (bi-Otobasion).

Figure 27 discloses a significant positive association between the time out of treatment (*i.e.*, T3-T2), which was tied to the person's age, and Midface width (bi-Otobasion). In other words, the older the person (and, thus, the longer the duration from T2 to T3), the broader the face; the face broadened significantly between the ages of about 15 and 30, presumably because of increases in the integumental tissues.

The other significant covariate found in Table 8 was the Lower lip exposure, St-Li (Figure 28). It was found earlier that this distance (the amount of exposure of the vermilion of the lower lip) decreased from T2 to T3. Here we see that it was an ongoing dynamic process that persists at least through the age interval of 15 to 30 and perhaps longer. One assumes from prior studies (*e.g.,* Bishara *et al.* 1998) that this decrease was due to the age-progressive uprighting of the lower lips that was secondary to loss of incisor support as these teeth upright with age (Behrents 1985).

The other noteworthy finding from the ANCOVA tests in Table 8 was the significant sex-by-duration interaction for Outer canthus width (bi-Exocanthion breadth). The nature of the interaction is shown in Figure 29, where we see that the least-squares regression line for men was slightly (not significantly) upward-trending with age. In contrast, the regression line for women was significantly negative, meaning that, in this span of around 15 to 30 years of age, Outer canthus width progressively decreases. These differences in maturation

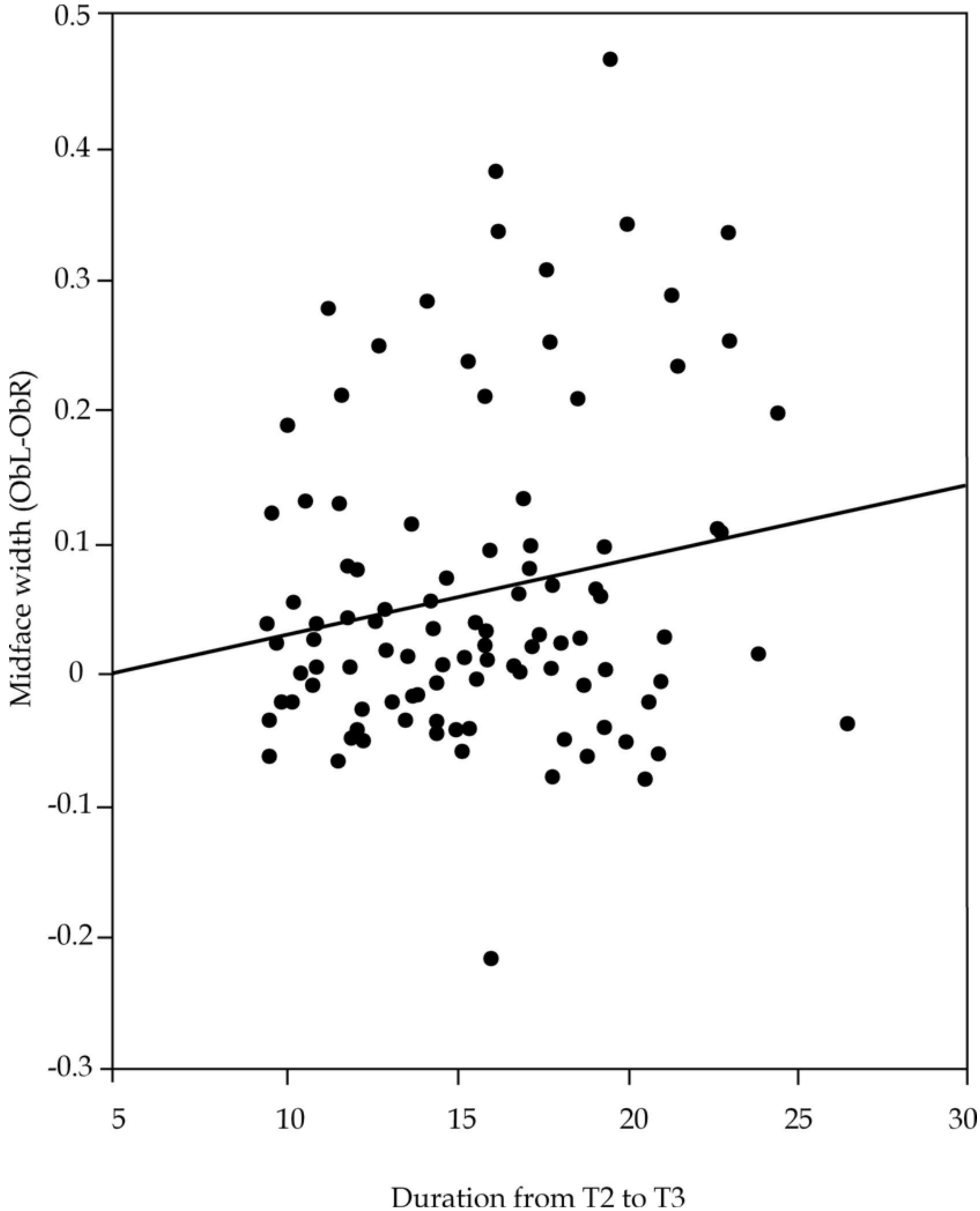


Figure 27. Scattergram between duration from T2 to T3 (X-axis) and the amount of change in Midface width (ObL-ObR).

