DOI: 10.2478/aoj-1980-0009

Cephalometric appraisal for craniofacial imbalances in orthodontic & surgical anomalies

B.Darryle Bowden, M.D.Sc., F.D.S., D.Orth., R.C.S. (Eng), F.R.A.C.D.S., Melbourne, Australia.

Abstract:-
The clinical application of a cephalometric analysis developed to define the areas of craniofacial imbalance is described. Data was derived from computer analysed serial data from lateral radiographs of 60 boys and 64 girls from 2 to 20 years of age and from other surgical and orthodontic cross sectional data. The cephalometric analyses are illustrated on a "normal" 18 year old female and on a 24 year old male with a maxillary deficiency and with severe mandibular overclosure, pre and post operatively. The methodology determines variations in cranial base, orbit and zygoma positions, craniofacial divergence, maxillary and mandibular positions, relations and size, dental arch size and position and the effects of the combined parameters on the soft tissues of nose and lips.

Key Words:- Cephalometric, computer assessment, treatment planning, craniofacial anomalies.

INTRODUCTION:

Surgical

Surgical intervention for craniofacial skeletal imbalances has changed recently. Innovations to maxillary and mandibular surgery have produced major technique changes under influences of Obwegeser (1964/69), Bell (1969/75/80), Epker et al., (1974/80), and many others. Craniofacial surgery, profoundly influenced by Tessier (1968/76), has produced startling changes to the craniofacial complex, although Whitaker et al., (1976), in a review of inherent serious complications, emphasised the moral desirability of limiting this extensive surgery to major craniofacial units. Indeed, extensive orthograthic surgery is not without its complications, ranging from the minor, temporary or permanent loss of adjacent nerve sensitivity (Vladivelo 1980) to the infrequent and rare malunion and other bone grafting sequelae (Bell et al., 1980), and even condylar atrophy after sagittal osteotomy (Philips & Bell 1978) emphasized the desirability of limiting this surgery to major craniofacial units, because of its extensive nature and inherent risk of serious complications.

Traditionally, the various types of cranio facial, including maxillary and mandibular surgery, were restricted to individuals in whom active growth had ceased. However, some evidence is accruing to substantiate early intervention (Munro 1978, Wolford et al., 1979), whereas somewhat contrary evidence has documented the varying post surgical alterations achieved, not only in this "growing group" (Freihofer 1975/77), but also in other surgical groups (Cook et al., 1973, Wilmark 1974 Isaacson et al., 1976/77, Hovinga et al., 1979.)

One of the difficulties in orthodontic surgical intercommunications in these fields has been the differences in interdisciplinary assessment techniques. The surgical field has principally utilised assessments related to the patient's complaint e.g. soft tissue disfigurement (nose, chin, lips, etc.). Patients were assessed from clinical photographs and study casts, although utilisation of cephalometric analysis (Hinds et al., 1972), has markedly increased, particularly over the last decade, and now includes application of computerised digitising technology, at least in some major centres, (Schendel et al., 1976, Wolford et al., 1978/79). Prediction of post surgical contours by these technological changes (Kanazawa et al., 1978), and/or by reshaping of radiographic image sized photographs (Henderson 1974/78), is now considered an important element of case analysis.

Orthodontic

Orthodontically, case analysis has followed a similar "developmental pattern" often with orthodontic research providing the basic methodology for adaption to allied inter-disciplinary fields. These methodologies include roentgenographic cephalometrics (Broadbent 1931, et al., 1975, Bjork, et al., 1963-72), coordinate system analyses (Walker 1971/72), computer technological applications (Walker 1972, Solow 1970/73, Chebib et al., 1976, Burstone 1980, Faber et al., 1978) and in utilising combinations of these technologies and concepts for predicting craniofacial growth (Ricketts 1957-72, Johnson 1968/75, Popovich et al., 1973/74/77)

Cephalometric methodology, no matter how scientifically applied is dependent on the validity of points selected for analysis, as well as the statistical parameters quantifying the data sets.

Cephalometrics contribution to clinical analysis is indirectly allied to the evolution of traditional concepts for lines of reference (Broadbent, et al., 1941/75, Bjork, et al., 1947-75, Enlow et al., 1969/75), for lines of superimposition in serial studies (Broadbent, et al., 1941/75, Bjork, et al., 1947-75, Ricketts 1957-79, Coben 1979), and for assessing individual growth patterns and deviations (Brodie 1941/42, Bjork, et al., 1947-75, Moorees & Kean 1958, Sassouni 1969/74, Ricketts 1957-79).

Data Analysis

Severe limitations are imposed on the accuracy of analysis and also of prediction concepts, by sample sizes in many serial studies. For example, 16 males and 16 females throughout all ages in Bolton Broadbent published tables (Broadbent et al., 1975); a variation from 47 males at 9 years to 23 at 16 years and 36 females at 8 years to 9 at 16 years shown in the University of Michigan series (Riolo et al., 1974). Similar limitations exist in many other serial studies of craniofacial growth (Nanda 1955, Burstone 1967, Ricketts 1972/79). The lack of adequate statistical validation of individual (Brodie 1942), and group (Bhatia et al., 1979) craniofacial growth patterns in serial studies, which frequently have data analysed cross sectionally, imposes severe limitations in making sweeping statements on constancy of pattern concepts and on growth prediction tendencies eg, "after the age of 5 years the basic dento-skeletal morphology is established in almost all (97%) individuals", (Wolford et al., 1979). Frequently, patterns of craniofacial development undergo considerable and subtle changes with age (Bjork 1955, Tweed 1966, Bjork et Skeiller 1972/77, Ricketts 1972/79), and particularly during adolescent maturation, changes in direction may occur as the mandible accelerates its growth in a predominant horizontal direction (Bowden 1978) and this acceleration is not always matched or compensated for by other craniofacial elements (Hunter 1966, Roche & Lewis 1976).

The prediction of growth dependent parameters has many inherent deficiencies, be they as diverse as height, (Tanner et al., 1975, Roche et al., 1975), heart size (Maresh 1948), or craniofacial skeleton (Ricketts 1957-72-79, Bjork 1947-75, Johnson 1968/75, Woodside 1970, Mitchell et al., 1975, Moyers et al., 1971/79, Popovich et al., 1975/76 Houston 1979).

Prediction methodology is based on the statistical function of parameters (Cameron 1978, Moyers et al., 1971/79), but it is also equally dependent on the reliability of assessment techniques utilised to determine initial size, (Knott 1941, Speilman 1972, Cameron 1978) and the changes in body pattern development with age (Bayley 1959, Tanner et al., 1975, Roche 1978). All developmental tissues, craniofacial skeleton included, respond differently to the flowing and ebbing of genetic and environmental influences with age, and these are reflected in biochemical changes and particularly neuro endocrine activities. (Winter 1978, Grumbach et al., 1974/78/80). The combined circulating biochemical factors institute profound and variable responses to the varying receptor and effector mechanisms at the cellular levels (Roth et al., 1980), and thus modulate genetic and environmental influences.

MATERIALS AND METHODS

Material

The data used in the present investigation were analysed from the records of 60 boys and 64 girls enrolled in a serial, multidisciplinary study at the University of Melbourne Child Growth Study (Roche and Sunderland 1959), from 2 years to over 20 years of age. The tables in this paper utilise specifically the statistics derived from Child Growth Unit data of 60 boys and 64 girls at 9 years and variable serial data from 9-19 years but include at a minimum 38 boys and 49 girls, the numbers at 19 years of age. The basic Child Growth Unit data was augmented by cross-sectional data of 580 from an orthodontic group and 115 from a surgical assessment group.

The radiographs were taken on a Bolton Broadbent cephalometer and the enlargements for the lateral radiographs were similar to those defined by Broadbent et al., 1975. Enlargement factors are a potential source of considerable error in assessment, not in angular dimensions, but certainly in size analysis and these enlargements have been extensively reviewed recently (Bergersen 1980). For example, Y Axis Length (S-Gn) may be over 150 mm and the variations produced on different head holders change from Bolton Broadbent (object film distance of 9 cm), to the Ricketts (object film distance of 18 cm), i.e. a potential difference in a 150 mm length of 12.5 mm (i.e. 2 x S.D's). The object film distance also will have a significant bearing in the amount of distortion of mid line structures (S) compared with lateral structures (Go, Co) as detailed by Slagsvold Pederson 1979. The figures quoted in this publication have not been computed to actual size to simplify direct clinical adaption to measurements on radiographs, however, the Growth Unit computer analyses perform actual size corrections in those analyses where size parameters are utilised (Bowden 1978).

All radiographs were preliminarily traced and digitised directly on the radiographs (Bjork & Solow 1962), solely by the author in a regimented pattern after experimentally having defined specific anatomical shadows (Bowden 1970). The whole series for each child were initially superimposed manually on a "constant" cranial base pattern according to the techniques of Bjork, (1975/78). This superimposition was transferred throughout the serial group by cross grid identification procedures. Later complex computer controlled superimposition procedures duplicated and checked the superimposition methodologies (Bowden 1980).

Data Analysis Technique

The data analysis technique has been developed and redefined over the last eight years and is based on storing radiographic images (in contra-distinction to reference points) in a computer compatible format by means of a sonic Graf pen digitiser, coupled to a rigidly controlling PDP11/10 and 11/34 mini computer programming system. A connection to a Tektronic 4006/1 graphic terminal allows for preparatory cleaning of data directly at input, and corrects for "electronic glitches" (Baumarind & Miller 1980). The data structure is anatomically, not cephalometrically based and is a further development of techniques described by Walker 1972, Solow 1973 and Miller et al., 1970. The mini computers are connected by data lines to the University of Melbourne's Cyber, the C.R.J.E. (PDP11/70) and to the VAX computers for rapid data analysis, storage and data base systems development.

It should be emphasized that the anatomical basis of the data allows for the computer identification and calculation of "cephalometric" reference points. Many of the errors of cephalometric reference point digitising (Baumarind & Miller 1980), may be compounded by human limitations both in precision of "fiducial point" alignment and the larger source of errors, inter- and intra-operator variations in strict identification protocols for reference points. These errors may be computer "meaned" to give "scientific" authenticity, but they do not fix inherent operator deficiencies. Many so-called simple reference points e.g. S,Po tend to be "eye-balled" and lend themselves to 1-2mm inter- and intra-operator errors. The "whole image anatomically based" system concept allows for computer controlled re-identification of reference points, according to the strictest mathematical protocols and "operator equivalent" methodologies are almost impossible to attain by even well disciplined professionally trained operators, not to mention the laborious nature of a similarly regimented operator identification approach.

The reference point analysis system calculates 247 reference points from whole images, cross checks these by a variety of identification protocols, and also compares 31 of them with 31 classical reference points entered by the operator as "single points". Errors in reference point identification are printed and retained before "calculations" protocol calculates 155 craniofacial dimensions. These reference craniofacial dimensions are compared with data base means, both chronological age and maturation age based, by "comparison" protocols and deviations from the "means" statistically analysed and flagged (Ricketts 1972).

The Growth Unit data base analyses include at present 155 measurements from the lateral radiographs and these have been narrowed to those shown in the tables, specifically with clinical usage in mind. Separate publications (Bowden 1978/81) deal with definition of cephalometric points, statistical parameters and the variations of these results compared with other studies.

Methods of Determining Clinical Variation

The variability of the structural components composing the craniofacial area have historically been highlighted by statistically defining the parameters of the degree of variation from the mean. Whilst in strict statistical terms this should be defined by the coefficient of variation (S.D./Mean), (Fischer 1950, Garn 1958), the clinician frequently utilises the number of S.D.'s the variable deviates from the mean as a measure of the degree of deviation or outlying of a measurement (Downs et al., 1948/52/56, Bjork 1961/63, Ricketts et al., 1957-79, Solow 1980).

Adaption of "the comparison with mean" principles have taken graphic format by production of template superimpositions and these look at selected areas which are different to a "mean" template (Moorees et al., 1958/76, McEwan & Martin 1967, Walker 1972, Ricketts et al., 1972, Broadbent et al., 1975, Ackerman 1979, Popovich & Thompson 1977). The clinician applying such reference template systems, needs to know not only whether there is a deviation from the mean, but also, to be alerted to the amount of the deviation and the "t x S.D.'s" attempts to alert to this amount, however, strictly speaking it alerts only to the percentage of the population in which the deviation may occur e.g. 3 x S.D.'s = 0.01% of the population.

The inclusion of serial Growth Unit, and cross sectional orthodontic and surgical data in the combined data base section was an attempt to extend the range of variability in extreme patterns, making the data more applicable to gross clinical cases. In this regard all means and S.D.'s quoted in this publication's tables were rounded up to the next whole number, attempting to accentuate this variability, to make the tables clinically easier to calculate and to highlight definite statistical associations.

Description of Table Format

Throughout the Tables, the data is presented in a similar format, to facilitate clinical use, i.e., four columns for 19 years and four for 9 years. The data shows "rounded" means and standard deviations (S.D.) separately for males (♂) and for females (♀). The "means" and the S.D.'s for each sex and for each age are shown separately, only when there are significant differences; where no significant sex or age differences exist, the figures are combined and listed in the male columns only. This has been done to emphasize the sex and age related nature of some measurements, i.e. sexual dimorphism.

Table 1

MEASUREMENT		AGE	MEAN		S.D.	
Cranial Base Relations			♂	♀	♂	♀
1. Ba S N	Angle	19	131	—	6	—
	deg	9	130	—	—	—
2. S-N	Length	19	75	70	4	3
	mm	9	69	66	3	2

In the male columns for example, the angle Ba S N is significantly different at 9 years and at 19 years. The changes are minimal from 130-131°, but the change is significantly different, however, there are no significant sex differences and the standard deviations are similar at 6°. For SN length there are significant age and sex differences, i.e., for females at 9 years the mean is 66 mm with a S.D. of 2 mm; at 19 years the mean is 70 mm with a S.D. of 3 mm. For males, who show significant differences to females both at 9 and 19 years, the mean is 69 mm at 9 years with a S.D. of 3 mm and this mean increases to 75 mm at 19 years when the S.D. is 4 mm.

In the results section, 4 columns on the right hand side are added to show the actual measurements for a female "C.M." of 18 years and a male "B.A." of 24 years, together with the number of S.D.'s each measurement deviates from the mean for that age:-

● signifies no significant difference;
-- signifies 2 x S.D.'s below the mean for that age and sex;
+++ signifies 3 x S.D.'s above the mean for that age and sex.

It should be emphasized the Tables attempt, for convenience of presentation, to delineate abnormality in specific areas, but the significant differences should be finally grouped by the clinician to interpret the degree of inter-dependence of relationships as to causality (Solow 1966/80), and for treatment planning, small deviations should not be interpreted too freely. Within the Growth Unit, multivariate analyses highlight inter-relationships, similar in concept to many other reports, (Solow 1966/80, Johnson 1968, Bhatia et. al., 1979), but these are to be reported separately.

