TREATMENT OF CLASS II, DIVISION 1, DEEP OVERBITE MALOCCLUSION IN THE ADOLESCENT, USING THE EDGEWISE APPLIANCE

LAWRENCE FREDERICK SMITH

BDS (Sydney)

A treatise submitted in partial requirement

for the degree of

MASTER OF DENTAL SURGERY

UNIVERSITY
OF SYDNEY
DENTAL LIBRARY

Department of Preventive Dentistry

Faculty of Dentistry

University of Sydney

1987

ACKNOWLEDGEMENTS

Associate Professor Keith Godfrey, as my Supervisor, has greatly assisted me with both the range and understanding of the material in this Treatise. His availability and guidance, especially with diagnosis and treatment planning, throughout the M.D:S. Program, is also very much appreciated.

The text of the Treatise has been improved by the knowledge, careful proof-reading and assistance generously given by my dear friend, Joan Martin.

I wish to especially thank my Parents and also my family and friends for their encouragement and understanding over the past three and a half years.

During the progress of this period of study and writing to complete the Treatise, I have received valuable assistance from several people. I extend my appreciation to these:

Mrs. Sheena Hughes:	For her care and patience in typing and preparing this Treatise
Mrs. J.M. Simon:	The Librarian, Hardwick Memorial Library (A.D.A., N.S.W. Branch)
The Staff and Patients of my Dental Practice:	For their support and for their understanding of any inconvenience that may have been caused

----oOo----

TABLE OF CONTENTS

Acknowledgements		ii
Table of contents		iii
List of Tables		v
List of Figures		vi
Abbreviations		x
INTRODUCTION		1
1.	DESCRIPTION OF CLASS II, DIVISION 1 DEEP OVERBITE MALOCCLUSION	
	Table of chapter contents (N.B. A full table of contents precedes each chapter in this treatise).	3
1.1	Morphological Description	5
1.2	Aetiology	15
1.3	Growth Studies in Relation to Morphology and Aetiology	23
1.4	Cephalometric Analysis	31
1.5	Significance	46
2.	DIFFERENTIAL DIAGNOSIS, GROWTH AND TREATMENT PLANNING	
	Table of chapter contents	54
2.1	Differential Diagnosis	57
2.2	An Overview of Growth of the Jaws	66
2.3	Treatment Planning when Growth is Substantially Finished ...	92
2.4	Treatment Planning in the Vertical Plane	103
2.5	Diagnostic Aids in Treatment Planning	113
3.	AN OVERVIEW OF THE EDGEWISE APPLIANCE	
	Table of chapter contents	133
3.1	Introduction	135
3.2	Passive Attachments	136
3.3	Active Components	149
4.	SELECTION OF TREATMENT MECHANICS	
	Table of chapter contents	172

4.1	Introduction	175
4.2	Anteroposterior Correction	178
4.3	Vertical Correction	200
4.4	Control of Unwanted Reciprocal Forces in the Edgewise Appliance	214
4.5	Summary - Selection of Edgewise Mechanics	219
4.6	Selection of Headgear	222

5.	STABILITY GOALS, POST-TREATMENT RELAPSE STUDIES AND METHODS OF RETENTION	
	Table of chapter contents	236
5.1	Stability Goals...	238
5.2	Post-treatment Relapse Studies ...	251
5.3	Methods of Retention	266

6.	DISCUSSION	
	Table of chapter contents	279
6.1	Description	281
6.2	Treatment Planning	286
6.3	The Edgewise Appliance - Its Present Evolutionary State	298
6.4	Mechanics Selection	307
6.5	Stability Goals, Post-treatment Relapse Studies and Methods of Retention	315

SUMMARY	322
CONCLUSION	325
BIBLIOGRAPHY	327

-----oOo-----

LIST OF TABLES

TABLE NUMBER	TITLE	PAGE NUMBER
2.1	Class II treatment factors	90
2.2	Class II treatment procedures used to maximise growth potential	91
2.3	Björk's structural method of prediction of forward or backward mandibular growth rotators	117
2.4	Expected tooth size relationships modified from Bolton's tables	124

-----oOo-----

LIST OF FIGURES

FIGURE NUMBER	TITLE	PAGE NUMBER
1.1	Measurement of overbite	12
1.2	Forward rotation of the mandible and centres of rotation	26
1.3A	Schematic representation of forward rotation of the mandible when vertical incisal occlusion is insufficient	30
1.3B	Centre for forward rotation of the mandible at the incisors	30
1.4	Comparison of patterns for skeletal open-bite to skeletal deep-bite	35
1.5	Skeletal deep-bite pattern (an example of total inheritance)	36
1.6	Correct proportions for normal anterior face height	37
1.7	Facial growth axis	38
1.8	Sassouni Analysis	41
1.9	Gingival trauma from Class II, Division 1 deep overbite malocclusion (Photograph)	47
2.1	Differential diagnosis of Class II malocclusions using: Moyers et al Type A,B,C,D,E	60
2.2	Vertical typing of Class II, Division 1: Moyers et al Type 1, 2, 3, 4, 5 (with Michigan Growth Study norms)	62
2.3A	Postnatal craniofacial growth systems from age 7 years	69
2.3B	Remodelling of the hard palate	69