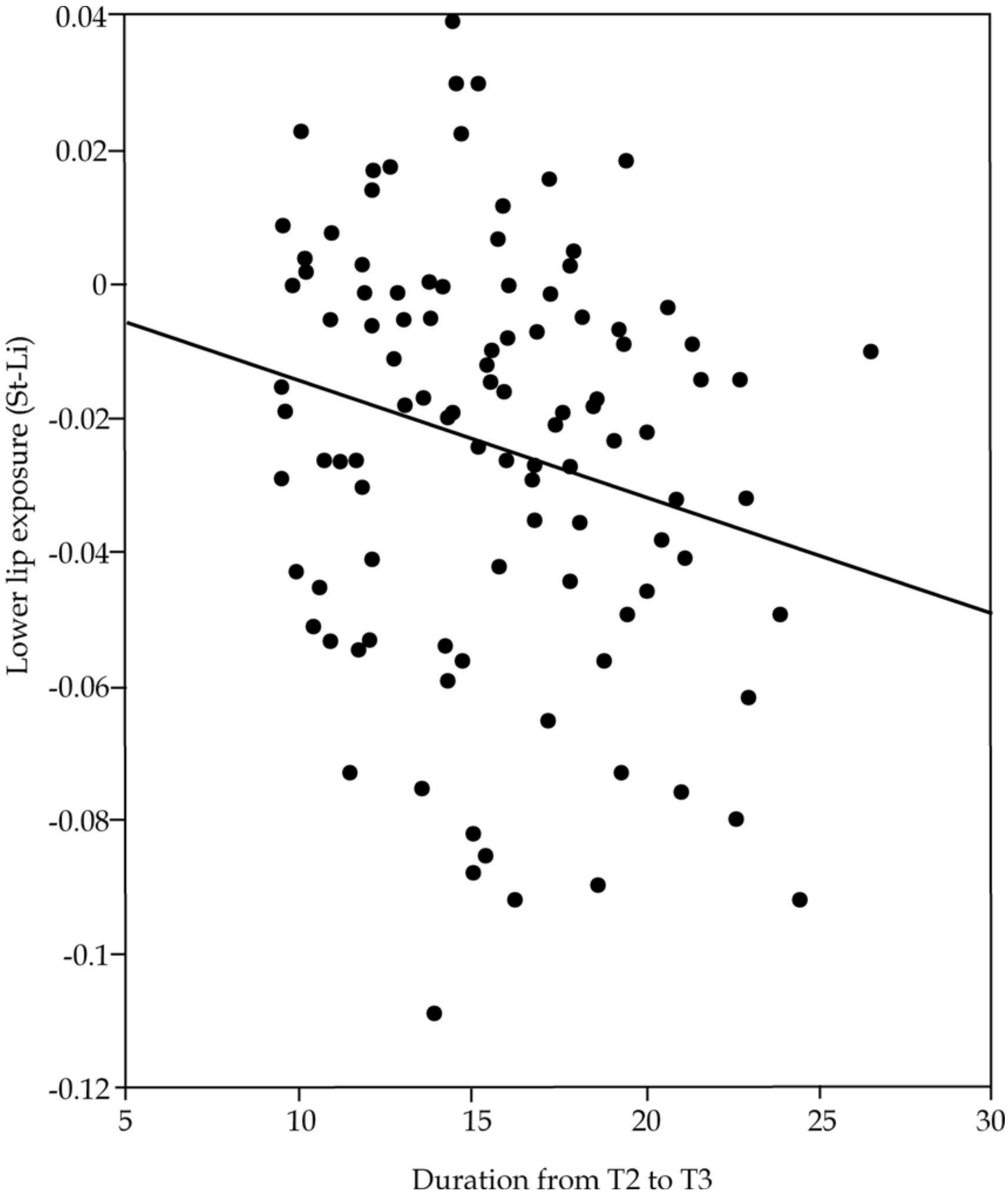


Figure 28. Scattergram between duration from T2 to T3 (X-axis) and the amount of change in Lower lip exposure (St-Li).