Clinical Interpretations from Tables

The use of ages 9 and 19 years were selected for various reasons but among which may be listed deliberations of:-

(i) Common ages of assessment e.g. 9 years for orthodontic analysis, 19 years "after growth cessation" for surgical analysis.
(ii) 9 years is usually just after the midgrowth spurt and prior to the adolescent growth spurt, two periods characterised by accelerated phases of general and craniofacial growth (Nanda 1955, Bjork, et al., 1947-75, Woodside 1970/77, Grave et al., 1971, Popovich et al., 1975/76, Bowden 1976/78/81).
(iii) 9 years and 19 years allows for ready comparison with other investigations (Ricketts et al., 1972, Broadbent et al., 1975, Riolo et al., 1974, Bhatia et al., 1979).

Whilst there are no specific mean increments per year shown from 9-19 years (it would have added to table size and complication), nevertheless they would be of limited value, because size increments should be extrapolated not as much on chronological age but more meaningly on maturational age. However, some indication of "average" increments may be extrapolated, dependent upon the clinician's application of growth and development principles. The tables allow approximate interpolations of 5 years to maturity for females i.e. 9 to 14 years, and 10 years to maturity for males i.e. 9-19 years. This allows additions of approximate increments per year e.g. female (♀) SN = 66-70 i.e., 5 years = 0.9 mm/yr and male (♂) SN 69-75 i.e., 10 = 0.6 mm/yr.

The clinician should be aware of the variability in maturation with age and select valid maturation related criteria e.g., marked statural acceleration (Frish 1974, Burstone 1967), secondary sex characteristics, (Tanner 1962/69, Marshall et al., 1970-78), hand-wrist and knee radiographic epiphysial maturation, (Greulich & Pyle 1959, Tanner et al., 1962/75. Roche 1975/78), to validate such interpolations by assessing the relative skeletal maturity of the components being analysed (Bjork et al., 1967/71, Bowden 1971/76/78). Clinical extrapolations of these derived "average" annual increments may be made further by allowing for varying maturation rates at different ages. For example, if a female is early maturing, and a prediction of adolescence from epiphysial markers is for adolescence to occur from 10-13 years, the modules of incremental growth should be advanced or retarded from the "average" e.g.,

RESULTS & METHODS OF ASSESSMENT

Cranial Base Measurement

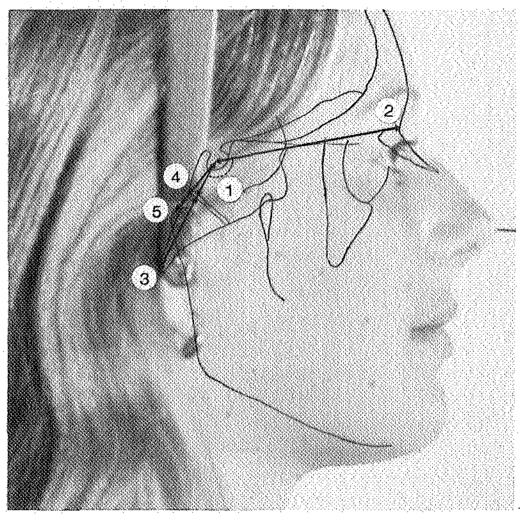


Fig. 1 C.M. ♀ 18 yrs. Cranial Base Relations

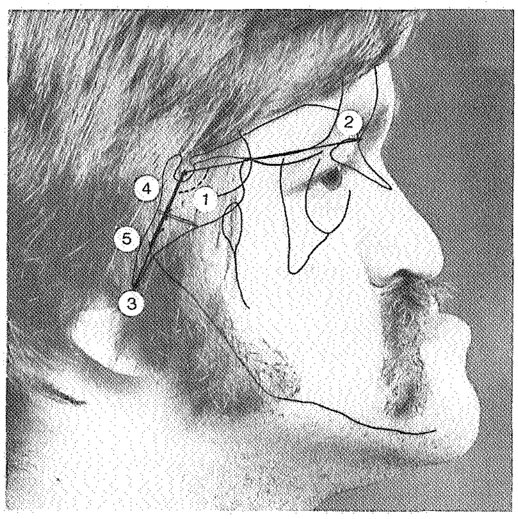


Fig. 2 B.A. ♂ 24 yrs. Cranial Base Relations

Table 2

MEASUREMENT		AGE	MEAN		S.D.		C.M. ♀ AGED 18		B.A. ♂ AGED 24	
Cranial Base Relations			♂	♀	♂	♀	Actual	Deviation	Actual	Deviation
1. ANTERIOR/POSTERIOR	Angle	19	131		6					
Ba S N	deg	9	130				129	●	125	—
2. TOTAL ANTERIOR	Length	19	75	70	4	3				
S-N	mm	9	69	66	3	2	71	●	66	--
3. TOTAL POSTERIOR	Length	19	48	45	3					
S-Ba	mm	9	42				46	●	47	●
4. POSTERIOR SPHENOID	Length	19	20	18	3					
S-S.O.S (Mid)	mm	9	16	15	2		17	●	17	
5. CONDYLAR POSITION	Length	19	26	25	4					
S-Co(h)	mm	9	20	19	3		25	●	24	●
6. POST/ANT. LENGTH	Ratio	19	64		6					
S-Ba Length / S-N Length	%	9	60	63	3		64	●	71	+
7. COND/POST. LENGTH	Ratio	19	54	55	5					
S-Co(h) LengthS-Co(h) Length / S-Ba Length	%	9	48	45			54	●	51	●
8. POST.SPHENO/LENGTH	Ratio	19	42	40	3					
S-S.O.S Length / S-Ba Length	%	9	39				37	—	37	

SN length 0.8 mm/yr increments accordingly would be more likely 0.5 mm for 9-10 years, 1.0 mm from 10-13 years and 0.5 mm for 13-14 years, etc.

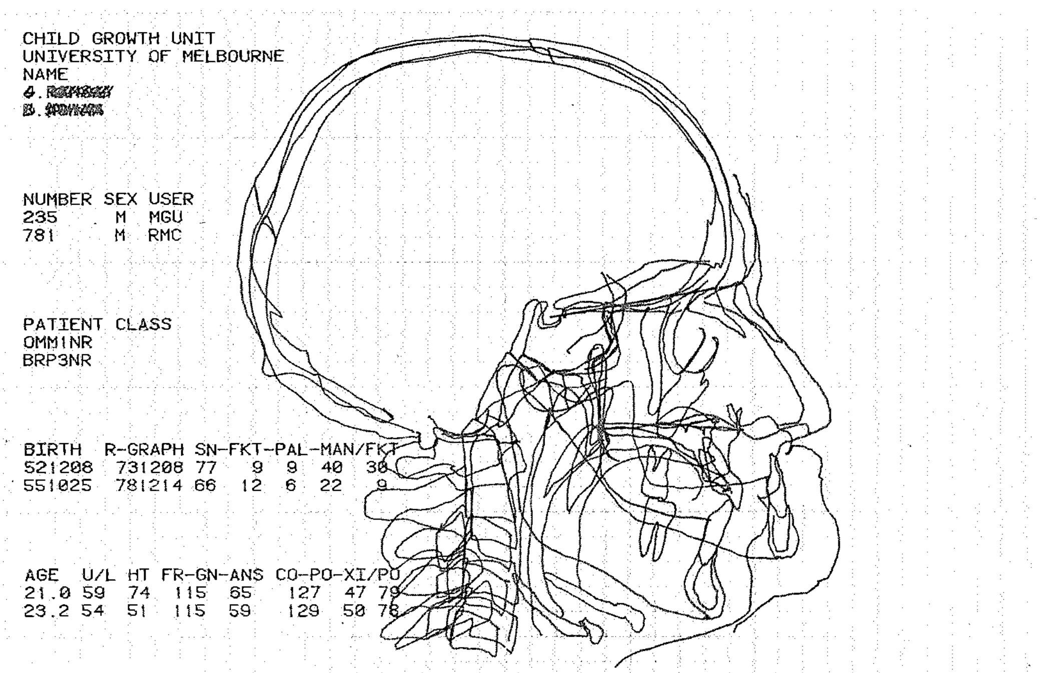
Table 2 for Cranial Base Relations summarizes in the "MEAN" columns the changes with age and sex. It illustrates a pattern of significant increase in cranial base angle (Ba S N) from 9-19 years with no sex differences but sexual dimorphism is seen (♂ > ♀) in length measurements and in changes from 9-19 years, e.g. S-N ♂ 69-75 mm and ♀ 66-70 mm. Similarly sexual dimorphism is shown for S-Ba, S-S.O.S., S-Co(h) and in the ratios shown in Measurements 6, 7, and 8. The ratios are an important component of an individual's assessment, because they attempt to coordinate size with the area of mal-relationship or disproportion. For example, if S-N length is small, has there been a proportional reduction in other dimensions e.g. S-Ba? A dimension smaller than the "mean" is not of great consequence clinically, if other dimensions are also small and in proportion. The compensatory changes make for harmonious relations, be it in "miniature" or "gigantism", but disproportion is more important in producing disharmony in interrelationships.

Fig. 1 and Table 2 illustrate that for female "C.M." at 18 years the cranial base angles, lengths and proportions approach the mean and "normalcy". They are not significantly different from the mean figures, apart from the ratio of sphenoid to occipital proportions in the posterior cranial base (Meas. 8 = 42 c.f. 37%). The S-S.O.S. (Spheno-occipital synchondrosis) compared with S-Ba length (Meas. 3), shows mild disproportion, maybe because S-Ba length is 1mm "high" and S-S.O.S. length is 1 mm "low", i.e. the individual measurements are not "abnormal", but combined suggest a "slight" statistical suspicion of the proportions being reduced.

In contrast, Fig. 2 and Table 2 for male "B.A." at 24 years, shows a slightly reduced cranial base angle Ba S N, (131°-125°) a markedly reduced S-N anterior cranial base length (75-66 mm), and a slightly reduced posterior sphenoidal basal bone (S-S.O.S. length = 20-17 mm). The anterior cranial base length (S-N) is not only small for age and sex but in proportion to posterior cranial base length (S-Ba), which is "normal", the anterior cranial base proportion (Meas. 6) is reduced (64-71%). The S-Co(h) is not reduced significantly in absolute size (26-24 mm), neither is it reduced in proportion to S-Ba length (Meas. 7 = 54-51%). Similarly, the sphenoid component (S-S.O.S.) of the posterior cranial base is reduced (42-37%). Other computer measurements, not shown in the Tables but illustrated in Fig. 3 show that patient "B.A." has a primary defect in the cranial base produced by a small sphenoidal complex, anteriorly displayed by a S-spheno-ethmoid (S.E.) reduction, posteriorly by a S-S.O.S. measurement reduction, and also spheno-ethmoid to nasion (i.e. ethmoid-frontal) complex is reduced.

These cranial base changes are illustrated in template format when a computer selected "mean" adult male individual from the Growth Unit data base "J.R." is compared with "B.A." in Fig. 3 and the differences are reflected in cranial base angles and sizes. The proportions in anterior cranial base of S-spheno-ethmoid, S-middle fossa are obvious as are the changes in relationships of the posterior cranial base. Fig. 3 illustrates the changes in condyle head position, zygoma, maxillary and mandibular areas

Fig. 3 Computer graphic comparison of "B.A." and "J.R." — the "mean" male adult standard of Child Growth Unit.



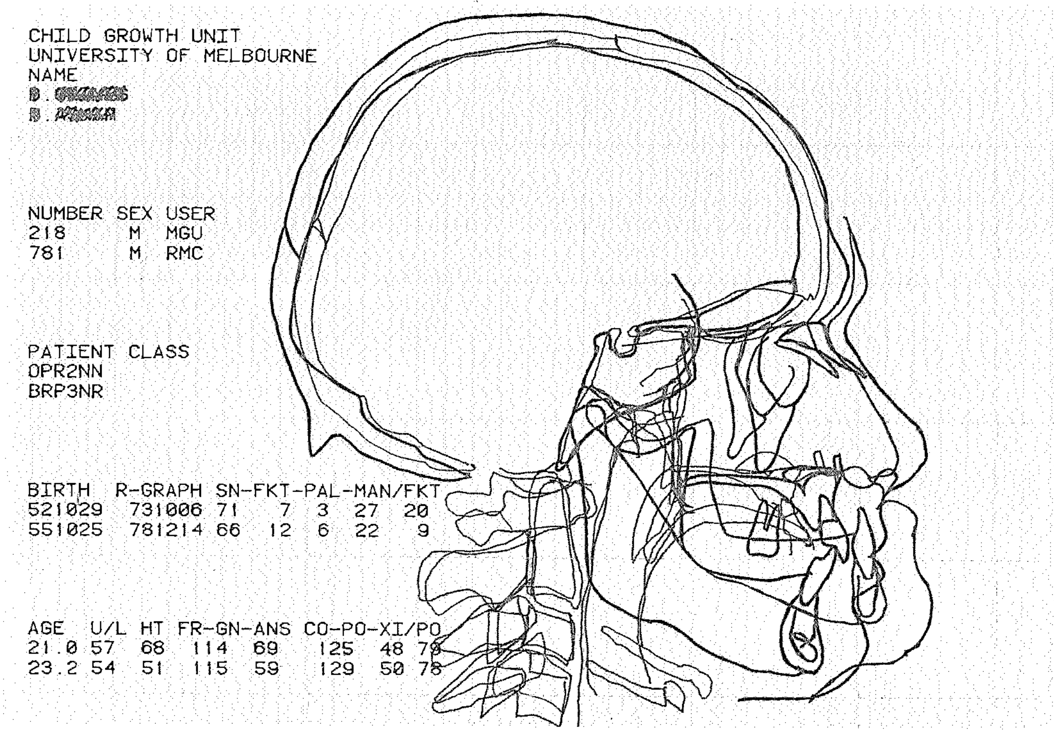


Fig. 4. Computer graphic comparison of "B.A." and "P.G." — an individual with similar cranial base relations from data base of Child Growth Unit.

showing changes in size and position. Angular changes for SN - FKT (Frankfort), SN - Pal (atine), SN - man(-dible) and man(-dible) to FKT (Frankfort) are illustrated. Figs. 3 & 4 also compare the U/L HT (upper/lower facial heights), FR -GN (mandibular facial axis length), FR - ANS (mandibular length), Co - Xi (ramus condylar length) and Xi - Su Po (body corpus length). In Fig. 4 the comparisons of size discrepancies in anterior cranial base are made more obvious when the computer selected and superimposed an individual "P.G.", with a similar Ba S N angle and the smallest S-N length recorded in the Growth Unit male sample. Although the cranial base measurements of "B.A." and "P.G." are similar, differences are to be noted e.g., SN (66-71 mm) and S-spheno-ethmoid and S-middle fossa are reduced in "B.A." by 5 and 4 mm respectively. Notice how in spite of these anterior cranial deficiencies, the orbital roof of "B.A." is longer than "P.G." and the posterior cranial base (S-Ba) is 5 mm shorter as is S-Co(h). These compensations in middle fossa position and condylar head position etc., have allowed "P.G." to develop a more satisfactory and harmonious pattern, by subtle compensatory modifications (Solow 1966).