FIGURE NUMBER	TITLE	PAGE NUMBER
2.4	Mandibular growth	70
2.5A	Intramatrix rotation of the mandible (forward)	77
2.5B	Matrix rotation of the mandible (pendulum)	77
2.6	Characteristic pattern of forward jaw rotation ("short face", brachyfacial)	81
2.7	Matrix and intramatrix rotation of the mandible (backward)	82
2.8	Characteristic pattern of backward jaw rotation ("long face", dolichofacial)	82
2.9	AP line and soft tissue balance	99
2.10	Facial patterns: A. hyperdivergent, B. hypodivergent, C. Normal	109
2.11	The Johnston forecast grid	118
2.12	Wrist x-ray (pubertal growth spurt indicators)	122
3.1	Angulation of molar tubes	141
3.2	Moments of rotation: A. molar tube, B. tip, C. torque	143
3.3	Torque built into the bracket and its effect on tooth position	146
3.4	In/out and molar offsets in the SWA	147
3.5	A. and B. torque built into bracket base C. rotational moments from torque forces	149
3.6	Angle's ideal arch form	156

FIGURE NUMBER	TITLE	PAGE NUMBER
3.7	Jarabak helical loops	159
3.8	Jarabak, torquing helical loop	160
3.9	Burstone, anterior retraction assembly	162
3.10	Burstone, anterior intrusive arch mechanics	163
3.11	Ricketts, buccal traction section	168
3.12	Anterior retraction using the Ricketts bioprogressive upper closing utility arch	169
4.1A	Effects of Class II elastics	194
4.1B	Rotation of the occlusal plane with Class II elastics	195
4.2A	Normal interlabial gap	203
4.2B	Redundant lip (with no inter-labial gap)	203
4.3	Creating a step in the occlusal plane in a high angle case	204
4.4	Upper incisor intrusion in a high angle case	208
4.5	Dangers of using a continuous arch on incisal supraeruption	213
4.6	Burstone intrusion arch mechanics	214
4.7	Unwanted forces from bracket torque couples	217
4.8	Force analysis from combined torque and tip back bends	219
4.9	Five directions of extraoral force	222

FIGURE NUMBER	TITLE	PAGE NUMBER
4.10	Occipital headgear, resolution of forces plus moments	228
4.11	Ideal highpull extraoral force to the maxillary arch	233
5.1A	Centric occlusion exhibiting Andrews' six keys	241
5.1B	Seated condylar position in centric relation	241
5.1C	Normal condyle-fossa relationship (as it appears on a cephalometric tomogram)	242
5.2	Occlusal check-off for ideal finishing arch ...	244
5.3	Interincisal angulation	248
5.4	Growth in the brachyfacial pattern showing forward rotation, flattening the mandibular plane and increasing overbite	253
5.5	Mandibular incisor changes with late maturation (superimposition Age 11 - 17 years)	254
5.6	Five planes that have been used to position the lower incisor	261
5.7	The fixed,, cingulum bite platform retainer	274

-----oOo-----

LIST OF ABBREVIATIONS

Point A to pogonion line or plane	A.P.
Anterior nasal spine	ANS
Archwire	A.W.
Beta titanium	B.Ti.
Centre of resistance	C.R.
Centre of rotation	C.Rot.
Circumferential Supracrestal Fibrotomy	C.S.F.
Extraoral appliance	E.O.A.
Frankfurt horizontal	F.H.
Flexible spiral wire	F.S.W.
L.A. point [mid point of clinical centre of crown (on LA.CC)]	L.A.
Long axis of the clinical crown (straightwire appliance)	LA.CC
Mandibular plane	M.P.
Nasion-Sella plane	N.S. (S.N.)
Nickel titanium alloy	Ni Ti.
Occlusal plane to mandibular plane angle	O:M.
Peak height velocity	P.H.V.
Posterior nasal spine	P.N.S.
Rocky Mountain Data System	R.M.D.S.
Straightwire Appliance	S.W.A.
Temperomandibular joint	T.M.J.
Visual treatment objectives	V.T.O.

INTRODUCTION

The aim of the treatise shall be to examine Class II, Division 1, deep overbite malocclusion with particular reference to its morphology, the differential diagnosis and the orthodontic treatment of the malocclusion in the adolescent, using the edgewise appliance. The following list of subjects will be described and discussed to achieve this aim:

* the extent and variation of the morphology;
* current views of the role of environmental factors and genetic factors in the aetiology of the malocclusion;
* differential diagnosis in the anteroposterior and vertical planes and its application to treatment planning;
* jaw growth and facial growth patterns associated with the malocclusion and the potential for growth to aid or hinder Class II skeletal jaw correction;
* an overview of the philosophies that underlie the edgewise mechanotherapy and the current "evolutionary" state of the appliance;
* the selection of appropriate mechanotherapy to suit the needs of the individual case, with reference to the relevant aspects of differential diagnosis and the patient's pattern of growth.
* the goals of treatment stability that are particularly relevant to this malocclusion and also the selection of suitable methods of retention.