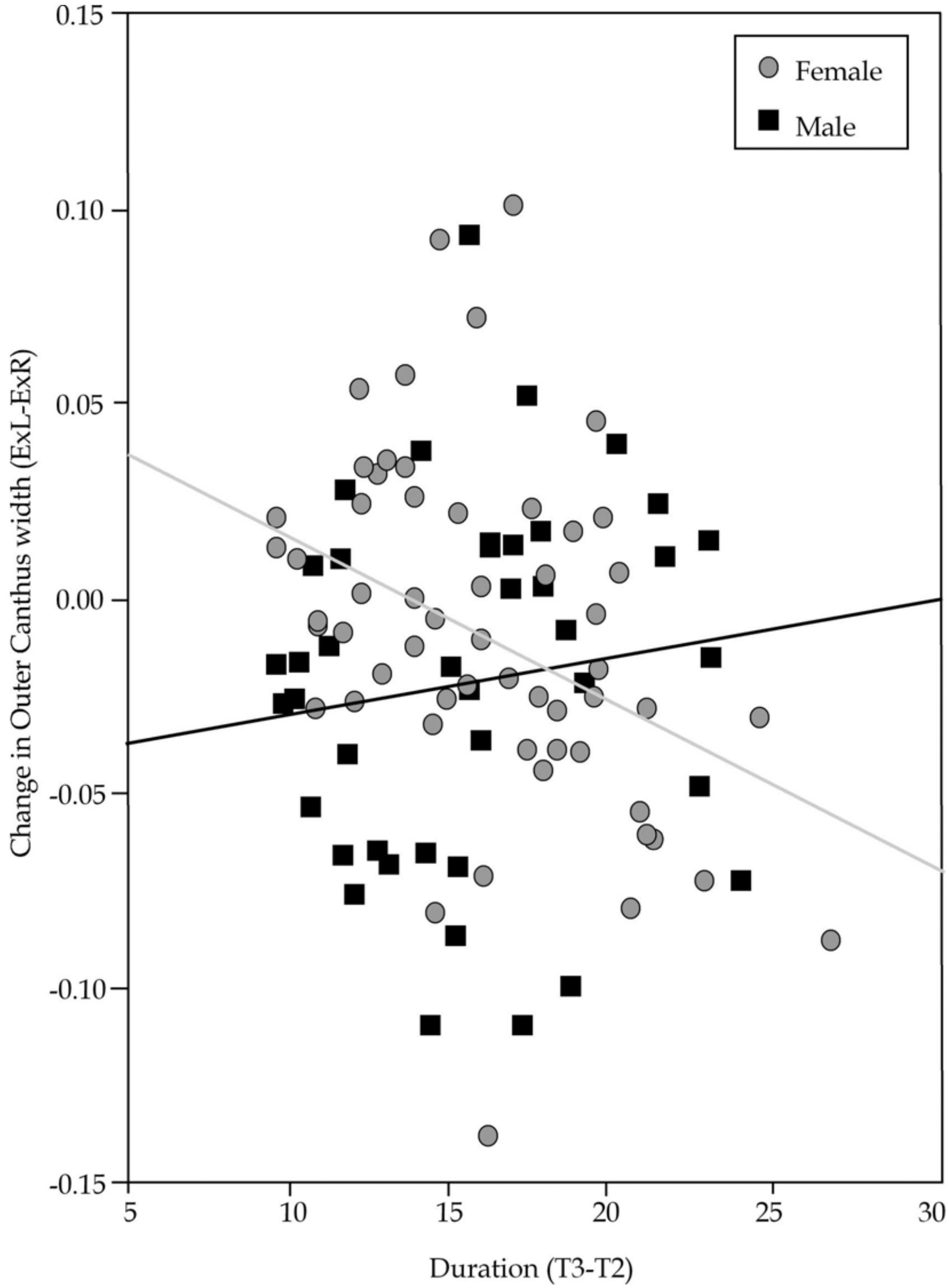


Figure 29. Scatterplot, by sex, between duration of time from T2 and T3 on the X-axis and the corresponding change in Outer canthus width (ExL-ExR).

between the sexes—no effective change with age in men but a significant decrease in women—produces the significant interaction effect for this variable.

CHAPTER V

DISCUSSION

The availability of the frontal facial photographs from the Charles H. Tweed collection provided us with the uncommon opportunity to longitudinally monitor the soft tissue changes that take place from late adolescence to adulthood, at about 30 years of age. In the present study, frontal facial photographs of 101 orthodontic patients were assessed to determine the changes that occurred from adolescence to adulthood. Photographs had been taken at the end of orthodontic treatment and at a long-term recall examination, a minimum of 10 years following the end of the active phase of treatment. The photographs were obtained from the orthodontic records collected by the Charles H. Tweed Foundation from several private practices. The objectives of the present study were to quantify the effects of growth on facial dimensions and to determine the extent of sexual dimorphism involving growth of the face in frontal view from a posttreatment examination to a long-term examination.

There was no metric scale in the photographs, so it was not possible to provide millimetric dimensions of the variables measured. Instead the facial dimensions were presented as a ratio of the person's interpupillary width (IPW). Based on previous studies (*e.g.*, Pryor 1969; Fledelius and Stubgaard 1986;

Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003), IPW stabilizes after mid-adolescence. In the present study, IPW was given a nominal value of 1, and each facial dimension was expressed in relation to IPW. Assuming that IPW is a 66.9 mm in men of western European descent and 62.6 mm in women (Farkas 1994), calculations were made to estimate the facial distances (in millimeters) at posttreatment (Table 9), at the long-term recall examination (Table 10), and the changes between the examinations (Table 11).

According to Bartlett *et al*. (1992), most previous studies concerning facial growth and development have involved either age-related changes in the maturing craniofacial skeleton of the child and adolescent or isolated studies of elderly aged samples. Analyses of post-maturational changes during early adulthood are scarce (Farkas 1994; Farkas and Hreczko 1994).

During the present interval (about 15 to 30 years), significant increases in Midface width (ObL-ObR), Lower face width (GoL-GoR), and Mouth width (ChL-ChR) were noted in both sexes. Lower face height (Sn-Me) and Chin height (Li-Me) were also found to increase with age. Additional findings included decreases in Outer canthus width (ExL-ExR), Inner canthus width (EnL-EnR), Upper lip exposure (Ls-St), and Lower lip exposure (St-Li). The changes in the transverse and craniocaudal dimensions were sexually dimorphic with males displaying larger overall differences in each measured variable. The

Table 9. Calculated mean distances (mm) based on the assumption that interpupillary width (IPW) is 66.9 mm in males and 62.6 mm in females at the adolescent examination.