The cranial base measurements for "B.A." particularly S-N length, demand that any measurements utilising S-N as a base or reference line must be initially compensated for in length for that age, i.e. S-N length should be grown 9 mm (from 66-75) before valid use can be made of SNA, SNB, SNPo, angles etc. (Downs 1956, Hinds et al., 1972, Coccaro et al., 1974/80), and this "growth" is illustrated later in Fig. 5, where analysis of maxilla and mandibular positions show obvious differences. The clinical implications from the analysis in Table 2, for the surgical management of "B.A.", is that he would appear closer to "mean" measurements or to the computer templates, either of the standard "J.R." or to a "similar" cranial base individual "P.G.", if Surgical Le Fort II or III procedures were contemplated in his treatment, thus enhancing the S-N length and particularly compensating for the very small sphenoidal complex.

Facial Divergence

It should be noted, the "normal tendency" with development, for facial divergence shown in Table 3 "MEAN" columns, is for no significant sex differences in any of these angulations except measurements utilising mandibular position for mandibular plane angles. There are significant changes with age for mandibular plane to SN and to Frankfort plane, to reduce

Facial Divergence

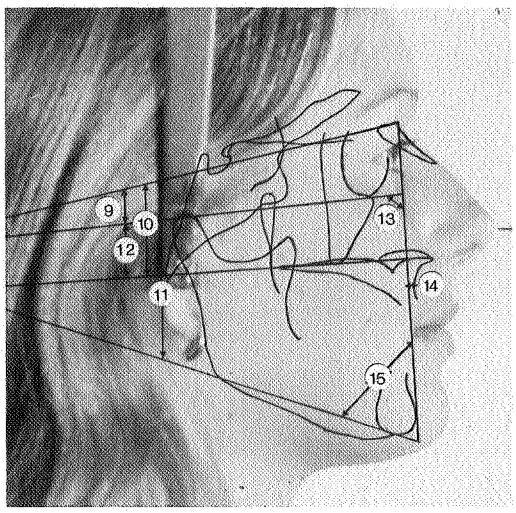


Fig. 5 C.M. ♀ 18 yrs. Facial Divergence

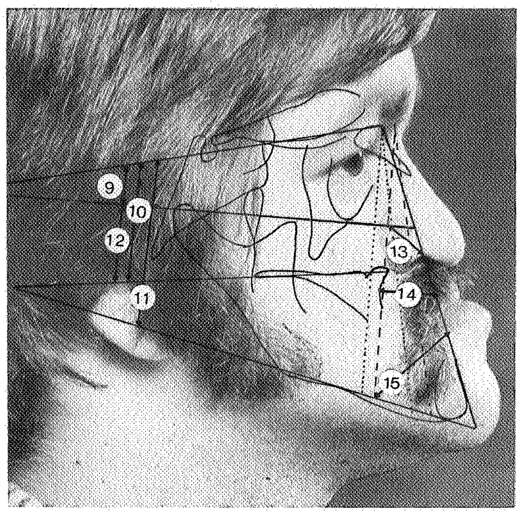


Fig. 6 B.A. ♂ 24 yrs. Facial Divergence

Table 3

MEASUREMENT		AGE	MEAN ♂	MEAN ♀	S.D. ♂	S.D. ♀	C.M. ♀ AGED 18 Actual	C.M. ♀ AGED 18 Deviation	B.A. ♂ AGED 24 Actual	B.A. ♂ AGED 24 Deviation
Facial Divergence										
9. SN-FRANKFORT	Angle	19	10			3				
S N/Po Or	deg	9					10	●	14	+
10. SN-PALATINE	Angle	19	10			4				
S N/ANS PNS	deg	9	9			3	11	●	9	●
11. SN-MANDIBULAR	Angle	19	33			7				
S N/Go IMS	deg	9	36			5	35	●	26	
12. FRANKFORT—MANDIB	Angle	19	24			5				
Po Or/N Po	deg	9	27			4	23	●	12	—
13. FACIAL PLANE	Angle	19	89			3				
Po Or/N Po	deg	9	86			3	90	●	112	++++++
14. CONVEXITY	Depth	19	2			2				
A-N Po	mm	9					2	●	—21	-----
15. FACIAL TAPER	Angle	19	67			4				
N Po/Go IMS	deg	9					71	+	56	—

from 9-19 years in both males and females by 3°. Later in Table 7, similar changes are shown for occlusal plane to follow the mandibular plane changes. The data confirms a pattern of forward or anterior rotation of mandible with development (Bjork 1969, Ricketts 1972/75/79), and it has been shown that this is a sex maturation phenomena, as it predominantly occurs during adolescence (Bowden 1978/81).

Fig. 5 and Table 3 for female "C.M." at 18 years show "normal" facial divergence (i.e. skeletal, saggital or vertical dysplasia), with only a mild increase in facial taper angle (67-71° Meas 7 = N Po/Go I.M.S.). The measurements indicate that for "C.M." the cranial base, palate and mandible are angulated satisfactorily to the SN and Frankfort lines, but the mandible in profile is low angled from chin to lower border (facial taper).

In contrast, "B.A." at 24 years in Fig. 6., shows marked changes in comparison with the "mean" figures.

(i) SN-Frankfort is increased from 10°-14° with anterior cranial base diverging from the horizontal — i.e. not only is S-N length short (Table 2) but S-N line diverges, demanding that as well as corrections for the SN length (Table 2) any angular measurements to SN must be corrected for this angulation, to Frankfort plane before e.g., SNA, SNB, Convexity, SN Po measurements may be used for assessments. (Downs 1956, Moorees and Kean 1958, Hinds et al., 1972 Coccaro et al. 1974).

(ii) SN — Mandibular Plane is significantly reduced from 33°-26°, as is Frankfort to mandibular plane from 24°-12°. This reduction occurs in spite of "high" gonial and corpus mandibular angles (Table 5) and such a clinical phenomena are explainable usually by an element of anterior mandibular posture or over closure, producing an anterior mandibular positioning and thus disguising the high mandibular gonial angle.

(iii) Facial plane of 112° is markedly increased from 89° and even if SN length is grown to "normal" i.e. 9 mm, the facial plane still remains high. This is also unusual, because the mandible is not large in size (CoPo length is normal Table 5), but the indications are for a positional mandibular overclosure problem.

(iv) Convexity (A-NPo) is markedly reduced from +2 to -21 mm and even if SN is grown 9 mm to "normal", the facial plane converted to 89° on this "new" SN, the maxillary convexity is still -12mm indicating a posteriorly positioned maxillary base at "A".

(v) The Facial Taper is greatly reduced from 67°-57°, even after correction of SN (grow length 9 mm and change SN-Frankfort angulation by 4°) there remains a reduced facial taper.

It is particularly important when a combination of cranial base angle (Ba S N) and SN-Frankfort angulation show variations from "normal" to analyse where the abnormality lies. Is "S" too low? Is "N" too high? Is "B.A." too far forward? The use of BaN will obviate one of these potential anomalies, i.e. the position of "S" and the use of Ba-Horizontal as suggested by Coben (1979) also is a help, however, they are dependent on the vagarities of "N" and "Ba", the former quite variable and the latter less so, although "Ba" also changes significantly with development (Bjork 1955, Thilander & Ingervall 1973, Melsen 1974, Solow 1980). The best alternative is to use a combination approach of many planes to minimise point dependent assessment errors.

The analysis of the relationship of "S" and "N" to an "anterior cranial base line" represents another approach to this problem. This so-called "NSL Line" of Bjork (1955-78) represents a check on "S" and "N" positions. For the "NSL" line, the Child Growth Unit computer analyses use an interpolated line of anterior cranial base (i.e. entirely along cranial base from anterior pituitary fossa to tubercullum sella, along planum sphenoidale, the median image of frontal-orbital roof and the cribriform plate (Bowden 1970). The computer derives and draws a "mean" line representing these areas, which is almost equivalent to Bjork's superimposing manually on cranial base line. If the anterior cranial base or "NSL" line remains constant with age, as suggested by De Coster 1951/53, Bjork 1975/78 and endorsed with reservation by Thilander and Ingervall 1973, Melsen 1974, Solow 1980, then "N" appears to go inferiorly with development.

It should be remembered that Frankfort plane may not truly represent "natural" head position" and has a possible variation of +1° to -3° (Downs 1956, Moorees and Kean 1958, Solow et al., 1976/79). Similarly, the angle of SN to Frankfort plane is variable by up to 6° in an excellent occlusion sample (Thurow 1970), and the mean angulation ina serial group may change from 4 to 6.5° between 4-16 years of age (Riolo et al., 1974). Obviously the variations within groups maybe real, but are dependent on precise definitions of landmarks, Porion particularly, (anatomical v ear rod) requires extreme operator consistency and orbitale does have the possibility of range of inter and intra operator inaccuracy. (Baumrind & Franz 1971). It should be remembered in allowing for a variation in interpretation and although serial radiographs should improve operator "consistency" they need not necessarily improve the operator's anatomical "accuracy".

Orbit and Zygoma Positions

The orbital rims and zygoma positions are fundamental to the facial appearance, especially from the frontal view, (Hinds et al., 1972, Tessier 1967, Munro 1978, Engel et al., 1979), and discrepancies in anteroposterior position highlight some of these alterations to the "malar bases" (Leonard & Walker, 1977). The measurements in Table 4, analyse the position of the orbital rims (Or), and key ridge (KR), relative to cranial base (S), to the back of the maxillary complex (FR = "Foramen Rotundum") and to the front of the maxillary complex (ANS = anterior nasal spine). It should be noted that FR position throughout the series does not attempt to represent a true anatomical foramen rotundum, (the reproducibility tests inter- and intra- operator were very poor, Bowden 1977/78). "FR" was taken as the computer selected mean of the most posterior and the most superior position of the anatomical shadow of the pterygo-palatine/maxillary fossae (mean right and left), being careful not to include the superior shadow of the spheno-palatine foramen (Bowden 1970/78).

The angles to Or, KR and FR reflect changes in position of these respective anatomical points, but give no idea as to the size of any discrepancy unless the angles are related to a specified length (e.g., SN length and/or height). The positioning of any point e.g., orbital rim (Or) can be

Orbit & Zygoma Positions

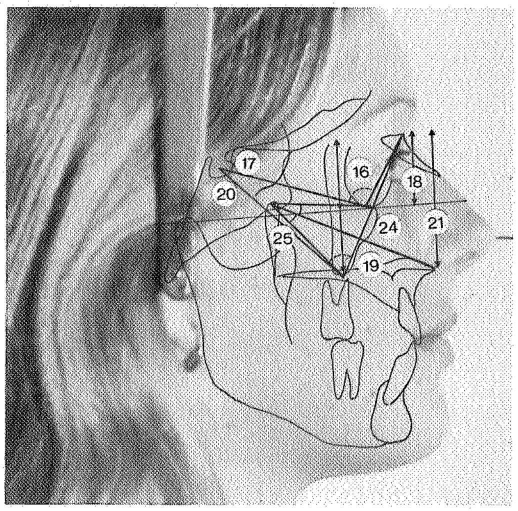


Fig. 7 C.M. ♀ 18 yrs. Orbit & Zygoma Positions

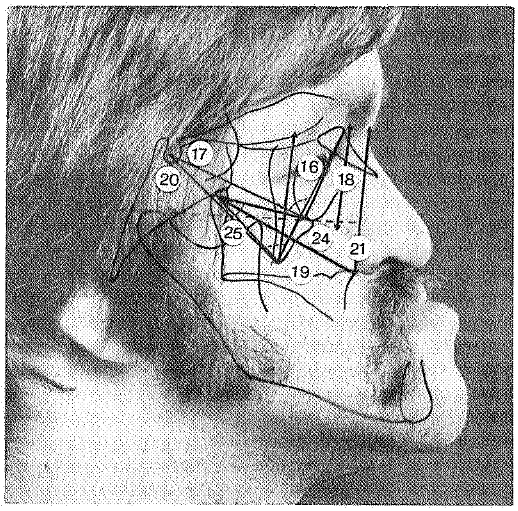


Fig. 8 B.A. ♂ 24 yrs. Orbit & Zygoma Positions

Table 4

MEASUREMENTS		AGE	MEAN		S.D.		C.M. ♀ AGED 18		B.A. ♂ AGED 24	
Orbit & Zygoma Positions			♂	♀	♂	♀	Actual	Deviation	Actual	Deviation
16. ORBITAL RIM	Angle	19	99	101	4					
S Or N	deg	9	98	100			103	●	86	--
17. ORBITAL RIM	Length	19	62	60	3					
S-Or	mm	9	55	56	2		58	●	56	—
18. ORBITAL RIM	Height	19	34	27	2	1				
N-Or (perp to Frank.)	mm	9	32	24			27	●	34	●
19. KEY RIDGE	Angle	19	74	79	4					
S KR N.	deg	9	75	80			70	—	70	●
20. KEY RIDGE	Length	19	62	58	3	2				
S-KR	mm	9	56	54	2		58	●	56	—
21. KEY RIDGE	Height	19	58	48	2					
N-KR (perp. to Frank.)	mm	9	51	44	1		48	●	52	--
22. ORB/KEY. HEIGHT	Ratio	19	60	55	2					
N-Or / N-KR (perp. to Frank.)	%	9	60	55	1		56	●	66	+++
23. ORB/KEY. LENGTH	Ratio	19	100	103	3					
S-Or / S-Kr	%	9	98	103			100	—	102	●
24. UPPER MAXILLARY	Angle	19	17	16	3					
Or FR ANS	deg	9	15	14			19	●	14	
25. LOWER MAXILLARY	Angle	19	22	16	2					
KR FR ANS	deg	9	19	14			23	+++	21	●
26. UPPER MAXILLARY	Length	19	43	41	3	2				
FR-Or	mm	9	35	36	2		39	—	38	
27. LOWER MAXILLARY	Length	19	44	37	3					
FR-KR	mm	9	39	34	2		37	●	35	--
28. UP/LOW MAXILLARY	Ratio	19	97	108	3					
FR-Or / FR-KR	%	9	96	106	2		105	—	92	—

accurately positioned by geometric truncation by using the height of Or from N, (N-Or measured perpendicular to Frankfort Plane), the length from S (S-Or) and the S-N length. It is this combination of angle (S Or N), length (S-Or) and height (N-Or) which provides optimum positioning. The addition of Rickett's Nasal Gnomen (N FR ANS) has been computed in the data base and will be considered and included in another publication (Bowden 1981).