CHAPTER 1

DESCRIPTION OF CLASS II, DIVISION 1,

DEEP OVERBITE MALOCCLUSION

CHAPTER 1

DESCRIPTION OF CLASS II DIVISION 1

DEEP OVERBITE MALOCCLUSION

1.1 MORPHOLOGICAL DESCRIPTION

1.1.1 Classification

1.1.1.1 Anteroposterior morphology

1.1.1.2 Classification based on the labial segment relationship

1.1.2 The Presence of Deep Overbite

1.1.2.1 Clinical assessment

1.1.2.2 Measurement of overbite

1.1.2.3 Dental eruption and its relationship to deep overbite

1.1.2.4 The curve of Spee

1.1.2.5 Freeway space

1.2 AETIOLOGY

1.2.1 Soft Tissue Morphology and Environmental Factors

1.2.1.1 Environmental factors

1.2.1.2 Incompetent lip morphology and hyperactive mentalis muscle

1.2.1.3 Genetic factors

1.2.1.4 Summary of aetiological factors

1.3 GROWTH STUDIES IN RELATION TO MORPHOLOGY AND AETIOLOGY

1.3.1 Condylar Growth and Mandibular Rotation

1.3.2 Tooth Eruption and Facial Growth

1.3.2.1 Effects of orofacial dysfunction

1.3.3 Centres of Growth Rotation and Development of Deep Overbite

1.4 CEPHALOMETRIC ANALYSIS

1.4.1 Anteroposterior Analysis

1.4.1.1 Maxillary skeletal position

1.4.1.2 Maxillary dentoalveolar position

1.4.1.3 Mandibular skeletal position

1.4.1.4 Mandibular dentoalveolar position

1.4.2 Analysis in the Vertical Plane

1.4.2.1 Cephalometric description

1.4.2.2 Skeletal vertical analysis

1.4.2.3 Hyperdivergent versus hypodivergent patterns

1.4.2.4 Sassouni analysis

1.4.2.5 Analysis of deep overbite using linear measurement

1.4.3 Soft Tissue Analysis

1.4.4 Recent Cephalometric Analyses

1.5 SIGNIFICANCE

1.5.1 In Periodontal Damage

1.5.2 The Role of Class II, Division 1 Malocclusion and Deep Overbite in TMJ Disorders and Myofacial Pain

1.5.3 The Patient's Socio-cultural Expectations

1.5.4 Summary

---oOo---

DESCRIPTION OF CLASS II DIVISION 1

DEEP OVERBITE MALOCCLUSION

1.1 MORPHOLOGICAL DESCRIPTION

1.1.1 Classification

Angle's classification of this malocclusion was first described in 1899 and became widely used soon after. However, the validity of accepting the upper first molar as a point of reference and Angle's later contention (1907) that the upper jaw was normal in size and position, while the lower jaw was underdeveloped, or retruded, has become the subject of many studies and much controversy. (Craig, 1951)

1.1.1.1 Anteroposterior morphology

Several investigations have found that Class II molar relationships occur in a variety of skeletal and dental configurations. (Wylie and Johnson, 1952; Henry, 1957; Sassouni, 1958; Moyers, Riolo, Guise et al, 1980; and McNamara, 1981) Other studies have found a definite anterior positioning of the maxillary structure relative to craniofacial structures (Altemus, 1955; Rothstein, 1971) or have found that the maxilla is in a normal position in relationship to the craniofacial structures. (Craig, 1951; Wylie and Johnson, 1952; Hitchcock, 1973) Studies of the mandibular skeletal position also indicate a variety of opinions. However, the majority of recent studies agree that mandibular skeletal retrusion associated with either a mandibular length deficiency or a normal mandibular form positioned posteriorly, is that most commonly seen. (Moyers et al, 1980; McNamara, 1981)

A recent computer-based statistical examination of cephalometric orthodontic analyses by Moyers et al (1980) found that while 20% of cases examined had prognathic maxillae the most common finding was mandibular retrognathism with little or no maxillary prognathism. McNamara (1981) also found that mandibular skeletal retrusion was the most common characteristic with the maxilla in a neutral craniofacial relationship, representing two-thirds of his sample. In view of these studies it may be concluded that Class II, Division 1 malocclusion should not be considered as a single clinical entity as suggested by Angle's classification, but that a diverse range of skeletal and dental relationships may exist within this classification.

Investigations reported by McNamara (1981) perhaps summarise the most common dento-skeletal, morphological features of the malocclusion:

(a) Class II malocclusion is not a single clinical entity but may result from numerous combinations of the skeletal and dental components.

(b) on average the maxilla was in a neutral position and only rarely was skeletal maxillary protrusion seen relative to the cranial base structures (if not neutral, more often it was in a retruded position).

(c) the degree of maxillary dental protrusion, when present was less than reported by earlier investigators.