Variable	Males	Females
ZyL-ZyR	142.8	133.5
ObL-ObR	135.1	124.0
GoL-GoR	123.6	113.9
ExL-ExR	98.5	92.4
EnL-EnR	35.1	33.4
AlL-AlR	39.1	35.4
ChL-ChR	47.6	42.5
Ex-Me	121.7	109.3
Ex-Sn	45.8	41.9
Sn-Me	75.9	67.5
Sn-St	25.7	21.8
St-Me	50.2	45.6
Sn-Ls	20.2	16.9
Ls-St	5.5	4.9
St-Li	10.8	10.0
Li-Me	39.4	35.6

Table 10. Calculated mean distances (mm) based on the assumption that interpupillary width (IPW) is 66.9 mm in males and 62.6 mm in females at the adult examination.

Variable	Males	Females
ZyL-ZyR	146.4	134.0
ObL-ObR	143.4	125.3
GoL-GoR	135.6	118.4
ExL-ExR	97.1	91.9
EnL-EnR	34.4	33.0
AlL-AlR	39.3	35.2
ChL-ChR	48.8	44.4
Ex-Me	124.8	108.6
Ex-Sn	45.1	40.5
Sn-Me	79.7	68.2
Sn-St	26.1	22.5
St-Me	53.7	45.6
Sn-Ls	21.3	17.8
Ls-St	4.8	4.7
St-Li	8.8	8.8
Li-Me	44.9	36.9

Table 11. Calculated mean changes (mm) from adolescence to adulthood based on the assumption that interpupillary width (IPW) is 66.9 mm in males and 62.6 mm in females.

Variable	Males	Females
ZyL-ZyR	3.6	0.5
ObL-ObR	8.3	1.3
GoL-GoR	12.0	4.5
ExL-ExR	-1.4	-0.5
EnL-EnR	-0.7	-0.4
AlL-AlR	0.2	-0.2
ChL-ChR	1.2	1.9
Ex-Me	3.1	-0.7
Ex-Sn	-0.7	-1.4
Sn-Me	3.8	0.7
Sn-St	0.4	0.7
St-Me	3.5	0
Sn-Ls	1.1	0.9
Ls-St	-0.7	-0.2
St-Li	-0.2	-1.2
Li-Me	5.5	1.3

largest changes were found to be in Midface width and Lower face width. The Lower face width significantly increased, more so than any other dimension, over the observation period. As a result of this change, the face became wider in the transverse dimension and, to a lesser degree, longer in the vertical dimension.

Changes with Growth

Changes in Transverse Distances

According to Bishara *et al*. (1995), the Upper face width (ZyL-ZyR) increases by approximately 9% during the 9-year period from 4 to 13 years of age. In the present study (between 15 and 30 years of age), Upper face width exhibited a 5% increase in males. Although women displayed increases in Upper face width (1%), the changes were not significant. The absence of significant changes of Upper face width in women in the present study contrasts the work of Pessa (2001). Pessa suggested that continued differential growth of the maxilla occur well into adulthood based on small (n = 10) cross-sectional samples taken at roughly 20 and roughly 60 years of age. He found that the increase in upper facial width measured between the lateral orbital rims for women was significant. Bishara *et al.* (2004) found that between 21 and 40 years of age, the Upper face width (bi-Zygion) increased significantly in both sexes on both the skin and bony surfaces.

Because Midface width (ObL-ObR) and Lower face width (GoL-GoR) measure a similar transverse dimension, it is appropriate to discuss them together. Previous studies (*e.g.*, Farkas *et al.*, 2004*)* on facial anthopometry seem to prefer the Lower face width (bi-Gonion) as the measure of choice for this region of the face. In the present study, the increase of the Lower face width is of particular interest because this distance changed more in both sexes than any of the other 15 dimensions studied. There was, on average an 18% increase in this width in men and a 7% increase in women. Raadsheer *et al. (*1996) proposed an explanation for this increase in Lower facial width. They measured masseter muscle thickness using ultrasonography. In 329 Greek individuals, aged 7 to 22 years, the masseter muscle thickness was found to increase with age in both sexes. The size of the masseter muscle coincided with increased stature and *weight gain*. Farkas *et al. (*2004) observed that even in late adulthood (between 71 and 90 years), the lower jaws showed a transverse change, increasing on both the skin and bony surface.

An investigation by Israel (1973) revealed that bone deposition at the gonial angles of the mandible might be responsible for at least part of the change in Lower face width (GoL-GoR). Israel studied dried mandibles of white males from the Terry skeletal collection and T. W. Todd collection. Israel found continued expansion and apposition of bone in the adult mandible with advancing age. The effect of the considerable increases in the Midface width and Lower face widths (bi-Gonial and bi-Otobasion) in the present study, especially in men, was to round-out the face, increasing its width-to-height ratio (Bartlett *et al*. 1992).

In the present study, the Inner canthus width (EnL-EnR) and Outer canthus width (ExL-ExR) decreased. We attribute the decrease of the Inner canthus width to the progressive "drooping" of the eyelids with age (*e.g*., Ferrario *et al.* 2001). We assume that this horizontal decrease in the Outer canthus width actually reflects an oblique (downward-and-medial) "sagging" of the outer canthus with age. Ferrario *et al.* (2001) found a significant effect of age on the inclination of the eyes. Their study confirmed the downward-and-medial movements of the outer canthi.