It should be noted from the "MEAN" columns for age and sex, that sexual dimorphism exists in most measurements, including the angulations, thereby indicating the close inter-dependence of these areas of the upper craniofacial skeleton to similar sex differences in the general developmental tendencies of the upper face (Table 5) and the significance of this pattern of sexual dimorphism is discussed elsewhere (Bowden 1981).

Fig. 7. and Table 4 for Female "C.M." at 18 years suggest most measurements are within a "normal" range but the lower inter maxillary angle (KR FR ANS) is significantly increased. The measurements illustrate for a female a tendency for a slightly long upper maxillary component compared with lower maxillary components (Meas 24 & 25), but slightly reduced in measurements analysing the orbital rim position (S-Or, FR-Or and ratios with Or), although these measurements are only one S.D. outlying, apart from KR FR ANS angle.

Fig. 8 and Table 4 for male "B.A." at 24 years illustrate the effect of the anterior cranial base length reductions, including the associated sphenoidal components, reflected on orbit and zygoma positions. The angles S Or N and OR FR ANS, are reduced slightly and in absolute dimensions, S-Or length (Orbital Rim position) S-Key Ridge and FR-Key Ridge are significantly reduced. In combination, the small sphenoidal and ethmoidfrontal complex, of the cranial base components (Table 2 and Figs., 2, 3 and 4) reflect or occur in conjunction with a reduced maxillary and zygomatic complex Table 4., Fig. 8. The upper face is small in absolute antero-posterior dimensions (S-N length) and the combinations of zygoma, orbital rim positions, pterygo-palatine/maxillary fossa position (FR) and maxillary base length to ANS are all showing reductions.

The indications from these analyses, confirm that "ideal" improvement should eventuate from a surgical Le Fort II or III anterior and vertical downward movement of the anterior cranial base and it should include the zygomatic and maxillary complexes. The anterior movement would change the middle third of the face and the downward movement would compensate for the extremely small sphenoid and maxillae and their resulting retruded and inferior positions. Whether this reduction in maxillary complex of "B.A." is merely "associated with" or "resulted from" the mandibular over closure position is very debatable. More likely the maxillary and zygomatic deficiency is a direct result of the small sphenoidal complex in the cranial base, which has been spatially dominated by the mandible. Perhaps they resulted from early loss of teeth and subsequent loss of vertical dimension from a very early age, particularly as these changes occurred prior to the large accelerations in these craniofacial areas at puberty (Nanda 1955, Bjork 1967, Bowden 1978/81). These are fundamental reflections on the interconnecting roles of form and function in maxillary and mandibular development and the experimental evidence of Harvold et al., on monkeys (1973), in first branchial arch defects (1975), and in cleft palate deformities (1973, Chierici 1973/77) do not allow these apparent "over statements", to be completely dismissed.

Maxillary & Mandibular Relations

Attention is drawn to the "normal" pattern of change from 9-19 years with an increase in mean figures with age for Y Axis Angle (Meas. 29-N S Gn 59-60°) and of Mandibular Facial Axis Angle (Meas. 31-Ba C F 6n 87-89°). The mean changes occur predominantly in males and suggest the tendency for more anterior rotation of mandible with development, (i.e. from 9-19 years) somewhat agreeing with Bjork concepts from implant studies (1969/75), and follows the concept of Ricketts (1972/75) on forward mandibular growth rotation. These figures do not substantiate the "R.M.D.S." concepts that Mandibular Facial Axis (Ba CF Gn) does not change with age, but do concur for a reduction of mean corpus (Co(h) Xi SuPo) and gonial (Co(p) Go IMS) mandibular angles, (Schulhof & Bagha, 1975, Ricketts et al., 1972/75/79).

There is sexual dimorphism shown in the length measurements i.e. in Y, Mandibular and Maxillary Facial Axes lengths, Mandibular lengths (total, ramus and body) but also in angular measurements involving the mandible. These changes endorse the concept of anterior rotation with development (Bjork 1969/75, Ricketts 1972), principally occurring during adolescent acceleration (Bowden 1978/81). The sex related changes are somewhat hidden in the mean female measurements, who would tend to mature earlier (Tanner 1962) and would therefore show less of the sex related changes. It is interesting that there is sexual dimorphism with age for mandibular corpus angle but not for mandibular gonial angle. This suggests that either corpus angle (Ricketts 1972) or the

Maxillary & Mandibular Relations

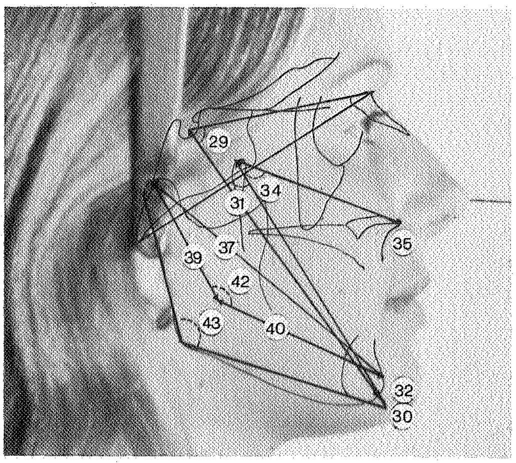


Fig. 9 C.M. ♀ 18 yrs. Maxillary & Mandibular Relations

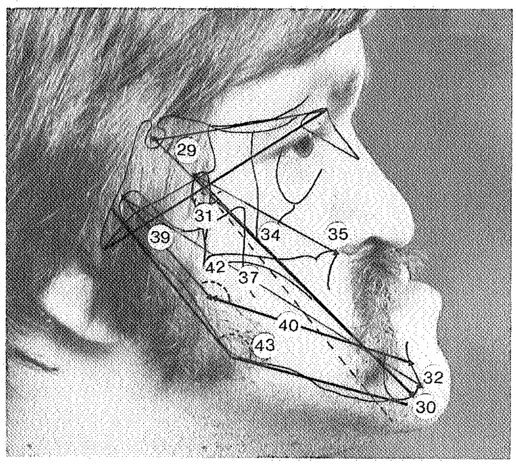


Fig. 10 B.A. ♂ 24 yrs. Maxillary & Mandibular Relations

Table 5

MEASUREMENT		AGE	MEAN ♂	MEAN ♀	S.D. ♂	S.D. ♀	C.M. ♀ AGED 18 Actual	C.M. ♀ AGED 18 Deviation	B.A. ♂ AGED 24 Actual	B.A. ♂ AGED 24 Deviation
Maxillary & Mandibular Relations										
29. Y. AXIS	Angle	19	60	58	4					
N S Gn	deg	9	59				63	+	55	
30. Y. AXIS	Length	19	140	127	6	5				
S Gn	mm	9	116	112	5	4	123	●	136	●
31. MAND. FACIAL AXIS	Angle	19	89		5					
Ba CF Gn	deg	9	87	89	4		87	●	103	+++
32. MAND. FACIAL AXIS	Length	19	115	104	5					
FR-Gn	mm	9	92	89	4		102	●	115	●
33. Y/MD. FACIAL AXIS	Ratio	19	82		3					
FR-Gn Length / S-Gn Length	%	9	79		2		82	●	84	●
34. MAX. FACIAL AXIS	Angle	19	126	125	5		125	●	120	—
Ba FR ANS	deg	9	123		4					
35. MAX. FACIAL AXIS	Length	19	69	64	5	4				
FR-ANS	mm	9	58	57	3		66	●	61	—
36. MX/MD FACIAL AXES	Ratio	19	61		3					
FR-ANS Length / FR-Gn Length	%	9	64		3		65	+	53	---
Mandibular Dimensions										
37. MANDIBULAR	Length	19	126	114	6	5				
Co-Po	mm	9	104	101	4		115	●	129	●
38. MD. FACIAL AXIS	Ratio	19	91		3					
FR-Gn Length / Co-Po Length	%	9	88		3		89	●	90	●
39. RAMUS	Length	19	49	44	4	3				
Co-Xi	mm	9	40		3		46	●	50	●
40. BODY	Length	19	76	69	4	3				
Xi-SuPo	mm	9	62	61	3		70	●	78	●
41. RAMUS/BODY	Ratio	19	65		5					
Co-Xi Length / Xi-SuPo Length	%	9					65		64	●
Mandibular Angles										
42. CORPUS	Angle	19	147	145	5					
Co(h) Xi SuPo	deg	9	149		4		144	●	152	+
43. GONIAL	Angle	19	126		6					
Co(p) Go IMS	deg	9	129				123	●	144	+++

"mandible superimposition plane" (Bjork 1969/78) probably represent a better reflection of mandibular maturation, than mandibular gonial angle (Ricketts 1975, Bowden 1978/81). It should be noted that both Y Axis Angle (N S Gn) and mandibular Facial Axis Angle (Ba CF Gn) are both dependent on N, and the latter also on Ba, which is variable in its developmental pattern (Bjork 1955), but "tends" to go posteriorly with age (Melsen 1974). It is most probable that mandibular anterior rotation accelerates the mandible more than the cranial base, particularly as cranial base is reflected in the position of "N".

Fig. 9 and Table 5 for female "C.M." at 18 years show normal maxillary and mandibular relations, although the Y Axis Angle (N S G) is slightly increased and Y Axis length is reduced, showing lowered face height. The maxillary facial axis length (FR-ANS) is insignificantly increased 2 mm, as is the mandibular facial axis length (FR-Gn) decreased by 2 mm and this indication of a lowered face height is substantiated when the ratios of MX/MD facial axis length show a significant increase to the "normal" pattern (61-65%).

For Mandibular Dimensions & Angles (Fig. 10 and Table 5) for female "C.M." also shows a normally sized mandible (CoPo), well proportioned in ramus (Co(h)-Xi) and body (Xi-SuPo) lengths, with gonial (Co(p) Go IMS) and corpus (Co(h) Xi SuPo) angles normal.

Fig. 10 and Table 5 illustrate that for male "B.A." aged 24 years, a reduction of Y Axis Angle (N S Gn 60-55°) and a reduction in Y Axis length (S-Gn 140-136 mm) the latter occuring even when the mandible looks prognathic. There is an increase in Mandibular Facial Axis Angle (Ba CF Gn = 89-103°), but a "normal" mandibular facial axis length (Fr-Gn). These measurements and others in Tables 2, 3, & 4, suggest that the anomaly in "B.A." is only slightly related to the positions of cranial base (sphenoid bone and "N" particularly), also to orbit and zygoma positions, but there is also a large component of a positional problem particularly related to mandibular plane & "Po" position. In addition the maxillary facial axis length (FR-ANS) is significantly reduced, both absolutely by 8mm, and in proportion to mandibular facial axis length, which shows a more significant reduction of 8%.

Fig. 10 and Table 5 illustrate that for male "B.A." at 24 years the mandible is slightly but insignificantly increased by 3mm to 129 mm for total length (CoPo), but ramus (Co(h)-Xi) and body lengths (Xi-SuPo) are within a "normal" range. The mandibular angles are high, both for corpus angle (Co(h) Xi SuPo) from 147-152° and extremely high for gonial angle (Co(p) Go IMS), and increase from 126-144°. This means the mandible is steeply angled at its lower border, less markedly in its internal or corpus angulation; the total mandibular length, ramus and body lengths are all within normal limits. The mandible appears positionally forward, and even though it is steeply angled, it has a low mandibular plane to SN angle and correlating all data from Tables 2, 3, & 5, overclosure must be suspected.

Face Height

The analysis of facial height components for surgical assessments are usually divided into upper and lower total face heights, i.e., N-ANS & ANS-Gn, measured perpendicular to SN (Hinds et al., 1972, Henderson 1978, Wolford et al., 1978). Sometimes N-"A", "A"-Po, are utilised instead and these measurements reflect a portion of maxillary dento/alveolar height ("A") and deletes portion of the mandibular height, Po compared with Gn. Increasing emphasis is being placed in the proportions of height of the upper face for craniofacial surgery (Tessier 1967, Henderson 1973/74/78, Munro 1978), particularly in detailed surgery of the orbit and zygoma associated with Le Fort II and III procedures. Allied to this in orthognathic surgery, maxillary impaction for the "long face syndrome" (Bell et al., 1975/77/80, Epker et al., 1974/78/80) requires quantification of areas of abnormality for upper and lower facial heights, but further clarification is desirable of the components for upper and lower dental heights, as these areas are assessed in determining segmental or alveolar surgery within these areas.

The general developmental tendency shown in Table 6, for upper facial heights, i.e., to ANS, to orbital rims (Or) and to key ridge (KR) is for sexual dimorphism, with males being greater than females. These tendencies also exist for lower face height, particularly where distances rather than angles (Meas. 49 = ANS Xi SuPo) are measured. Surprisingly the ratio for upper to lower face height (Meas. 52), also exhibits sexual dimorphism and increases in the upper segment with age, mirroring the descent of the occlusal plane.