(d) the lower incisors were usually well positioned relative to AP plane.

(e) mandibular skeletal retrusion was the most common single characteristic of Class II malocclusion.

(f) a wide variation in vertical development was observed; almost half the samples exhibited excessive vertical development.

In summary, abnormalities in both the horizontal and vertical development of the mandible are the most common components of Class II, Division 1 malocclusion, while maxillary skeletal protrusion is not a common finding (McNamara, 1981).

1.1.1.2 Classification based on labial segment relationships

In an attempt to classify Class II, Division 1 malocclusion in a manner that gives thought to a wide range of morphological features, Ballard (1957) writes that the following considerations should be made: skeletal pattern (dental base relationship), soft tissue morphology, pattern of motor activity of the soft tissues and dentoalveolar structures.

Ballard (1957) classified Class II, Division 1 morphology on the basis of labial segment relationship rather than molar relationship. He describes two basic categories of this malocclusion along with their respective morphological features:

Type 1 - Dentoalveolar: the upper and lower labial segments become tilted on their apical bases associated with the position and action of the lips, tongue and in some cases initiated by oral habits. Commonly the upper incisors are proclined and more rarely the lower incisors are retroclined. The dental base relationships basically remain Class I; the molars may or may not be in Class II

relationship. The soft tissue morphology is summarised as follows:

i. incompetent lip morphology

ii. atypical swallowing behaviour

iii. competent lip morphology

iv. other orofacial morphology or behaviour often associated with i. or ii.

Type 2 - Skeletal or Class II Dental Base Relationship: a basal pattern is seen where the lower apical base is posteriorly related to the upper apical base creating an overjet in the labial relationship. The soft tissue morphology can be summarised as follows:

i. competent lip morphology

ii. incompetent lip morphology

iii. atypical swallowing behaviour

iv. ii. and iii. together

v. other variations of orofacial morphology behaviour.

Sub-division: Mandibular labial segment proclined in soft-tissue balance to compensate for the post-normality of dental base relationship (Ballard, 1957).

1.1.2 The Presence of Deep Overbite

Nanda (1981) describes deep overbite as a complex orthodontic problem that may involve a group of teeth or whole dentition, alveolar bone, mandible and maxilla and/or soft tissues of the face. In the concept of normal occlusion, the maxillary central incisors

slightly overlap the mandibular incisors and are either described in millimetres or as a percentage of the mandibular incisor crown length, overlapped by maxillary central incisors. Nanda suggests that notation of overbite in percentage is more descriptive (since crown length varies in individuals).

If overbite is considered alone, without skeletal and soft tissue parameters, then an ideal overbite may range from 5-25 per cent overlap of mandibular incisors. Even if it ranges from 25-40 percent, without functional problems during various movements of the temporomandibular joint, it may be considered normal. Correction of an overbite is highly desirable if it affects the facial aesthetics and impairs dental health of an individual, (Nanda, 1981).

Both Skieller (1967) and Nanda (1981) divide deep overbite into two descriptive types: dentoalveolar or skeletal (or basal) overbite.

i. Dentoalveolar deep overbite

Normal vertical skeletal development is present; either the maxillary and/or mandibular incisors erupt to a plane that is occlusally located and out of harmony with the occlusal plane. Deep overbite may alternatively be associated with an infraeruption of posterior buccal segment teeth in one arch or both. Other possible anomalies associated with deep overbite:

(a) abnormal vertical overlap of the incisors resulting from a combination of supraocclusion of the incisors and infraocclusion of posterior teeth,

(b) a complete lingual occlusion of the molar and premolar teeth

of the mandibular dentition,

(c) buccal occlusion of the molar and premolar teeth of the maxillary dentition.

[(b) and (c) rarely occur. (Strang, 1934)]

(d) Skieller (1967) also describes how posterior bite collapse, associated with early loss of maxillary or mandibular molars, may result in a rotation of the lower jaw upwards and forwards closing the bite.

ii. **Skeletal (basal) deep overbite:** may be related either to a malrelationship of alveolar bones and/or underlying mandibular or maxillary basal bones or to an overgrowth or undergrowth of one or more alveolar segments. In the mandibular dentition it may manifest as a deep curve of Spee and a compensating curve in the maxillary dentition. If the problem is in the anterior maxillary region, the patient often shows excessive gingival tissue during smiling or speaking, even when the upper lip is of adequate length (Nanda, 1981).

Skieller (1967) suggests that implant growth studies by Björk in 1963 indicate that forward rotation of the mandible during growth takes place towards the maxilla, the centre of rotation is not at the condyles but normally at the incisors. When there is no incisal contact or incisal instability the centre of rotation lies posterior to this and excessive forward rotation of the mandible occurs during growth, the vertical dimension decreasing and overbite increasing.

1.1.2.1 Clinical assessment of deep overbite

Differentiation of the different types of overbite can be made by examining the patients themselves or by cephalometric analysis, (see 1.4.2.2).