In the present study, Alar width (bi-Alare) did not change systematically in either sex. This finding is different from previous studies (*e.g.,* Snodell *et al*. 1993; Bishara *et al*. 1995), but these studies were performed on younger subjects. Bishara *et al*. (1995) found that the width of the nose increased 18% between the ages of 4 and 13 years. Snodell *et al*. (1993) assessed growth changes in a serial study from posteroanterior cephalometric radiographs on males from 4 to 25 years of age and females from 4 to 20 years of age. The increase in skeletal Alar width was more than any other transverse measurement in that study. Alar width increased 25% for females and 33% for males between 6 to 18 years. However, Snodell and colleagues study that found Alar width was stable by age 17 in females. Minimal changes in Alar width occurred in males after 18 years of age. Ricketts *et al.* (1982) found skeletal Alar width (bi-Alare) to have a mean of 25 mm from the 9-year-old subjects, increasing 0.7 mm per year until about 20 years of age in both sexes. The present study measured facial changes after the onset of adolescence. Given that Alar width did not change in the present study, it may be inferred from previous studies (*e.g.*, Ricketts *et al.* 1982; Snodell *et al.* 1993) that bi-Alare width stops increasing in early adulthood.

The present study disclosed that Mouth width (ChL-ChR) increased with age in both sexes relative to interpupillary width (IPW), but slightly more so in women (3%) than men (2%). Based on a mixed longitudinal and a cross-sectional study, Ferrario *et al.* (2000) concluded that from the age of 15 years to adulthood the width of the mouth increased from 53.1 mm to 55.6 mm for males and from 50.6 mm to 50.9 mm in women. Assuming that IPW is a 66.9 mm in men of western European descent and 62.6 mm in women (Farkas 1994), the present sample would have shown an increase from 47.5 mm to 48.8 mm for men, and from 42.6 mm to 44.4 mm for women (Table 11). In the present study, mouth width was narrower at each examination (Table 9-11) compared to the study by Ferrario and colleagues; however, the magnitude of change between the two studies is similar.

Changes in Craniocaudal Distances

In the present study, Total face height is the craniocaudal distance from the Exocanthion down to Menton (Figure 23). The two sexes grew differently with respect to this dimension. There was a substantial (5%; P = 0.002) *increase* in face height in males. In contrast, females exhibited no systematic change ($\bar{x}_d$ = 1%; P = 0.15). The findings in the present study are different than what Bishara *et al*. (1995) saw in a younger sample. Bishara *et al*. (1995) observed that Total face height (Ex-Me) increased by approximately 18% during the 9-year period of study between 4 and 13 years of age. Upper face width (ZyL-ZyR), which changed more than the Lower face width (GoL-GoR) in Bishara's (1995) sample, increased less than half the amount recorded for Total face height. Other authors have recognized that vertical growth of the face occurs at a greater rate during this time of development (4 to 13 years) than does horizontal growth (Meredith 1960; Bishara *et al*. 1995). Behrents (1985) also found that adults continued to grow more in vertical dimension than transverse dimensions, causing a disproportionate increase in facial height. This was not the case in the present study, where the largest changes were actually in the transverse dimension. Lower facial width (bi-Gonion) changed more dramatically than any other measurement in the present study (between 15 and 30 years of age). The increases in facial width exceeded craniocaudal development. In the present study, Total face height increased by 5% in males and did not change in females, and Lower face width increased by 18% in males and 7% in females. The findings in the present study are opposite of previous findings (*e.g.*, Meredith 1960; Bishara *et al*. 1995) in younger samples. The findings in the present study suggest that the facial changes from adolescence to adulthood (greater transverse changes) tend to round out the face; whereas, the facial changes in younger individuals (before 15 years of age) tend to elongate the face.

Forsberg (1979) concluded that a major part of changes of the bony profile were due to a downward-backward rotation of the mandible and subsequent adjustment of the upper incisors. This downward-backward rotation of the mandible suggests that Lower facial height (Sn-Me) and Chin height (Li-Me) should increase. Indeed, increases in Lower face height and Chin height were documented in the present study. We ascribe the changes in Lower face height and especially Chin height to soft-tissue growth surrounding the bony chin. According to Bradshaw (2002), the vertical distance from skeletal Menton to soft tissue Menton increases substantially with age, and more so in males.

Changes in the dimensions of the mouth are of interest to orthodontists, because treatment decisions made when patients are adolescents may either positively or negatively impact mouth proportionally as an adult. Upper lip height (Sn-Ls) increased significantly with age in both sexes. Again, assuming that interpupillary width (IPW) is 66.9 mm in men of western European descent and 62.6 mm in women (Farkas 1994), the distances in the present sample

(Table 11) would be an increase in Upper lip height of 1.3 mm in men and 0.6 mm in women. Ferrario *et al*. (2000) found that Upper lip height increased 0.05 mm in men and 0.08 mm in women between the ages of 15 years and adulthood. The smaller changes found by Ferrario *et al*. (2000) may be attributed to the age of their adult sample. Their adult sample had a younger average age (21 years) than the adult sample (30 years of age) in the present study. It may be assumed that if Ferrario's sample was observed past 30 years of age, the continued decrease in Upper lip height may have been similar to that of the present study. The changes in Upper lip height in the present study are in concert with prior observations (*e.g*., Bishara *et al.* 1995) that the age-progressive decrease in muscle tone and in tautness of the integument causes the lip line to descend so that, with advancing age, more of the lower incisors (and less of the upper incisors) are exposed during oral functions like speaking and smiling (Dong *et al.* 1999).