Fig. 11 and Table 6 for female "C.M." at 18 years show an increased upper facial height of 3 mm to 58 mm, and the proportions of orbit and key ridge to upper face height reveal where the disproportion lies. Associated with a "normal" lower face height, the upper dental and lower dental height proportions are slightly reduced. These reduced dental height proportions are also contributing to a slight anterior position of the mandible. The upper face height (N-ANS) (Fig. 12 & Table 6), is small for "B.A.", a male

Facial Height

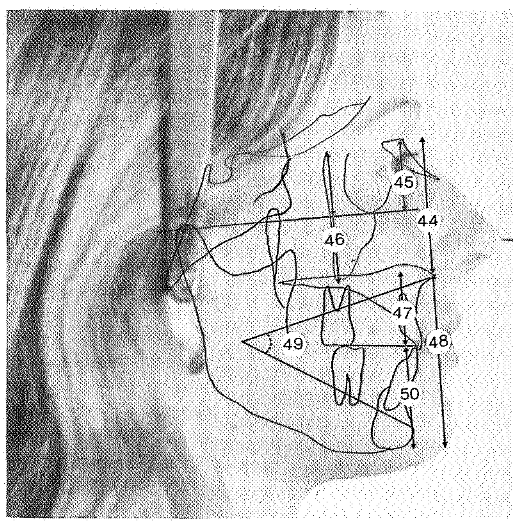


Fig. 11 C.M. ♀ 18 yrs. Facial Height

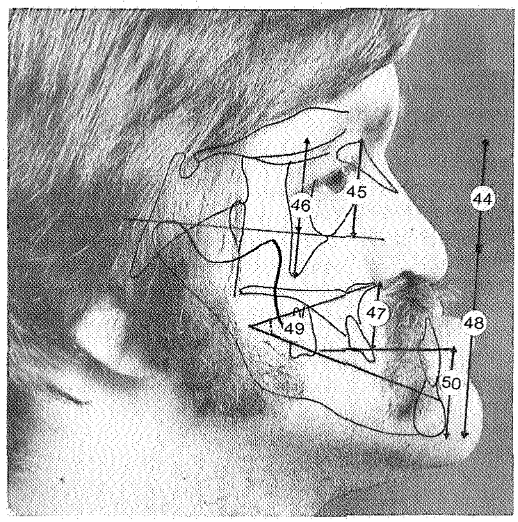


Fig. 12 B.A. ♂ 24 yrs. Facial Height

Table 6

MEASUREMENT		AGE	MEAN ♂	MEAN ♀	S.D. ♂	S.D. ♀	C.M. ♀ AGED 18 Actual	C.M. ♀ AGED 18 Deviation	B.A. ♂ AGED 24 Actual	B.A. ♂ AGED 24 Deviation
Facial Height										
Upper										
44. TOTAL UPPER FACE	Height	19	62	55	4					
N-ANS	mm	9	49	47	3		58	+	54	--
45. ORBITAL/UPPER	Ratio	19	54	49	3					
N-Or / N-ANS	%	9	65	51	4	3	46	--	63	+++
46. KEY RIDGE/UPPER	Ratio	19	93	93	6					
N-KR / N-ANS	%	9	104	97	7	6	87	--	96	●
47. UPPER DENTAL	Height	19	28	26	3					
ANS-FOP 3's	mm	9	25		2		26	●	22/35	--/++
Lower										
48. TOTAL LOWER FACE	Height	19	68	63	5	4				
ANS-Gn	mm	9	60	56	4		63	●	54/82	--/++
49. TOTAL LOWER FACE	Angle	19	46		4					
ANS Xi SuPo	deg	9	44		4		45	●	38/55	--/++
50. LOWER DENTAL	Height	19	46	44	4					
FOP-Gn	mm	9	25		2		37	—	33/48	--/+
Upper/Lower										
51. UPPER LOWER DENT.	Ratio	19	60		5					
ANS-FOP 3's / FOP-Gn	%	9	68	6			70	++	67/73	+/++
52. UPPER LOWER FACE	Ratio	19	92	88	6	9				
N-ANS / N-Gn	%	9	83		7		91	●	100	+

at 24 years, and there is a marked proportional reduction of the lower segment, i.e., Orbital rim to ANS position shown in Meas. 45. The total lower face height (Meas. 48 ANS-Gn) are compared first in postured occlusion and with an overlay occlusal denture of 28 mm in position, i.e., 54 c.f. 82 mm. The dental heights both upper and lower are reduced until restored by an artificial occlusal plane in the overlay denture. Proportionally (upper c.f. lower), the lower face height is more reduced. The reconciliation of a low mandibular plane to Frankfort and to SN, together with high corpus and gonial angles and also with extremely small lower face heights, confirms a problem of overclosure. Whilst this overclosure can be verified clinically by the apparent vertical dimension decrease and the increased free way space clinically of 10 mm, the extent of this overclosure is truly visualised by comparing "B.A." with a morphologically matched individual from the Child Growth serial data base "P.G." and illustrated in Fig. 4. Whilst clinical devices are available (Timmer 1969, L'Estrange 1976), to facilitate the determination of "true" vertical dimension, the quick computer comparison with "P.G." provides a graphic illustration of computer matching potential, utilising rudimentary discriminate analysis functions.

Dental Arch Positions

It should be noted that the "normal" tendency with development (shown in Table 7) is for sexual dimorphism to occur in those measurements correlating occlusal plane to the mandibular position (Meas. 54 & 53), but not to palatine plane (Meas. 53). The Occlusal-mandibular plane angle for males (♂) changes from 17° at 9 years to 20° at 19 years whilst in females (♀), the changes are 15° to 18° respectively. These changes have been shown previously Knott et al., 1961, but their significance has been misunderstood and minimised, Gianelly 1974. Similar sexual dimorphism exists for the occlusal to mandibular facial axis. The sexual dimorphism also expresses itself in posterior dental base lengths, (Meas. 55 & 60), incisor height (Meas., 57, 63 & 64) and molar heights (Meas., 58,65 & 66) particularly. Although the ratios of incisor to molar heights are altered with age, as the maxillary molar descends with the mandibular plane, the extent of these ratio changes are less than those for the absolute length measurements.

Fig. 13 and Table 7 for "C.M.", a female at 18 years, show the dental arches are not divergent to their respective bases, and occlusal, palatine, mandibular and facial axis planes are normal in their angulation. Clinically, in orthodontic appliance treatment, these latter measurements are the dimensions that demand close scrutiny in assessing the potential occlusal or dental contributions to mandibular rotation, particularly when reciprocating extrusion forces are placed on molars by treatment mechanics, (Schudy 1964/65, Creekmore 1967, Merrifield & Cross 1968, Isaacson et al., 1977, Bowden 1981). It should be emphasised that these angulations are 4 point variable dependent, and hide many subtle individual variations with development (Bowden 1978). They need to be co-ordinated with other variables, e.g. molar dental heights, mandibular morphology (Bjork 1969, Ricketts 1972/75/79), to optimise prediction of mandibular rotation. For "B.A." aged 24 years, the occlusal to palatine as well as to the facial axis planes are considerably reduced, presumably with loss of adequate molar support and subsequent anterior drifting and resulting overclosure.

Female "C.M." shows normal maxillary dental base lengths (6/6D to P.T.V.) with maxillary incisor and molar height and angulations all in good proportions. The mandibular base length (6/6 to Xi) is increased, as is the lower molar height to corpus (6/6 to Xi-SuPo) and the proportions of lower molar to incisor height is correspondingly increased, particularly to corpus (Xi-SuPo). These latter increased measurements merely reflect some of the effects of orthodontic treatment, as the patient had a Class II Division II type malocclusion treated by extraction of 4/4 and 4/4 and definite attempts made not to over reduce the profile by incisor retractions or changes in angulations and to close residual arch spacing after extractions, from the distal. This result of mechanotherapy is reflected in the molar height, as 6/6 have been moved mesially.

Fig. 14 and Table 8 for "B.A." a male at 24 years, show the effects of loss of teeth particularly of posterior dental support of $\frac{875432/\ 7}{876543/67}$. The functional occlusal to palatine plane and to mandibular facial axis reflects the extreme anterior positioning of the mandible. The maxillary dental base length appears increased from 23-29 mm, but is due to mesial drifting after teeth loss and the maxillary molar height is reduced, absolutely in height, as well as in proportion (the incisor to molar height ratio). In the mandible, the dental bases also reflect molar drifting, the lower incisors are substantially retroclined, reducing any support to the lip and eliminating the mental sulcus angle. The lower incisor position to "A" Po shows them to be anteriorly placed, although the incisors are retroclined, and this disparity merely reflects the forward positioning of the mandible to an over closed position. The lower incisor height is reduced, principally to the lower mandibular border but also to the mandibular corpus and these changes are reflected in the small lower face height and reduced mandibular molar height, with the molars having drifted mesially. The mandible whilst of normal size has a mandibular arch which is collapsed, and with the decreased dental height, in the upper and lower arches this combination makes a significant contribution to the overclosure problem. Just as "BA' shows reduced molar heights, the analyses in Table 8 offer the potential to maximise the delineation of molar and or incisor height

Dental Arch Positions

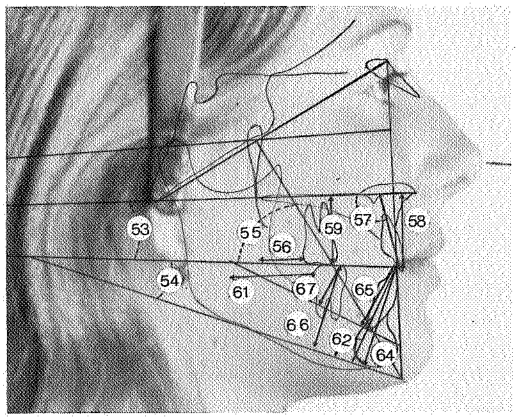


Fig. 13 C.M. ♀ 18 yrs. Dental Arch Position

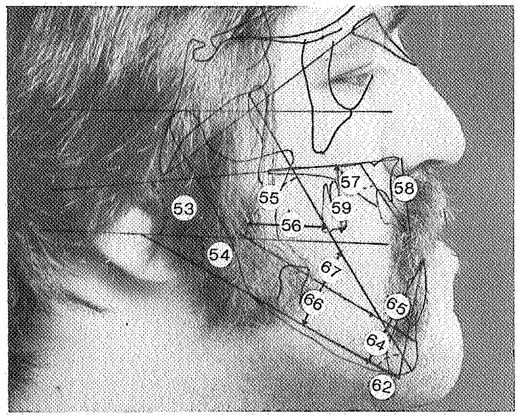


Fig. 14 B.A. ♂ 24 yrs. Dental Arch Position

Table 7

MEASUREMENT		AGE	MEAN ♂	MEAN ♀	S.D. ♂	S.D. ♀	C.M. ♀ AGED 18 Actual	C.M. ♀ AGED 18 Deviation	B.A. ♂ AGED 24 Actual	B.A. ♂ AGED 24 Deviation
Dental Arch Positions										
53. OCCLUSAL-PALATINE	Angle	19	6		4					
FOP-ANS PNS	deg	9	12		3		8	●	5	--
54. OCCLUSAL-MANDIBUL.	Angle	19	20	18	5	4				
FOP-Go IMS	deg	9	17	15	4	4	16	●	18	●
55. OCCL. MD. FAC. AXIS	Angle	19	60	55	4					
FOP-FR Gn	deg	9	63	58			58	●	48	--
Maxillary										
56. POST. DENT. BASE	Length	19	23	21	3	3				
D 616 to PTV	mm	9	13	12	3	2	21	●	29	+++
57. INCISOR ANGULATION	Angle	19	109		6					
1/1 to ANS-PNS	deg	9	104					●	110	●
58. INCISOR HEIGHT	Height	19	32	30	3	3				
1/1 to ANS-PNS	mm	9	28	26	2	3	31	●	31	●
59. MOLAR HEIGHT	Height	19	26	23	3	2				
6/6 to ANS-PNS	mm	9	18		3		24	●	23	
60. INCIS/MOLAR HEIGHT	Ratio	19	80		5					
6/6 to ANS-PNS / 1/1 to ANS-PNS	%	9	68		8		78	●		
Mandibular										
61. POST. DENTAL BASE	Length	19	33	29	4	6				
6/6D to Xi	mm	9	21		5		32	+		
62. INCISOR ANGULATION	Angle	19	91			7				
1/1 to Go.IMS	deg	9					94	●	70	---
63. INCISOR POSITION	Length	19	2.5	1.5	2					
1/1 to APO	mm	9	1		2		1.4	●	24	++++++++
64. INCISOR HEIGHT	Height	19	44	40	4					
1/1 to Go IMS	mm	9	37	35	2		39	●	33	---
65. 1/1 to Xi- SuPo	Height	19	27	23	3					
	mm	9	22		2		23	●	23	—
66. MOLAR HEIGHT	Height	19	36	32	4	3				
6/6 to Go IMS	mm	9	28	27	2	2	33	●	20	----
67. 6/6 to Xi SuPo	Height	19	16	13	4	3				
	mm	9	11		2		16	+	7	---
68. INCIS/MOLAR HEIGHT	Height	19	82	79	5	4				
6/6 to Go IMS / 1/1 to Go IMS	mm	9	77		4		84	+	30	----
69. 6/6 to Xi SuPo		19	59	54	8	7				
1/1 to Xi SuPo		9	51		6		69			

contributions to variations in "dental height" associated so profoundly in "long and short face" syndromes, (Bell 1975/77/80, Epker et al., 1974/78/80).

Soft Tissue Profile

Analysis of the soft tissue profile logically should begin the aesthetic assessment (Hinds et al., 1972, Holdaway 1964/70/78, Merrifield 1966, Steiner 1964, Burstone 1967), because it is the total profile which is of chief aesthetic concern to the patient. The soft tissue analysis logically should also end the assessment of imbalance as the soft tissue profile is primarily dependent on overall skeletal balance but, specifically, the final lip contour and position is supposed to be heavily dependent on teeth angulations for their support (Holdaway 1964/70/78, Burstone 1958/67, Subtleny 1959, Profit et al., 1970/78). Table 7 illustrates sexual dimorphism in almost all measurements, particularly Nasal shape (Meas. 71), Nasal tip position, (Meas. 72), and Nasal prominence, (Meas. 73). Similarly upper and lower lip measurements show sexual dimorphism including lip position (i.e. depth), height (Meas. 74-81), and lip and chin thickness, (Meas. 76, 82 & 83).

Fig. 15 and Table 8 shows "C.M." a female at 18 years, with a good facial harmony of lips, chin and nose, and this is reflected in the harmonious profile of 68° angulation to SN, i.e. of the "H" or profile line". The ideal line contacts soft tissue chin point, lower lip margin, upper lip margin and superior contour of nostril and co-ordinates all of these structures to facial type through the angulation of SN. The nose is well contoured (Meas. 71, SoN-NT-SUN 23°), with a slightly enlarged nasal profile length of tip to the facial profile (i.e. Meas. 72, SoN-Po/Nose Tip = 26 mm), but the nose length or prominence of the tip related to alar base and cheek is good (Meas. 73, Cheek to SoPo to Nose Tip). The upper lip margin to skeletal profile (Meas. 74, ULM to NPo) is good, as is upper lip thickness at the margin (Meas. 75, ULM to U1) and at the "A" point or superior sulcus contour (Meas. 76) and the superior sulcus contour of upper lip to "H" line (Meas. 77) is insignificantly reduced. The upper lip lengths, both aesthetic length i.e. length of lip from nose (Meas. 78, ANS to EM) and functioning length i.e. effective muscular length (Meas. 79, Or to EM) are normal for age and sex. Similarly, the lower lip margin to soft tissue profile (Meas. 80, LLM to "H" line) is normal, as is lower lip sulcus (Meas. 81, LL"B" to "H" line). The lower lip thickness (Meas. 82, LLM to L1) is on the mean value for age and sex as is the soft tissue chin thickness (Meas. 83, SoPo-Po).

Fig. 16 and Table 9 contrasts "B.A." a male aged 24 years, shown with a diagnostic 28mm overlay maxillary denture. "B.A." had a diagnosis of overclosure from clinical examination, statistical analysis of cranial base, facial divergence, maxillary and mandibular relations, and from computer graphic comparisons shown in Figs. 3 and 4.