Clinical assessment:

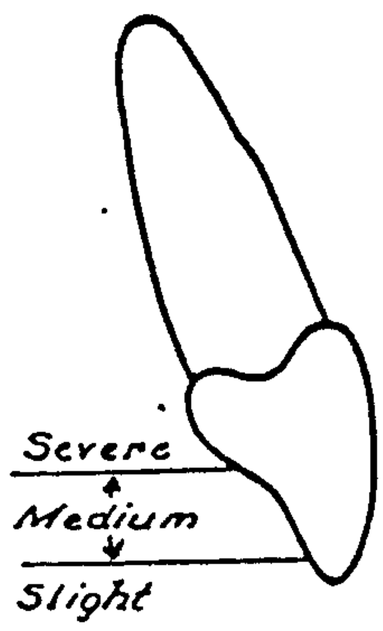
* if the facial lines show balance in the area below the nose with that above indicating sufficient vertical growth, then it may be assumed that the incisor teeth are in supraocclusion in one arch or both. Study of plaster casts indicates whether the maxillary and/or mandibular incisors are at fault.

* if, on the other hand, the vertical growth of the face below the nose is noticeably lacking, then the cause of overbite is located in the molar and premolar regions and consists of infraocclusion of these teeth (Strang, 1934).

* to determine if a combination of infraocclusion of the molars and premolars, and supraocclusion of the incisors is at fault, a test is recommended by Strang (1934) using softened impression material (25 mm square) is placed between the posterior teeth and the lips closed naturally. The patient is instructed to slowly close teeth until the facial proportions below the nose matches those above it. If, on separating the lips, the incisal overbite has completely disappeared, then the fault lies in the molar, premolar area. If some overbite still remains then the problem is a combination of infraocclusion of the posterior segments and supraocclusion of the anterior segments (Strang,1934).

1.1.2.2 Measurement of overbite

As mentioned earlier, overbite is perhaps best measured as a percentage of the lower incisor overlapped by the upper incisor, or as a linear overlap in millimeters. However, much of the literature describes the overbite as slight, medium and severe, depending on where the incisal edge of the mandibular incisor met the lingual of the maxillary incisor (Wylie, 1946; Baume, 1950; Backlund, 1958; Magill, 1960 and Nanda, 1981).



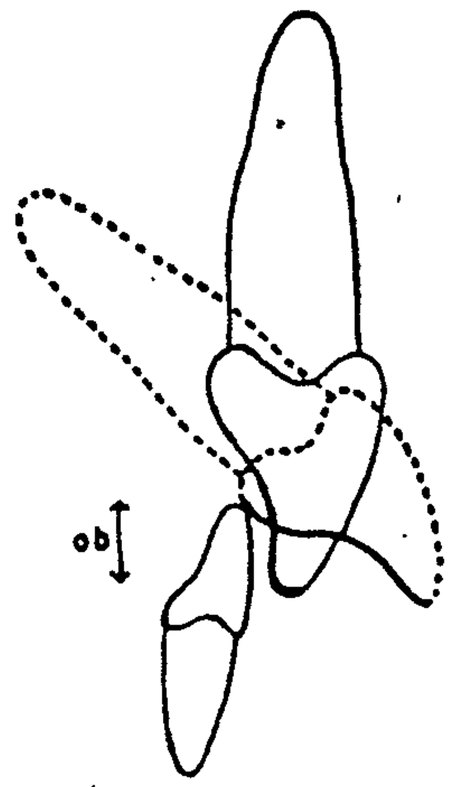


Figure 1.1
Prakash and Margolis, 1952: p661.

It has been suggested by Prakash and Margolis (1952) that though clinically useful the percentage method or linear measurement will be affected in cases of labial inclination of maxillary incisors as often seen in Class II, Division 1 malocclusion. (See Figure 1.1)

1.1.2.3 Dental eruption and its relationship to deep overbite.

Studies by Prakash and Margolis (1952) revealed a wide variation in deep overbite morphology: excessive overbite was commonly found to be associated with infraocclusion of mandibular molars and supraocclusion of maxillary incisors together with some infraocclusion of maxillary molars. Lower incisors are not usually

in supraocclusion in cases of deep overbite.

The study also described a pattern the authors called "closed bite" case, in which the vertical overlap of upper and lower incisors is not excessive, but the lower incisors are biting onto gingiva, palatal to the upper incisors. This may be seen in both dentoalveolar and skeletal malocclusions. These cases exhibited molar infraocclusion thus permitting an overclosure of the mandible, while the lack of vertical overlap is related to severe labial inclination of the upper incisors away from the occlusal plane to a position of relative infraocclusion. (Prakash and Margolis, 1952)

Failure of eruption:

* cleidocranial dysplasia presents a generalised failure of eruption of permanent teeth except for the first permanent molar associated with a lack of normal resorption of the bone overlying the permanent teeth. (Proffit, 1986: p63)

* recently the condition known as primary failure of eruption has been clarified in an article by Proffit and Vig (1981) in which they describe abnormalities of the periodontal ligament that result in eruption failure. They note that in this condition resorption of the bone does occur creating long cystic-appearing areas around the unerupted teeth, but eruption does not occur. Primary failure of eruption affects the posterior teeth and all teeth distal to the first tooth affected. The abnormal periodontal ligament does not respond to orthodontic tooth movement and will become ankylosed under orthodontic force, making orthodontic treatment impossible.