In the present study, Upper lip exposure (Ls-St) and Lower lip exposure (St-Li) decreased in males and females with advancing age. According to Behrents (1985, 1986), upper lip protrusion is associated with support of the underlying incisors. Behrents found that the maxillary incisors upright with age, leading to upper lip uprighting, which could decrease Upper lip exposure.

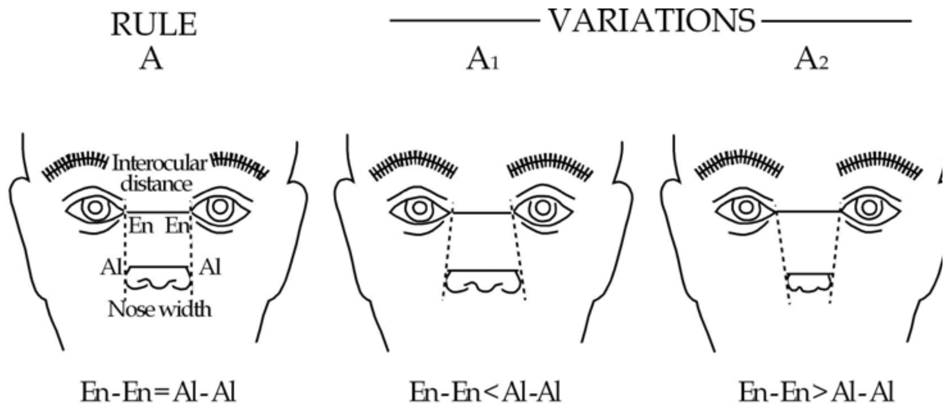
Lower lip exposure decreased to a greater extent than the Upper lip exposure (St-Ls). It is documented that lips become thinner and less well defined as a function of the aging process (*e.g.,* Fanous 1987; Austin *et al*. 1992;

Ferrario *et al*. 2000), which is what was documented in the present study. It has also been stated that youthful lips are considered to appear wider and taller (Bisson and Grobbelaar 2004). In the present study, the lips were indeed taller per se at the posttreatment examination, but Mouth width (ChL-ChR) was wider at the recall examination. So a revision to the statements made by Bisson and Grobbelaar (2004) should read that youthful lips are considered to be those that appear *narrower* and taller.

Comparisons to Neoclassical Proportions

Neoclassical proportions were originally formulated by scholars and artists of the Renaissance and were based on classical Greek canons to define the relationships between various areas of the head and face. The influence of the neoclassical canons, which were dominate in the 17th and 18th centuries, diminished by the late 19th century. Farkas *et al.* (1985) tested the validity of a number of the neoclassical rules using normative data obtained from measurements of eighteen-year old North American Caucasians. It is of interest to compare the findings in the present study to the findings of Farkas and colleagues.

Figure 30 illustrates a proportionality rule where the Inner canthus width (EnL-EnR) equals the Alar width (AlL-AlR). In the present study, Inner canthus width at both examinations (T2 and T3) equaled Alar width less than half as



	A	A_1	A_2
Farkas *et al.* (1985) n = 103	40.8%	37.9%	21.4%
Present Study n = 101			
Posttreatment (T2)	12.9%	37.6%	49.5%
Long-term recall (T3)	15.8%	12.9%	71.3%

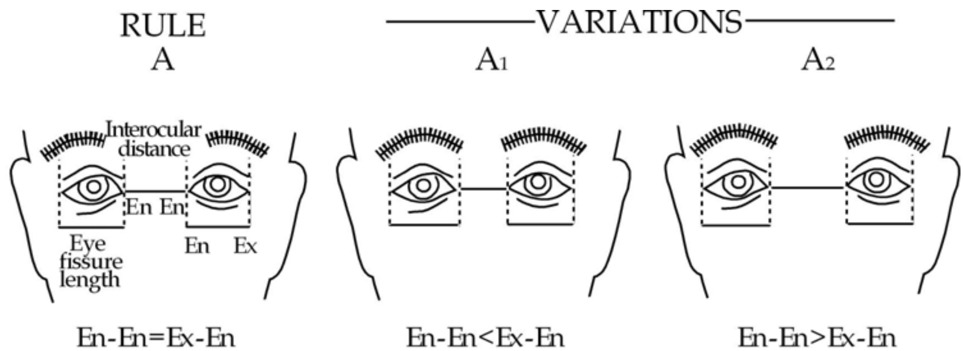
Figure 30. Comparisons between Farkas *et al.* (1985) and the present study with regards to the orbitonasal proportion rule (A) and two alternatives (A_1 and A_2). Rule: The interocular distance (EnL-EnR) equals the width of the nose (Alare left-Alare right, AlL-AlR).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

much as Farkas's sample (40.8%). The present sample tended to have an Alar width that was smaller than Inner canthus width (49.5% at T2 and 71.3% at T3). Figure 31 illustrates a proportionality rule where the Inner canthus width (EnL-EnR) equals the length of the average eye fissure length. In the present study, Inner canthus width at both examinations was equivalent to eye fissure length 24.8% at T2 and 23.8% at T3. The distribution of Farkas' findings is *similar* to that of the present sample. Figure 32 illustrates a proportionality rule where the width of the mouth (ChL-ChR) equals 1½ the width of the nose (AlL-AlR). The present sample had a mouth width that was disproportionately smaller than 1½ nose width when compared to Farkas' sample. Figure 33 illustrates a proportionality rule where the width of the nose (AlL-AlR) equals ¼ the width of the width of the face (ZyL-ZyR). A preponderance of the present sample had a nose width that was larger than ¼ face width. This was the situation in 21.4% in Farkas' sample.