Fig. 16 simulates the profile obtainable if the skeletal and facial heights and positions are increased by surgery. The remaining assessment of soft tissue components should be of the contributory role of teeth positions which may produce or influence nasal and lip contours. Fig. 14. emphasises that to achieve an aesthetically "ideal" soft tissue profile line, at least two alternatives should be considered. The "H" line--- drawn at 70° to SN through the superior contour of the nostril illustrates the soft tissue changes in the profile required to produce this alternative i.e. to harmonise the shadows of the existing nose size & shape with upper and lower lip contour changes (i.e. margins and sulci), with the position of soft tissue chin point. The "H" line drawn — — (at 70° to SN) through the superior contour of the nostril and illustrates the soft tissue changes in profile required in this alternative i.e. to harmonise a new position of nose (necessitating Le Fort II or Le Fort III surgery) with upper and lower lip changes and the position of soft tissue chin point.

From the Growth Unit analysis of the results of surgery and from the work of Henderson 1973/75/78 Epker et al., 1978, Munro 1978, in similar surgically treated skeletal imbalance cases, it appears that position of ANS controls the position of the back of the nose i.e cheek to alar base position and contributes slightly to nasal tip contour by altering nasal columella length and shape, particularly important in cleft palate patients. However, the position of the nasal tip is controlled by a combination of nasal bone and the attached nasal septum support. Whilst small nasal tip changes in shape may be produced by rhinoplasty, profound and significant nasal tip changes are produced usually by complex craniofacial surgery of Le Fort II or preferably Le Fort III type (Munro 78/79, Henderson 73/75/78, Tessier 1976), although onlay procedures also produce considerable change in the hereditary nasal septum deficiency syndromes eg. Binders syndrome (Munro 1979).

Table 9 shows "B.A" with a very poor retrusive nose related to a protrusive chin and an increased profile line to "H" line (87°). The ideal "H" line (70° to SN) when upper lip contour remains in its present position would highlight the small nose both in position (i.e. to a

Soft Tissue Profile

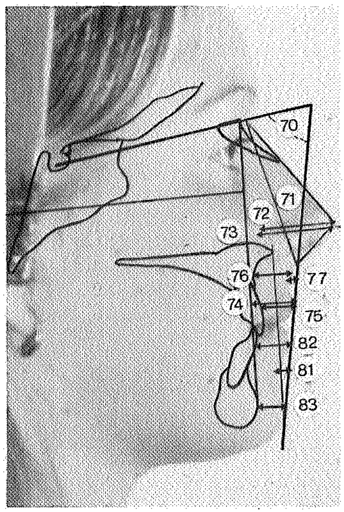


Fig. 15 C.M. ♀ 18 yrs. Soft Tissue Profile

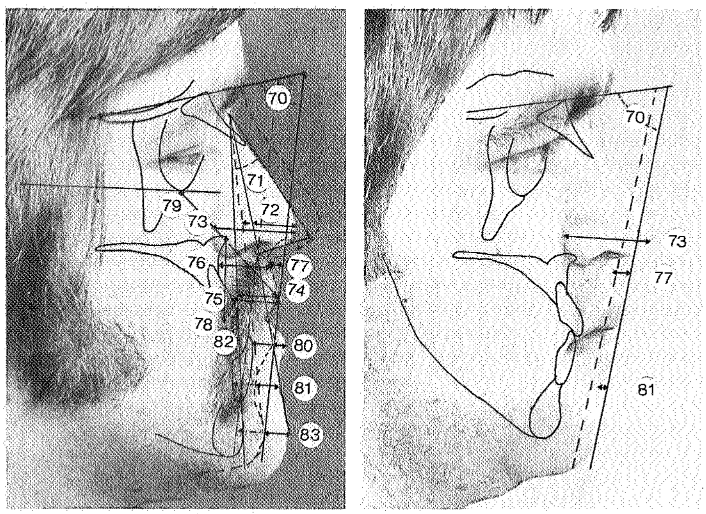


Fig. 16 B.A. ♂ 24 yrs. Soft Tissue Profile

Table 8

MEASUREMENT		AGE	MEAN ♂	MEAN ♀	S.D. ♂	S.D. ♀	C.M. ♀ AGED 18 Actual	C.M. ♀ AGED 18 Deviation	B.A. ♂ AGED 24 Actual	B.A. ♂ AGED 24 Deviation
Soft Tissue Profile										
Profile										
70. "H" LINE	Angle	19	70		5					
SN-SoN ULM	deg	9	68	70	4		68	●	87	+++
Nasal Contours										
71. NASAL SHAPE	Angle	19	26	24	4					
SoN-NT-SUN	deg	9	22		3		23	●	19	—
72. NASAL TIP POSITION	Depth	19	25	24	4					
SoN-SoPo to Nose Tip	mm	9	20		3		26	●	15	—
73. NASAL PROMINENCE	Depth	19	32	28	4					
Ch-SoPo to Nose Tip	mm	9	24		3		28	●	28	—
Upper Lip										
74. LIP POSITION	Depth	19	20	18	4					
ULM to N.Po	mm	9	20		3		17	●	20	●
75. MARGIN THICKNESS	Depth	19	16	12	2					
ULM to U1	mm	9	13		2		13	●	20	++
76. SULCUS THICKNESS	Depth	19	18	14	2					
UL"A" to "A"	mm	9	14				13	●	21	+
77. SUP. SULCUS CONTOUR	Depth	19	5	2						
UL"A" to "H" Line	mm	9	3				4	●	5/11	●/+++++
78. LIP/NOSE HEIGHT	Height	19	28	26	4					
ANS-EM	mm	9	24		3		25	●	27	●
79. LIP/MUSCLE	Height	19	52	45	5					
Or to EM	mm	9	42	45	4		48	●	45	—
Lower Lip										
80. LIP POSITION	Depth	19	0		2					
LLM to "H" Line	mm	9	2		2		0	●	4/15	--/----
81. SULCUS CONTOUR	Depth	19	6		2					
LL"B" to "H" Line	mm	9	4		2		5	●	7/10	●/++
82. LIP THICKNESS	Depth	19	16	14	3					
LLM to L1	mm	9	14		3		14	●	15	●
Chin										
83. CHIN THICKNESS	Depth	19	16	12	3					
SoP-Po	mm	9	12	10	3		12	●	15	●

"normal" "H" line —— should contact the superior nostril sulcus - - -) and reduce the nasal shape and nasal tip position (SoN.Po-No Tip 15 c.f. 25mm), and slightly in effective nasal prominence (cheek SPO to Nose Tip 28 c.f. 32 mm). The upper lip margin is in a good A-P position (aided by overlay) to "H" line and to N-Po (Meas. 74). The upper lip sulcus (Meas. 76) needs recontouring particularly to alternative - - -

Thus ideally the upper lip margin needs bringing forward 2mm, and the sulcus less so (i.e. 1/1 moved with crowns anteriorly). The upper lip thickness is slightly increased (Meas. 75.) and in Meas. 76, from superior sulcus to "A" and the upper lip/nose length (Meas. 78 ANS to Embrasure) is good although the functioning upper lip length (Meas. 79., Or to Embrasure) is reduced. The lower lip margin (Meas. 80) in Table 8 is protrusive to — "H" line and to — — "H" line, and need a 4mm reduction to meet the "H" line — and a 15mm reduction to the — — — "H" line. The inferior sulcus of the lower lip (Meas. 81) need 7 and 14mm reductions respectively to these two profile "H" lines.

The soft tissue chin point requires a 8mm reduction to the — "H" line and a 18mm reduction to the — — — "H"line. This means that ideally the mandibular surgical reduction requires a tilting of the mandible and or combined with presurgical orthodontics to change incisor angulations and help the mental sulcus angle.

Fig. 17 illustrates the final surgical result of a high Le Fort I procedure (bringing key ridges minimally forward, extruding and protruding the maxillary area, more at posterior than anteriorly to give a posterior "bite" opening i.e. mandibular clockwise rotation,) in combination with a mandibular sagittal split ostectomy, similarly designed to produce "bite" opening on mandible with mandibular clockwise rotation to increase vertical facial heights slightly less than the overlay denture. The photographs highlight in Figs. 16, the results of a compromise of —— accepting a rather small nose in a retrusive position, but producing a balanced upper and lower lip position and thickness, a mildly under contoured lower lip but with an acceptable chin position.

Fig. 17, for overall skeletal changes in "B.A." illustrate the changes from 1978 (black) to 1979 (green) with the increased vertical onlay denture, mandible 22 mm posteriorly and 28 mm inferiorly. In 1980 (red—post-operative) the maxilla has been brought anteriorly 7 mm and inferiorly 5 mm, the mandible was rotated posteriorly 27 mm and inferiorly 23 mm, due to the combination of maxilla repositioning, and the mandibular sagittal split osteotomy which also shortened the mandible in length by 12 mm.

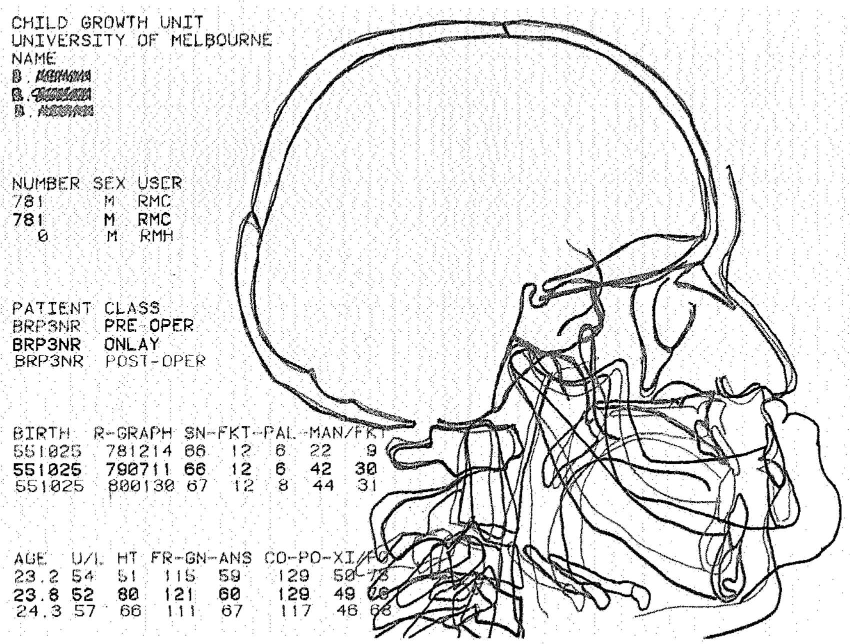
The overall profile changes illustrated in Fig. 18 show the vertical and horizontal changes produced in nasal length and position, also the profound lengthening in upper lip and the changes in upper and lower lip contours. The vertical onlay denture only (from 1978—black, to 1979—green), the nose has dropped 5 mm inferiorly and 5 mm posteriorly, the upper lip elongating 18 mm vertically, posteriorly 10 mm. The changes from 1978 (black–pre-operative) to 1979 (green—onlay denture) registered at incisive canal, shows how the nose and lip has dropped posteriorly 5 mm, and a further 5 mm drop occurred to 1980 (red—post-surgical), as well as vertical movements of 8 and 2 mm respectively. These analyses emphasise how changes in vertical dimensions, allow for profound changes in the lip length, lip contours, and reveals more effective red margin. They substantiate the changed anatomical position and the effect of the upper lip elevators (i.e., Levator labii superioris alaequae nasi, Levator labii superioris, Levator anguli oris, and Zygomaticus minor and major) as they interface "hook-like" through cross-sectional elements of Orbicularis oris, graphically illustrated by Lightoller (1926).

These changes reveal the interplay of skeletal with soft tissue relations, and how vertical dimension controls not only mandibular positions (Schudy 1964, Creekmore 1967, Merrifield & Cross 1970, Isaacson et al., 1977), but indirectly effects the anatomical functioning of, and therefore soft tissue position. The magnitude of changes in skeletal profile by anti- and clockwise "orthodontic" rotation of the mandible (Isaacson et al., 1977) in "convergent" and "divergent" faces has been confirmed surgically in "long" and "short" faced syndromes (Bell et al., 1977/80, Epker et al., 1976/77/80).

These effects on horizontal position of the soft tissues of nose and lips achieved by vertical changes in maxillary mandibular relations by surgery, also have a profound message for the control of these dimensions in orthodontics. Indirectly they substantiate the necessity to make soft tissue measurements conditional upon vertical and horizontal skeletal configurations, Holdaway 1964/70/78 Merrifield 1966, Engel et al., 1979.

The precise clinical applications of these analyses, particularly to orthodontic assessments will be the subject of a future publication.

Fig. 17 Computer graphic overall superimposition of "B.A."



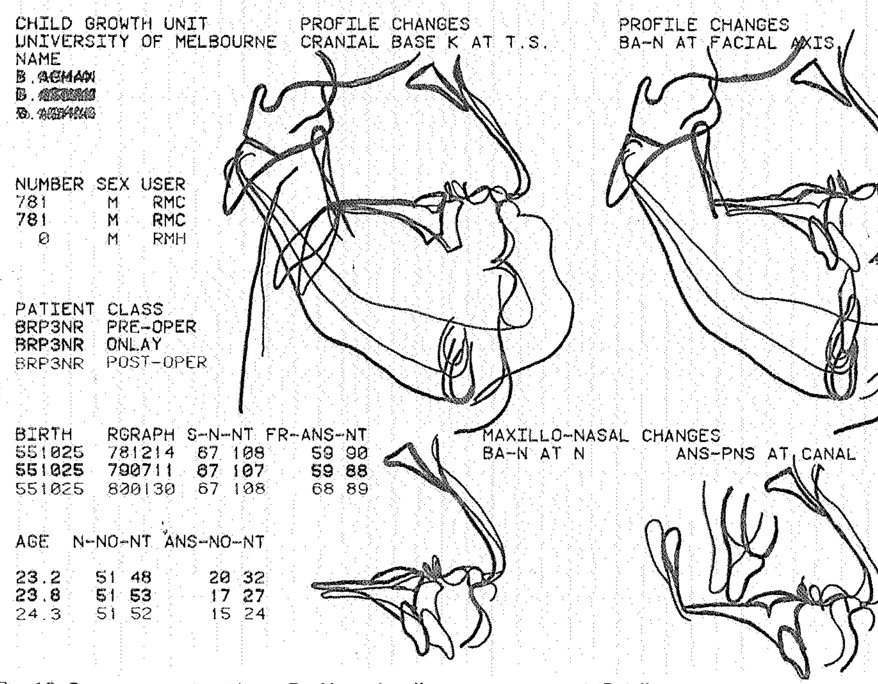


Fig. 18 Computer graphic "4 area Profile analysis" superimposition of "B.A."