1.1.2.4 The curve of Spee

Deep overbite may be manifested in the mandibular dentition as a deep curve of Spee with a compensating curve in the maxillary dentition. It was described originally as the plane or line joining the articular surface of the condyle to the tips of the buccal cusps of first and second molars, the bicuspids, cuspid tips and incisal edges. The articular surface included by Count Spee is no longer considered (Steadman, 1940).

Any dentition will present two curves of Spee of varying degrees of curvature. An analysis of overbite should include examination of the curve of Spee, which may be described as: (a) normal, (b) deep, (c) flat, (d) reversed. Correction of a deep curve of Spee will permanently correct the overbite only if the Class II relationship is changed to Class I and the labial segments are related normally (Steadman, 1940). This will be discussed under goals of stability, in chapter 5.

The curve of Spee depth is measured from the buccal groove of the lower second molar, the lower anterior plane to occlusal plane of the premolars. The average depth of both sides should be used. It takes 1 mm of arch length to level 1 mm of curve depth. (Graber and Swain, 1985: p646)

1.1.2.5 Freeway space

The relationship of the mandible to the rest of the face is established long before the eruption of the teeth and is constant

throughout life (Wylie, 1944). The physiologic rest position of the jaw is a definite consideration in planning the correction of deep bites.

It has been suggested from studies involving morphogenetic muscle pattern, buccal occlusion and freeway space, that if the freeway space is normal in deep bite cases, it may be unphysiological to extrude molars and the only successful treatment will be intrusion of anteriors. If on the other hand the freeway space is large then extrusion of the molars may be a choice of treatment and will not relapse under the force of morphogenetic muscle pattern. (Wylie, 1940; Nanda, 1981; Chaconas, 1986).

1.2 AETIOLOGY

1.2.1 Soft Tissue Morphology and Environmental Factors

Studies of unfavourable environmental factors that may be causal in a malocclusion, show that influences on tooth position in particular are dependent on the duration rather than the magnitude of soft tissue force against the teeth and supporting structures. Even light pressures, if maintained for a period of hours, have the potential to move teeth. Heavy pressures such as those resulting from function, i.e. swallowing, speaking, chewing, have little effect on tooth position because of their relatively short duration (Weinstein, Haack, Lightle et al, 1963; Proffit, 1978). Tongue pressure during swallowing or tongue thrust once suspected of being a causative factor in the labial overjet or anterior openbite would seem to be of much too short a duration to be significant (Weinstein

et al, 1963; Subtelny, 1970; Simpson, 1977; Proffit, 1978).

The environmental causes of malocclusion have been listed as follows:

(i) habits of long duration (e.g. sucking habits, mouth breathing (Harvold, 1981);

(ii) influences from posture of the head, mandible and tongue which determine resting soft tissue pressures;

(iii) influences of tooth eruption. Although the tooth eruption mechanism has not yet been clarified, its location in the periodontal ligament is now known (Proffit, 1978). The work of Harvold (1968, 1981) with monkeys has shown that growth can be modified to produce (under laboratory conditions) morphological characteristics of the Class II type malocclusions. The animal developed severe overbite and overjet with the use of permanently fixed plastic pieces in the palatal vault between the right and left premolars which interfered with occlusion.

1.2.1.1 Environmental factors

(a) **Finger sucking habits:** For the first three years of life the damage from thumb or finger sucking is confined largely to the anterior segment, it is usually temporary, provided the child starts with a normal occlusion. The effects of finger sucking are often seen to be similar to a common hereditary pattern of Class II, Division 1 malocclusion with retrognathic mandible, prognathic premaxillary segment, deep overbite, flaccid upper lip, high palatal vault and often narrow dental arches. This has resulted in some

controversy between those who support the view that oral environmental factors are influential and those who claim that such malocclusions are genetically inherited or predisposed (Graber, 1972: pp313-329).

Graber states that if the child has a normal occlusion and drops the habit by the end of the third year, the effect is little more than a temporary reduction in overbite, an increase in overjet and incisor spacing in the maxillary arch and possibly lingual malposition of the lower anterior teeth. It is unlikely that a bilateral Class II buccal segment relationship can be attributed to finger habits alone, unless combined with the following compensatory factors:

* abnormal perioral muscle function, e.g. mentalis hyperactivity;
* compensatory tongue thrust necessary for an anterior seal;
* the deciduous and early mixed dentition flush terminal plane (normal) at molars.
* a developmentally deeper than normal overbite;

when it may take only minor tooth drift or migration to create a Class II buccal relationship (Ballard, 1957; Graber, 1972: pp313-320; and Proffit, 1986: p109).