Changes in Facial Shape

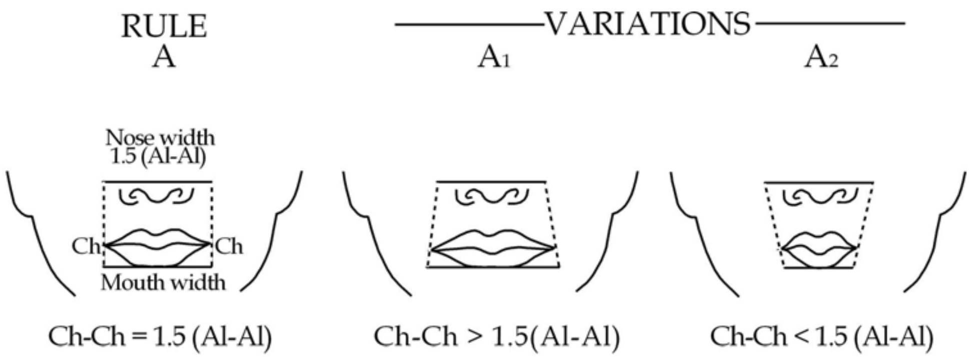
The present study observed the dynamics of facial growth and development from adolescence to young adulthood, at about 30 years of age. As described in this chapter, the dynamics of facial growth during adolescence have been studied in appreciable detail, but the growth and changes during adulthood are not well documented. Longitudinal studies in facial growth are



	A	A_1	A_2
Farkas *et al.* (1985) n = 103	33%	15.5%	51.5%
Present Study n = 101			
Posttreatment (T2)	24.8%	10.9%	64.4%
Long-term recall (T3)	23.8%	15.8%	60.4%

Figure 31. Comparisons between Farkas *et al.* (1985) and the present study with regards to the orbital proportion rule (A) and two alternatives (A_1 and A_2). Rule: The interocular distance (Endocanthion left-Endocanthion right, EnL-EnR) equals the length of the right or left eye fissure (Exocanthion-Endocanthion, Ex-En).

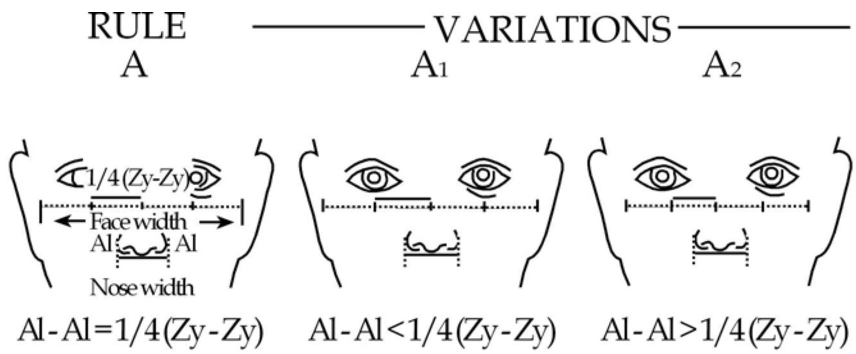
Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.



	A	A_1	A_2
Farkas *et al.* (1985) n = 103	20.4%	60.2%	19.4%
Present Study n = 101			
Posttreatment (T2)	1.0%	0.0%	99.0%
Long-term recall (T3)	5.9%	0.0%	94.1%

Figure 32. Comparisons between Farkas *et al.* (1985) and the present study with regards to the naso-oral proportion rule (A) and two alternatives (A_1 and A_2). Rule: The width of the mouth (Cheilion left-Cheilion right, ChL-ChR) equals 1 ½ the width of the nose (Alare left-Alare right, AlL-AlR).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.



	A	A1	A2
Farkas *et al.* (1985) n = 103	36.9%	38.8%	21.4%
Present Study n = 101			
Posttreatment (T2)	19.8%	15.8%	64.4%
Long-term recall (T3)	23.8%	13.9%	62.4%

Figure 33. Comparisons between Farkas *et al.* (1985) and the present study with regards to the nasofacial proportion rule (A) and two alternatives (A_1 and A_2). Rule: The width of the nose (Alare left-Alare right, AlL-AlR) equals ¼ the width of the face (Zygion left-Zygion right, ZyL-ZyR).