REFERENCES

ACKERMAN, R.J. (1979)
"The Michigan School Study cephalometric norms expressed in template form".
Amer.J.Orthodont. 75:282-290.

ANDERSON, J.P. & JOONDEPH. D.R., TURPIN, D.L. (1973)
"A cephalometric study of profile changes in orthodontically treated cases ten years out of retention".
The Angle Orthodont. 43:324-336.

BAYER, L.M. & BAYLEY, N. (1959)
"Growth Diagnosis".
The University of Chicago Press, Chicago.

BAUMARIND, S. & MILLER, D.M. (1980)
"Computer-aided head film analysis: The University of California, San Francisco method". Amer. J. Orthodont. 78:41-65

BELL, W.H. (1969)
"Revascularization and bone healing after maxillary osteotomy: A study using adult rhesus monkey". J.Oral Surg. 27:249-255.

BELL, W.H. (1975)
"Le Fort I Osteotomy for correction of maxillary deformities".
J.Oral Surg. 33:412-426.

BELL, W.H., CREEKMORE, T.D. & ALEXANDER, R.G. (1977)
"Surgical correction of the long face syndrome".
Amer.J.Orthodont. 71:40-67.
BELL, W.H., PROFFIT, W.T. & WHITE, R.P. (1980)
"Surgical correction of Dento Facial Deformities".
Vols. 1 & 2, W.B. Saunders & Co., Philadelphia.
BERGERSEN, E.O. (1980)
"Enlargement and distortion in cephalometric radiography: compensation tables for linear measurements".
Angle Orthodont. 50:230-244.
BHATIA, S.N., WRIGHT, G.W. & LEIGHTON, B.C. (1979)
"A proposed multivariate model for prediction of facial growth".
Amer.J. Orthodont. 75:264-281.
BJORK, A. (1947)
"The face in profile. An anthropological X-ray investigation on Swedish children and conscripts" Sven. tand.-Tids. 40: Suppl.
BJORK, A. (1955)
"Cranial base development. A follow up x-ray study of the individual variation in growth occurring between the ages of 12 and 20 years and its relation to brain case and face development".
Amer.J.Orthodont. 41:198-225
BJORK, A. & SOLOW, B. (1962)
"Measurement on radiographs".
J.Dent.Res. 41:672-683.
BJORK, A. & HELM, S. (1967)
"Prediction of the age of maximum puberal growth in body height".
Angle Orthodont. 37:134-143.
BJORK, A. (1969).
"Prediction of mandibular growth rotation".
Amer.J.Orthodont. 55:585-599.
BJORK, A. & SKIELLER, V. (1972)
"Facial development and tooth eruption".
Amer.J.Orthodont. 62:339-383.
BJORK, A. & SKIELLER, V. (1977)
"Growth of the maxilla in three dimensions as revealed radiographically by the implant method".
Brit.J.Orthodont. 4:53-64.
BJORK, A. & SKIELLER, V. (1978)
"Cephalometric Growth Analysis".
Course in Growth and Orthodontic Diagnosis, Copenhagen.
BOWDEN, B. D. (1970)
"Some applications of radiographic anatomy to cephalometric tracings".
Aust.Orthodont.J. 2:128-141.
BOWDEN, B.D. (1976)
"Epiphysial changes in the hand/wrist areas as indicators of adolescence".
Aust.Orthodont.J. 4:87-104.
BOWDEN, B.D. (1977)
"Manual for digitising lateral radiographs".
Technical notes, Cranio-facial Monograph series, Child Growth Unit, University of Melbourne.
BOWDEN, B.D. (1978)
"Manual of descriptions of data for lateral cephalometric measurements".
Technical notes, Cranio-facial Monograph series, Child Growth Unit, University of Melbourne.
BOWDEN, B.D. (1978)
"The influence of biologic age on the development of craniofacial morphology".
J.V. Mershon Memorial Lecture, A.A.O. Anaheim. To be published Amer.J.Orthodont. 1981.
BROADBENT, B.H. (1931)
"A new X-ray technique and its application to orthodontia".
Angle Orthodont. 1:45-66.
BROADBENT, B.H. Snr., BROADBENT, B.H. Jnr. & GOLDEN, W.H. (1975)
"Bolton standards of dentofacial developmental growth".
C.V. Mosby Co., St. Louis.
BRODIE, A.G. (1941)
"On the growth pattern of the human head from the third month to eighth year of life".
Amer.J. of Anat. 68:209-262.
BROWN, T., BARRETT, M.J. & GRAVE, K.C. (1971)
"Facial growth and skeletal maturation at adolescence".
Tandlae. 75:1211-1222.
BURKE, P.H. (1980)
"Serial growth changes in the lip".
Brit.J.Orthodont. 7:17-30.
BURSTONE, C.J. (1958)
"The integumental profile".
Amer.J.Orthodont. 44:1-24.
BURSTONE, C.J. (1967)
"Lip posture and its significance in treatment planning".
Amer.J.Orthodont. 53:262-284.
CAMERON, N. (1978)
"The methods of Auxological Anthropometry".
Human Growth: 2—Postnatal Growth, 35-90.
Ed: Falkner, F. & Tanner, J.M.
Plenum Press, New York and London.
CHACONAS, S.J. & BARTROFF, J.D. (1975)
"Prediction of normal soft tissue facial changes".
Amer.J.Orthodont. 45:12-25.
CHEBIB, F.S., CLEALL, J.F. & CARPENTER, K.J. (1976)
"On-line computer system for the analysis of cephalometric radiographs".
Angle Orthodont. 46:305-311.
CHIERICI, G. (1977)
"Experiments on the influence of oriented stress on bone formation replacing bone grafts".
Cleft Palate Journal 14:114-123.
COBEN, S.E. (1979)
"Basion Horizontal Coordinate Tracing Film".
J.Clin.Orthodont. 13:598-605.
COOK, R.M. & HINRICHSEN, G.
"The mandibular sagittal split osteotomy—a clinical and cephalometric review".
Trans. IVth Int. Conf. on Oral. Surg. Munksgaard, Copenhagen, 1973.
COCCARO, P.J., FIRMIN, F. & CONVERSE, J.M. (1974)
"Cephalometric analysis in diagnosis and treatment planning of craniofacial dysostoses".
J.Plast. & Recons.Surg. 54:300-311.
COCCARO, P.J., McCARTHY, J.G., EPSTEIN, G.F., WOOD-SMITH, D. & CONVERSE, J.M. (1980)
"Early and late surgery in craniofacial dysostosis: A longitudinal cephalometric study".
Amer.J. Orthodont. 77:421-436.
CREEKMORE, T.D. (1967)
"Inhibition or stimulation of the vertical growth of the facial complex: its significance to treatment".
Angle Orthodont. 37:285-297.
DE COSTER, L. (1953)
"A new line of reference for the study of lateral facial radiographs".
Amer.J.Orthodont. 39:304-306.
DOWNS, W.B. (1948)
"Variations in facial relationships: their significance in treatment and prognosis."
Amer.J.Orthodont. 34:812-840.
DOWNS, W.B. et al. (1952)
"The role of cephalometrics in orthodontic case analysis and diagnosis".
Amer.J.Orthodont. 3:162-182.
DOWNS, W.B. (1956)
"Analysis of the dentofacial profile".
Angle Orthodont. 26:191-212.
ENGEL, G.A., QUAN, R.E. & CHACONAS, S.J. (1979)
"Soft tissue change as a result of maxillary surgery: A preliminary study".
Amer.J.Orthodont. 75:291-300.
ENLOW, D.H. (1975)
"Handbook of facial growth".
Philadelphia: Saunders & Co.
ENLOW, D.H., MOYERS, R.E., HUNTER, W.S. & McNAMARA, J.A. Jnr. (1969)
"A procedure for the analysis of intrinsic facial form and growth".
Amer.J.Orthodont. 56:6-23
EPKER, B.N. & WOLFORD, L.M. (1975)
"New combined anterior and posterior maxillary osteotomy: A new technique".
J.Oral Surg. 33:842-851.
EPKER, B.N., WOLFORD, L.M. & FISH, L.C. (1978)
"Mandibular deficiency syndrome. Part II: Surgical considerations for mandibular advancement".
Oral Surg., Oral Med., Oral Path. 45:349-363.
EPKER, B.N. & WOLFORD, L.M. (1980)
"Dento Facial Deformities, Surgical orthodontic correction".
C.V. Mosby Co., St. Louis.
FABER, D., BURSTONE, C.J. & SOLANCHE, D.J. (1978)
"Computerised interactive orthodontic treatment planning".
Amer.J.Orthodont. 73:36-46
FREIHOFER, H.P.M. (1975)
"Late results after advancing the mandible by sagittal splitting of the rami".
J.Max-fac.Surg. 3:250-257.
FREIHOFER, H.P.M. (1977)
"Results of osteotomies of the facial skeleton in adolescence".
J.Max-fac.Surg. 5:267-297.
FISHER, R.A. (1950)
"Statistical methods for research workers".
11th Edition, Oliver and Boyd.

FRISCH, R.E. (1974)
"A method of prediction of age and menarche from height and weight at ages 9 through 13 years".
Pediatrics 53:384.
GARN, S.M. (1958)
"Statistics—a review".
Angle Orthodont. 28:149-165.

GRUELICH, W.W. & PYLE, S.I. (1959)
"Radiographic atlas of skeletal development of the hand and wrist".
2nd Edition, Oxford University Press, Oxford.
GRUMBACH, M.M., ROTH, J.C., KAPLAN, S.L. et al. (1974)
"The control of the onset of Puberty".
John Wiley & Sons, New York, 115-166.
GRUMBACH, M.M., RICHARDS, G.E., CONTE, F.A. et al. (1978)
"The endocrine function of the human adrenal complex".
Serono Symposium No. 18, Academic Press, London, 583-612.

GRUMBACH, M.M. & KAPLAN, S.L. (1980)
"Physiology of Puberty".
Endicrinology 1980. 43-48.
Australian Academy of Science, Canberra.
HAMBLETON, R.S. (1964)
"The soft-tissue covering of the skeletal face as related to orthodontic problems".
Amer.J.Orthodont. 50:405-420.

HARVOLD, E.P., VARGERVIK, K. & CHIERICI, G. (1973)
"Morphogenetic experiments in cleft palate, mandibular response".
Cleft. Palate.J. 10:51-61.
HARVOLD, E.P., CHIERICI, G. & VARGERVIK, K. (1973)
"Morphogenetic experiments in facial assymmetry: The nasal cavity".
Amer.J.Phys. Anthropol. 38:291-299.
HARVOLD, E.P. (1975)
"New treatment principles for mandibular malformation".
Transactions International Orthodontic Congress, Frogmore:
Crosby Lockwood Staples, 174-154.
HELM, S., SIERSBAEK-NIELSEN, S., SKIELLER, V. & BJORK, A. (1971)
"Skeletal maturation of the hand in relation to maximum puberal growth in body height".
Tandlae. 75:1223-1234.
HENDERSON, D. & JACKSON, I.T. (1973)
"Naso-maxillary Hypoplasia — the Le Fort II Osteotomy".
Brit.J.Oral Surg. 11:77-93.
HENDERSON, D. (1974)
"The assessment and management of bony deformities of the middle and lower face".
Brit.J.Plast.Surg. 27:287-296.
HENDERSON, D. (1978)
"Course notes on orthognathic surgery".
Department of Plastic Surgery,
Canniesburn Hospital, Bearsden.
HINDS, E.C. & KENT, J.N. (1972)
"Surgical treatment of developmental jaw deformities".
C.V. Mosby Co. St. Louis.
HOLDAWAY, R. (1964)
Cited in Hambleton, R.S.
"Soft tissue covering of the skeletal face as related to Orthodontic problems".
Amer.J.Orthodont. 50:405.
HOLDAWAY, R. (1978)
"The V.T.O. procedure".
The University of Texas, Department of Orthodontics, Houston, Texas.
HOUSTON, W.J.B. (1979) January
"The current status of facial growth prediction: A review".
Brit.J.Orthodont. 6:11-17.
HOVINGA, J., KRAAL, E.R. & ROORDA, L.A.M. (1979)
"A follow up of osteotomies for dysgnathia".
J.Max-Fac. Surg. 7:271-282.
HUNTER, C.J. (1966)
"The correlation of facial growth with body height on skeletal maturation at adolescence".
Angle Orthodont. 36:44-54.
ISAACSON, R.J., ZAPFEL, R.J., WORMS, F.W. & ERDMAN, A.G. (1977)
"Effects of rotational jaw growth on the occlusion and profile".
Amer.J.Orthodont. 72:276-286.
JOHNSON, L.E. (1968)
"A statistical evaluation of cephalometric prediction".
Amer.J.Orthodont. 38:284-304.
JOHNSON, L.E. (1975)
"A simplified approach to prediction".
Amer.J.Orthodont. 67:253-257.