(b) **Consider prolonged finger sucking** after three years of age: this will result in a more rapid onset of the malocclusion in an inherent Class II, Division 1 case and the attendant perioral muscle function and morphology may occur sooner and to a more marked degree. Again Graber emphasises that the "normal" flush terminal plane relationship of the first permanent molars and cuspids will

form, in effect, a transitional Class II tendency and this exists until the deciduous molars are lost and the leeway space is eliminated. Prolonged finger sucking with the perioral muscular habits associated with overjet will act to pull the maxillary denture forward or alter the forward growth of the mandible creating a Class II molar relationship in the permanent dentition (Graber, 1963; Graber, 1972: pp313-316; Moore et al, 1972).

(c) **Vertical development and environmental factors:** McNamara (1981) states that excessive vertical development is a characteristic of Class II malocclusion and it may be a manifestation of altered respiratory function.. Linder-Aronson (1970) showed that one characteristic of patients requiring adenoidectomy is a steep mandibular plane angle and animal studies have shown that a blocked nasal airway often leads to an increase in vertical development (Harvold, 1968, 1981).

1.2.1.2 <u>Incompetent lip morphology and hyperactive mentalis muscle</u> Incompetent lip morphology sometimes found in Class II, Division 1 malocclusions, is a failure of the lips to produce an anterior seal when the mandible is in its postural position and the orofacial muscles are in resting position. To produce an anterior oral seal there has to be circumoral contraction and, as a general rule, the mentalis muscle and orbicularis oris muscle in the lower lip are more active than the orbicularis oris muscle in the upper lip (Ballard, 1957). With the increased overjet, seen in this malocclusion, it becomes increasingly difficult to close the lips

and create the negative pressures required for normal swallowing; the lower lip drops behind the maxillary incisors and is thrust against the lingual surfaces of these teeth and abnormal hypertonic activity of the mentalis muscle is needed to effect closure while the upper lip remains hypotonic. (Ballard, 1957; Skieller, 1967).

In swallowing, the tongue thrusts forward to aid the lower lip achieve an oral seal. This exerts a force vector against the premaxillary segment and the severity of the malocclusion is enhanced, often creating an anterior openbite. The finger sucking habit, if present, may assume a secondary role, with many of these children sucking their lower lip and often dropping the finger habit altogether. (Graber, 1972: pp313-329).

The lack of restraining influence on the upper labial segment and the thrusting action of the mentalis muscle will promote the tendency of the maxillary labial segment to move forward producing a greater degree of proclination (Ballard, 1957).

Overall increased levels of mentalis muscle activity have been recorded in function when the trapped lower lip is associated with Class II, Division 1 malocclusion. However, no clear trends linking the degree of overjet to mentalis muscle activity levels have been found (Simpson, 1977; Mewing, MDSc Thesis, 1980).

1.2.1.3 Genetic factors

The other side of the controversy about the aetiology of Class II, Division 1 malocclusion is the role of heredity. Proffit (1986:

p115) states that malocclusion could be produced by inherited characteristics in two major ways. The first would be an inherited disproportion between the size of the teeth and the size of the jaws which would produce crowding or spacing. The second possibility would be an inherited disproportion between size or shape of the upper and lower jaws.

This view of malocclusion as primarily a genetic problem was strengthened by breeding experiments with animals carried out in the 1930s. Stockard's experiments indicated that dramatic malocclusions did occur in cross-bred dogs more from jaw discrepancies than tooth size/jaw imbalances (Stockard and Johnson, 1941: pp149-205).

Proffit (1986: p117) suggests that Stockard's studies with dogs are unreliable because of the dominant gene for achondroplasia found in dogs (rarely seen in humans) and many of the jaw size malocclusions were due to the expression of achondroplasia (i.e. an underdeveloped mid-face will occur). Proffit goes on to state that if tooth and jaw characteristics were imparted independently a very high prevalence of severe skeletal malocclusion would be expected in countries with a mix of ethnic and racial groups and he quotes statistics for Hawaii, where the effects of inter-racial crosses appear to be more additive than multiplicative. For example, about 10% of the Chinese who migrated to Hawaii had Class III malocclusion while 10% of the Polynesians had crowded teeth. The offspring of this cross seem to have about 10% prevalence of each characteristic but there is no evidence of dramatic facial deformities, (like those seen in the cross-bred dogs). If malocclusion is inherited it is clear that the

mechanism is not the inheritance of discrete morphologic characteristics like tooth and jaw sizes.

Studies of identical monozygotic twins with the same chromosomal DNA are interesting because any differences should be solely the result of environmental factors. By comparing identical twins, fraternal twins and ordinary siblings, an estimate of the effect of heredity in relation to the effect of the environment can be calculated. Lundström (1984) reports that about 40% of the dental and facial variations that lead to malocclusion can be attributed to hereditary factors, while others report this as being lower. (Corrucini and Potter, 1980).