Source: Farkas LG, Hreczko TA, Kolar JC, Munro IR. Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of Neoclassical canons. Plast Reconstr Surg 1985;75:328-38.

scarce because it is difficult to collect photographs (or measurements) of adults who were also observed in adolescence. It seems that there is a strong correlation between the expansion of craniofacial structures and the expansion of soft tissue landmarks (Bartlett *et al*., 1992). Behrents (1985) concluded that, "growth during adulthood was the norm." In general, transverse dimensions increased more than craniocaudal dimensions in the present study. The overall effect of the changes was to round out the face, whereas previous studies (*e.g.,* Meredith 1960; Bishara *et al*. 1995) have observed that the growth in childhood and adolescence has the effect of elongating the face. Although some of the changes noted in the present study differ slightly with previous studies, there seems to be agreement that facial changes from the mid-adolescence to adulthood are one of expansion and not atrophy (Bartlett *et al*. 1992). The generalization made by Bartlett and collegues differs in one respect from the present study, the lip exposures decreased in height (Ls-St and St-Li). The decrease in lip exposures has been documented by previous studies (*e.g.,* Fanous 1987; Austin *et al*. 1992; Ferrario *et al*. 2000).

Several facial changes took place in the present study, but some generalizations can be made. Lower face width (GoL-GoR) increased more than any of variable assessed in both men and women. In the present study, Lower face width increases more than twice the amount of any craniocaudal distance, as opposed to the growth trend seen in childhood and adolescence where face height increased twice as much as face width (Bishara *et al*. 1995). In the present study, the Lower face height (Sn-Me) developed differently in men and women. Similar to previous studies (*e.g.,* Bradshaw 2002), males had significantly more change in Lower face height, and more specifically in Chin height (Li-Me), than women. Chin height influences the changes in Lower face height more than any other component (*e.g.,* Sn-St; Sn-Ls; St-Li). The orthodontist should use this information as part of his/her armamentarium in treatment planning.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Most studies of facial growth in adults have relied on cross-sectional data. Longitudinal studies in this area are scarce. Few studies exist because it is difficult to collect measurements of adults across time and because the changes are less dramatic than during childhood or adolescence. An interesting sample exists in the Charles H. Tweed collection, where orthodontic patients were recalled 10 or more years after treatment with an average time out of treatment of about 15 years. The availability of frontal facial photographs from the Charles H. Tweed collection provided us with an uncommon opportunity to longitudinally quantify the changes in facial dimensions from adolescence into early adulthood. Frontal photographs were obtained from 101 subjects (41 males and 60 females) at posttreatment ($\bar{x}$ = 15.6 years) and long-term recall ($\bar{x}$ = 31.2 years) examinations. The objectives of the study were to quantify facial growth and to assess the extents of sexual dimorphism of the face across the age span.

There was no metric scale in these photographs, so it was not possible to provide millimetric dimensions of the variables. Instead facial dimensions are presented as a ratio of the person's interpupillary width (IPW). Based on previous studies (*e.g.*, Pryor 1969; Fledelius and Stubgaard 1986;

Lakshminaravana 1991; Farkas *et al.* 1992; Filipovic 2003), IPW stabilizes after mid-adolescence. Major findings were:

1. Transverse facial dimensions generally increased significantly in men and in women. Lower face width (GoL-GoR) increased more than any other measurement for both men (18%) and women (7%). The transverse changes were sexually dimorphic, with men experiencing larger average changes for all dimensions.
2. Craniocaudal changes were smaller than the transverse changes. For example, Lower lip exposure (St-Li) exhibited small decreases of 3% in men and 2% in women. Changes in craniocaudal dimensions were generally not sexually dimorphic.
3. There was a fundamental difference in the development of Lower face height (Sn-Me) between men and women. This distance increased significantly in men (6%), but did not change in women. When Lower face height is broken down into the individual components, it was observed that small changes occurred in both men and women for Stomion height (Sn-St), Lower lip height (St-Me), Upper lip height (Sn-Ls), Upper lip exposure (Ls-St), and Lower lip exposure (St-Li). However, the change in Chin height (Li-Me) was significantly different in men and women (8% and 2%, respectively). This finding suggests that men have a considerably larger soft tissue addition to Menton than women during this age interval.

4. Some changes were unanticipated. For example, Upper face height (Ex-Sn), which measures the height of the nose, decreased in the present study. According to Bishara *et al*. (1995), this dimension increases in a younger sample. We ascribe the changes to the drooping of the outer canthi, which changes the reference used to make the measurement. Inner canthus width (EnL-EnR) and Outer canthus width (ExL-ExR) also diminished. Farkas *et al.* (1992) suggested that these dimensions are stable after 15 years of age, though he only assessed these changes cross-sectionally. In the present study Alar width (AlL-AlR) did not change in either sex. Based on previous studies (*e.g.*, Bishara *et al*. 1995; Snodell *et al.* 1993), the changes that occur in Alar width in adolescents might be expected to continue, albeit to a different extent, into adulthood.

The present study examined the effects of growth after orthodontic treatment on facial balance and the soft-tissue profile in frontal view. The timing and magnitude of growth is different in the two sexes. Growth does not stop at the onset of "adulthood." Instead, the effects of growth produce a more rounded appearance of the face, and this maturing effect is more noticeable in males. The slow but cumulative growth documented here during the late teens and early adulthood alters facial morphology and the frontal facial profile (*e.g.,* Behrents 1986; Bishara *et al.* 1994). The specialist should be aware that continued growth alters facial sizes and proportionality in adulthood and should use the information in the present study as an aid for treatment planning.

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