KANAZAWA, E. & KAMISHI, H. (1978)
"Evaluation of facial osteotomy with the aid of moire contourography".
J.Max-Fac. Surg. 6:233-239.
KNOTT, V.B. (1941)
"Physical measurements of young children".
Univ.Iowa Stud. Child Welfare 18:3.
KNOTT, V.B. (1961)
"Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to adolescence".
Amer.J.Phys. Anthropol. 19:263.
L'ESTRANGE, P.R. (1976)
"Application of lateral skull cephalometry to prosthodontics".
Aust.Orthodont.J. 4:146-152.
LINES, P.A. & STEINHAUSER, E.W. (1974)
"Soft tissue changes in relationship to movement of hand structures in orthognathic surgery".
J.Oral Surg. 32:891-896.
MARESH, M.M. (1948)
"Growth of the heart related to bodily growth during childhood and adolescence".
Paediatrics 2:382-405.
MARSHALL, W.A. & TANNER, J.M. (1970)
"Variation in the pattern of pubertal changes in boys".
Arch. Dis. Child. 45:13-23.
MARSHALL, W.A. (1978)
"Puberty".
Human Growth: 2 Postnatal Growth. Edited by F. Falkner and J. M. Tanner.
Plenum Press. New York and London 1978. 141-181.
MELSEN, B. (1974)
"The cranial base".
Acta odont. Scand. 32: Suppl.62.
MERRIFIELD, L.L. (1966)
"The profile line as an aid in critically evaluating facial esthetics".
Amer.J.Orthodont. Nov. 804.
MERRIFIELD, L.L. & CROSS, J.J. (1968)
"Directional Forces"
Amer.J.Orthodont. 57:435-464
MILLER, R.L., HUNTER, W.S. & MOYERS, R.E. (1970)
"Computer storage and retrieval system for two dimensional outlines".
J.Dent.Res. 49:1176
MITCHELL, D.L., JORDAN, J.F. & RICKETTS, R.M. (1975)
"Arcial growth with metallic implants in mandibular growth prediction".
Amer.J.Orthodont. 68:655-659.
MOORREES, C.F.A. & KEAN, M.R. (1958)
"Natural head position, a basic consideration for the analysis of cephalometric radiographs".
Amer.J.Phys. Anthropol. 16:213-234.
MOORREES, C.F.A., VON VENROOIJ, M.E., LEBRET, L.M.L., GLATKY, C.B., KENT, R.L. & REED, R.B. (1976)
"New norms for the mesh diagram analysis".
Amer.J.Orthodont. 69:57-71.
MOYERS, R.E. & HIRSCHFIELD, W.J. (1971)
"Predictions of craniofacial growth. The state of the art".
Amer.J.Orthodont. 60:435-444.
MOYERS, R.E., BOOKSTEIN, F.L. & GUIRE, K.E. (1979)
"The concept of pattern in craniofacial growth".
Amer.J.Orthodont. Aug: 76:136-148.
MUNRO, I.R. (1978)
"The effect of total maxillary advancement on facial growth".
J. Plast & Recons.Surg. 62:751-762.
McEWAN, J.D. & MARTIN, J. (1967)
"The rapid assessment of cephalometric radiographs".
Dent. Pract. 17:195-198.
McNEIL, R.W., PROFIT, W.R. & WHITE, R.P. (1972)
"Cephalometric prediction for orthodontic surgery".
Angle Orthodont. 42:154-164.
NANDA, R.S. (1955)
"The rates of growth of several facial components measured from serial cephalometric roentgenograms".
Amer.J.Orthodont. 41:658-673.
OBWEGESER, H.L. (1964)
"The indications for surgical correction of mandibular deformity by the sagittal splitting technique".
Brit.J.Oral Surg. 1:157-161.
OBWEGESER, H.L. (1969)
"Surgical correction of small or retrodisplaced maxilla".
Plast.Reconstr.Surg. 43:351-364.
PIMENIDIS M.Z. & GIANELLY, A.A. (1972)
"The effect of early post natal contylotomy on the growth of the mandible".
Amer.J.Orthodont. 62:42-47.

PHILIPS, B.M. & BELL, W.H. (1978)
"Atrophy of mandibular condyles after sagittal ramus split osteotomy".
J.Oral Surg. 36:45-49.
POPOVICH, F. & THOMPSON, G.W. (1977)
"Craniofacial templates for orthodontic case analysis".
Amer.J.Orthodont. 71:406-420.
PROFFIT, W.R. & WHITE, R.P. (1970)
"Treatment of severe malocclusions by correlated orthodontic surgical procedures".
Angle Orthodont. 40:1-10.
QUAN, R.E., CHACONAS, S.J. & ENGEL, G.A. (1979)
"Soft tissue change as a result of maxillary surgery: A preliminary study".
Amer.J.Orthodont. 75:291-300.
RICKETTS, R.M. (1957)
"Planning treatment on the basis of the facial pattern and an estimate of growth".
Angle Orthodont. 27:14-37.
RICKETTS, R.M. (1972)
"A principle of arcial growth of the mandible".
Angle Orthodont. 42:368-386.
RICKETTS, R.M., BENCH, K.W. & SCHULHOF, R. (1972)
"An overview of computerized cephalometrics".
Amer.J.Orthodont. 61:11-28.
RICKETTS, R.M. (1975)
"Mechanisms of mandibular growth: A series of enquiries on the growth of the mandible".
Determinants of Mandibular form and growth.
Ed. by McNamara, J.A., 77-100.
RICKETTS, R.M. (1979)
"A four step method to distinguish orthodontic changes from natural growth".
Bioprogressive Therapy
Rocky Mountain Orthodontic services. 327-345.
RIOLO, M.L., MOYERS, R.E., McNAMARA, J.A. & HUNTER, W.S. (1974)
"An atlas of craniofacial growth".
Monograph 2, Craniofacial Growth Series.
Centre for Human Growth and Development.
Ann Arbor, Michigan, U.S.A.
ROCHE, A.F. & SUNDERLAND, S. (1959)
"Melbourne University Child Growth Study".
Med.J.Aust. 1:559-562.
ROCHE, A.F., WAINER, H. & THISSEN, D. (1975a)
"Predicting adult stature for individuals".
Monogr.Pediatr. 3:1-114.
ROCHE, A.F., WAINER, H. & THISSEN, D. (1975b)
"Skeletal maturity. The knee joint as a biological indicator". Plenum Press, New York and London.
ROCHE, A., LEWIS, A.B., WAINER, H. & McMARTIN, R. (1977)
"Late elongation of the cranial base".
J.Dent.Res. 56:802-808.
ROCHE, A.F. (1978)
"Bone growth and maturation".
Human Growth: 2 Postnatal Growth.
Eds. F. Falkner, J.M. Tanner.
Plenum Press, New York & London. 313-355.
ROTH, J., KAHN, C.R., NEVILLE, J.R., BAR, R.S. & MUGGED, M. (1980)
"Receptors for peptide hormones".
Edocrinology 1980 19-24 Eds. I.A.Cumming, J.W.Funder and F.A.O. Mendelsohn.
Australian Academy of Science, 19-24.
SASSOUNI (1969)
"A classification of skeletal facial types".
Amer.J.Orthodont. 55:109-123.
SASSOUNI, V.(1974)
"Diagnosis and treatment of dento facial abnormalities".
Springfield, E.C. Thomas.
SCHENDEL, S.A., EISENFELD, J.H., BELL, W.H. & EPKER, B.N. (1976)
"Superior repositioning of the maxilla: Stability and soft tissue osseous relations".
Amer.J.Orthodont. 70:663-673.
SCHENDEL, S.A. & EPKER, B.N. (1980)
"Results after mandibular advancement surgery: an analysis of 87 cases".
J.Oral Surg. 38:265-282.
SCHUDY, F.F. (1964)
"Vertical growth versus antero-posterior growth as related to function and treatment".
Angle Orthodont. 35:75-93.
SCHUDY, F.F. (1965)
"The rotation of the mandible resulting from growth, its implications in orthodontic treatment".
Angle Orthodont. 35:36-50.
SCHULHOF, R.J. & BAGHA, L. (1975)
"A statistical evaluation of the Ricketts and Johnston growth forecasting methods".
Amer.J.Orthodont. 67:258-276.
SLAGSVOLD, O. & PEDERSEN, K. (1977)
"Gonial angle distortion in lateral head films: A methodologic study".
Amer.J.Orthodont. 71:554-564.
SOLOW, B. (1966)
"The pattern of craniofacial associations. A morphological and methodological correlation and factor analysis study on young male adults".
Acta odont. Scand. 24:Suppl.46.
SOLOW, B. (1970)
"Computers in cephalometric research".
Computers in Biology and Medicine 1:41-49.
SOLOW, B. (1973)
"Graphical stimulation of craniofacial growth".
Trans. of the European Orthodontic Society. 516-521.
SOLOW, B. & TALLGREN, N. (1976)
"Head posture and craniofacial morphology".
Amer.J.Phys.Anthropol. 44:417-435.
SOLOW, B. & GREVE, E. (1979)
"Craniocervical angulation and nasal respiratory resistance".
IN McNamara, J.A., (ed.) Naso-respiratory function and craniofacial growth.
Ann Arbor, Center for Human Growth and Development, University of Michigan. 87-119.
SOLOW, B. (1980)
"The dento-alveolar compensatory mechanism: Background and clinical implications".
Brit.J.Orthodont. 7:145-161.
SPEILMAN, R.S., DA ROCHA, F.J., WEITKAMP, L.R., WARD, R.H., NEEL, J.V. & CHAGNON, N.A. (1972)
"The genetic structure of a tribal population, the Yanomama Indians. VII. Anthropometric differences among Yanomama villages.
Amer.J.Phys.Anthropol. 37:345.
SPERRY, T.P., SPEIDEL, T.M., ISAACSON, R.J. & WORMS, F.W. (1977) May
"Differential treatment planning for mandibular prognathism".
Amer.J.Orthodont. 71:531-541.
STEINER, C. (1964)
Cited in Hambleton, R.S. "Soft tissue covering of the skeletal face as related to orthodontic problems".
Amer.J.Orthodont. 50:405.
STOCKER, N.G. & EPKER, B.N. (1974)
"The posterior maxillary osteotomy: A retrospective study of treatment results".
Int.J.Oral Surg. 3:153-157.
SUBTELNY, J.D. (1959)
"A longitudinal study of soft tissue facial structures".
Amer.J.Orthodont. 45:481-507.
TANNER, J.M. (1962)
"Growth at adolescence".
2nd ed., Blackwell, Oxford.
TANNER, J.M. & MARSHALL, W.A. (1969)
"Variations in the pattern of pubertal changes in girls".
Arch. of Dis. in Child. 44:291.
TANNER, J.M., WHITEHOUSE, R.H., MARSHALL, W.A., HEALY, M.J.R. & GOLDSTEIN, H. (1975)
"Assessment of skeletal maturity and prediction of adult height".
TW2 Method, London Academic Press.
TESSIER, P. (1968)
"Transactions of 4th International Congress of Plastic Surgery".
Rome 1967.
TESSIER, P. (1976)
"Anatomical classification of facial, cranio-facial and latero-facial clefts".
J.Max-Fac.Surg. 4:69.
THILANDER, B. & INGERVALL, B. (1973)
"The human spheno-occipital synchondrosis II. A historical and microradiographic study of its growth".
Acta odont. Scand. 31:323-334.
THOMPSON, G.W. & POPOVICH, F. (1973)
"Relationship of craniofacial changes and skeletal age increments in females".
Hum.Biol. 45:595-603.
THOMPSON, G.W. & POPOVICH, F. (1974)
"Automated processing of cephalograms, facial photographs and dental casts".
Amer.J.Phys.Anthropol. 40:97-103.

THOMPSON, G.W. & POPOVICH, F. & ANDERSON, D.L. (1976)
"Maximum growth changes in mandibular length, stature and weight".
Hum.Biol. 48:285-293.
THUROW, R.C. (1970)
"Atlas of orthodontic principles".
St.Louis, The C.V.Mosby Co. 52:58.
TIMMER, L.H. (1969)
"A reproducible method for determining the vertical dimension of occlusion".
J.Pros.Dent. 22:621-630.
TWEED, C.H. (1966)
"Clinical Orthodontics".
Vol 1. C.V. Mosby St. Louis.
WALKER, G.F. & KOWALSKI, C.J. (1971)
"A two dimensional co-ordinate model for the quantification, description, analyses, prediction and stimulation of craniofacial growth".
Growth 35:191-211.
WALKER, G.F. (1972)
"A new approach to the analysis of craniofacial morphology and growth".
Amer.J.Orthodont. 61:221-230.
WALKER, G.F. & LEONARD, M.S. (1977)
"A cephalometric study of the relationship between the Malar bones and the maxilla in white American Females".
Angle Orthodont. 47:42-45.
WHITAKER, L.A., MUNRO, I.R., JACKSON, I.T. & SALYER, K.E. (1976)
"Problems in craniofacial surgery".
J.of Max-Fac.Surg. 4:131-136.
WHITE, R.P., PROFFITT, W.R., CRAMER, J.R. & KOHN, M.W. (1971)
"A study of facial height changes after mandibular osteotomy in 46 patients".
J.Oral Surg. 29:858-861.
WILLMARK, K. (1974)
"On Le Fort I osteotomy — Follow up study of 100 patients with maxilla-facial deformity".
Scand.J.Plast. & Reconst.Surg. Suppl. 7.
WINTER, J.S.D. (1978)
"Prepubertal & Pubertal Endocrinology"
Human Growth.
Eds. F. Falkner & J. Tanner. Plenum Press, New York & London. 2: 183-213.
WOLFORD, L.M., WALKER, G., SCHENDEL, S., FISH, L.C. & EPKER, B.N. (1978).
"Mandibular deficiency syndrome".
Oral.Surg. 45:329-377.
WOLFORD, L.M., SCHENDEL, S.A. & EPKER, B.N. (1979)
"Surgical orthodontic correction of mandibular deficiency in growing children".
J.Max-Fac.Surg. 7:61-72.
WOODSIDE, D. G. (1970)
"Distance and velocity curves of mandibular length".
University of Toronto Dept. of Orthodontics Notes, Toronto.
WOODSIDE, D.G. (1977)
"In removable orthodontic appliances".
Eds. Gaber, T.M. & Newmann, B., W. Saunders Co., 269-336.
WORMS, F.W., ISAACSON, R.J. & SPEIDEL, T.M. (1976)
"Surgical orthodontic treatment planning: Profile analysis and mandibular surgery".
Angle Orthodont. 46:1-25.
VLADIVELO, V. (1980)
"Regeneration of inferior dental nerve following trauma".
M.D.S.c. Thesis, Sydney.

Child Growth Unit
Anatomy Department
University of Melbourne
Parkville, 3052

EDITORIALS

Are You Strangling Our Journal?

In the first issue of the Australian Orthodontic Journal in June 1967, the Editor, John Moffat, outlined the embryonic development of our Society with its conception in 1927, its birth in 1950, and its growth to maturity with the first Australian Orthodontic Congress in Sydney in 1961. The Society grows stronger through the continuing guidance of a long list of devoted and hard working members of Council and more recently various on going Committees.

What of the Journal? Rightly or wrongly, the academic standing of a profession is judged by the scientific and clinical achievements portrayed within the publications of its Members. The Australian Orthodontic Journal has played a significant role in providing a forum or vehicle for these achievements to be presented to the scientific community. Through its creation by John Moffat in 1967, his guidance as Editor until 1974 and the guiding scientific hand of his successor, Terry Freer from 1974 to 1980, both helped not inconsiderably by conscientious regular contributors, the Journal has been given the impetus to survive in the competitive world of scientific publications. This issue sees a change of helm. An Editorial Board, composed of "all Indians" and "no chief", has seen the necessity for a change in format principally to enable each and every Member of the Society to feel it is "their Journal". Our aim is to encourage every Member to feel personally he has some important moral contribution to make to the continued development of the Journal. What do you need from your Journal? What does your Journal need from you? Take the opportunity to list ten of the most important features you personally desire in each category and send them to the Editor's office, for the Editorial Board's consideration. Better still make a committment and determine a treatment plan for the Journal. Contribute one article — scientific, clinical or a review type — at least every five years and you will be surprised what it does to consolidate and update your knowledge as well as giving you pride in your profession.

The current issue contains many changes of publication. The A.O.J. has begun,with this issue, the move towards automated production, from word processor to computer typesetting. With a two column format, similar to the earlier journals, the Editorial Board hopes to stimulate rapid reading and to facilitate the placement of illustrations. The incorporation of colour