Proffit (1986: p118) states that contemporary research has refuted the simplistic picture of malocclusion as resulting from independent inheritance of dental and facial characteristics, but has not yet clarified the precise role of heredity as an aetiological agent for malocclusion. He concludes that 15-20% of contemporary U.S. population have a Class II malocclusion and it is likely that most are inherited, there being little reason to believe that any significant number of Class II malocclusions result from functional causes and only a small proportion are from specific interference with growth. However, Proffit does say that functional alterations in equilibrium can accentuate these problems when they appear, the more severe skeletal discrepancies probably are inherited tendencies made worse by environmental effects., (Proffit, 1986: pp118-119). This latter view of the aetiology of Class II, Division 1

malocclusion is supported by Graber (1972: pp313-316).

The importance of hereditary influences has been summarised by Hovell (1950) who lists four factors which shape and position dental arches:

(i) skeletal morphology

(ii) soft tissue morphology

(iii) tooth size

(iv) orofacial behaviour.

Of these, he states that the first three are genetically determined and unchangeable by orthodontic treatment. Orofaciál behaviour he also suggests is genetically based, and habits such as digit sucking may be able to influence the shape of the dental arches, but by themselves in a normal skeletal pattern they produce little or no malocclusion. Analysis of Class II cases in which a thumb sucking history has been recorded generally also show that underlying genetic factors are responsible, such as, atypical swallowing (Hovell, 1950).

1.2.1.4 Summary of aetiological factors

The literature indicates that orofacial soft tissue behaviour, associated with Class II, Division 1 malocclusion, such as "tongue thrusting" and "mentalis activity", is an adaptation to, rather than a cause of, malocclusion. (Weinstein et al, 1963; Subtelny, 1970; Proffit, 1978).

Habits such as thumb sucking over a long period of time, say into

the early mixed dentition period, may be an aetiological factor in creating a dentoalveolar Class II, Division 1 malocclusion and will enhance the onset and degree of skeletal Class II, Division 1 inherited cases. (Graber, 1972: pp313-329; Proffit, 1986: p109). However, the influence of these environmental factors remains subject to some controversy, with a considerable body of literature suggesting that Class II skeletal malocclusion is generally inherited and that the role of any functional alterations in the equilibrium, or habits, is to simply accentuate these inherited conditions. (Hovell, 1950; Graber, 1972: pp313-316; Proffit, 1986: pp118-119).

In conclusion, contemporary research has refuted the simplistic aetiology of malocclusion, resulting from independent inheritance of dental and facial characteristics, but not yet clarified the role of heredity (Corrucini and Potter, 1980; Lundström, 1984). The role of postural (long term) forces and habits can not be totally discounted, but may only accentuate skeletal dysplasia rather than cause it. (Graber, 1972: pp313-329; Proffit, 1978; Proffit, 1986: p109).

1.3 GROWTH STUDIES IN RELATION TO THE MORPHOLOGY AND AETIOLOGY OF THE MALOCCLUSION

Cephalometric studies using metal implants have been carried out by Björk over the past thirty years. He has confirmed by implant marker techniques that growth in the length of the mandible in Man occurs essentially at the condyles. The anterior aspect of the chin is extremely stable, the thickening of the symphysis normally takes

place by apposition on the posterior surface and the lower border. Below the angle of the mandible there is normally resorption, (but not always). (Björk, 1955, 1969) This discussion will relate these mandibular growth studies to the aetiology and morphology of Class II Division 1 malocclusion.

1.3.1 Condylar Growth and Mandibular Rotation

Growth at the condyles usually does not occur in the direction of the ramus but slightly forward. Individual variations in the direction of condylar growth are large and in the adolescent period have been found to vary by almost 45^{o}. The growth is not always linear in direction but usually curves slightly forward (Björk, 1963, 1969).

Centre of Rotation of the Mandible: from the standpoint of growth, the mandible may be regarded as an unconstrained bone which may change its inclination in several ways, the critical factor being the site of the centre of rotation, which may be located at the posterior or anterior end of the bone or somewhere in between, in which case the ends of the mandible swing in different directions. The centre of rotation is not necessarily at the temporomandibular joint (TMJ). In a highly schematic manner, Björk (1969), describes several types of forward rotation of the mandible:

Type 1: There is a forward rotation about centres in the joints which gives rise to "deep bites" in which the lower dental arch is pressed into the upper, resulting in under-development of the

anterior face height. Björk lists several possible aetiological factors:

(i) loss of teeth;

(ii) powerful muscular pressure.

It may develop at any age and it has a similar pattern to Class II, Division 2 malocclusion. (See Figure 1.2 I)

Type 2*: Forward rotation of the mandible about a centre located at the incisal edge of the lower anterior teeth. This is a normal growth pattern and is usually associated with a marked development of the posterior face height; the posterior part then rotates away from the maxilla. The increase in posterior face height is due to:

(i) lowering of the middle cranial fossae, i.e. the cranial base bends, the condylar fossae becomes lowered.

(ii) an increase in the height of ramus. This will result in a more vertical lowering of the mandible and in the form of a forward rotation with the centre at the incisal edges of the lower incisor, eruption of the molars will keep pace with the vertical lowering and rotation.

---

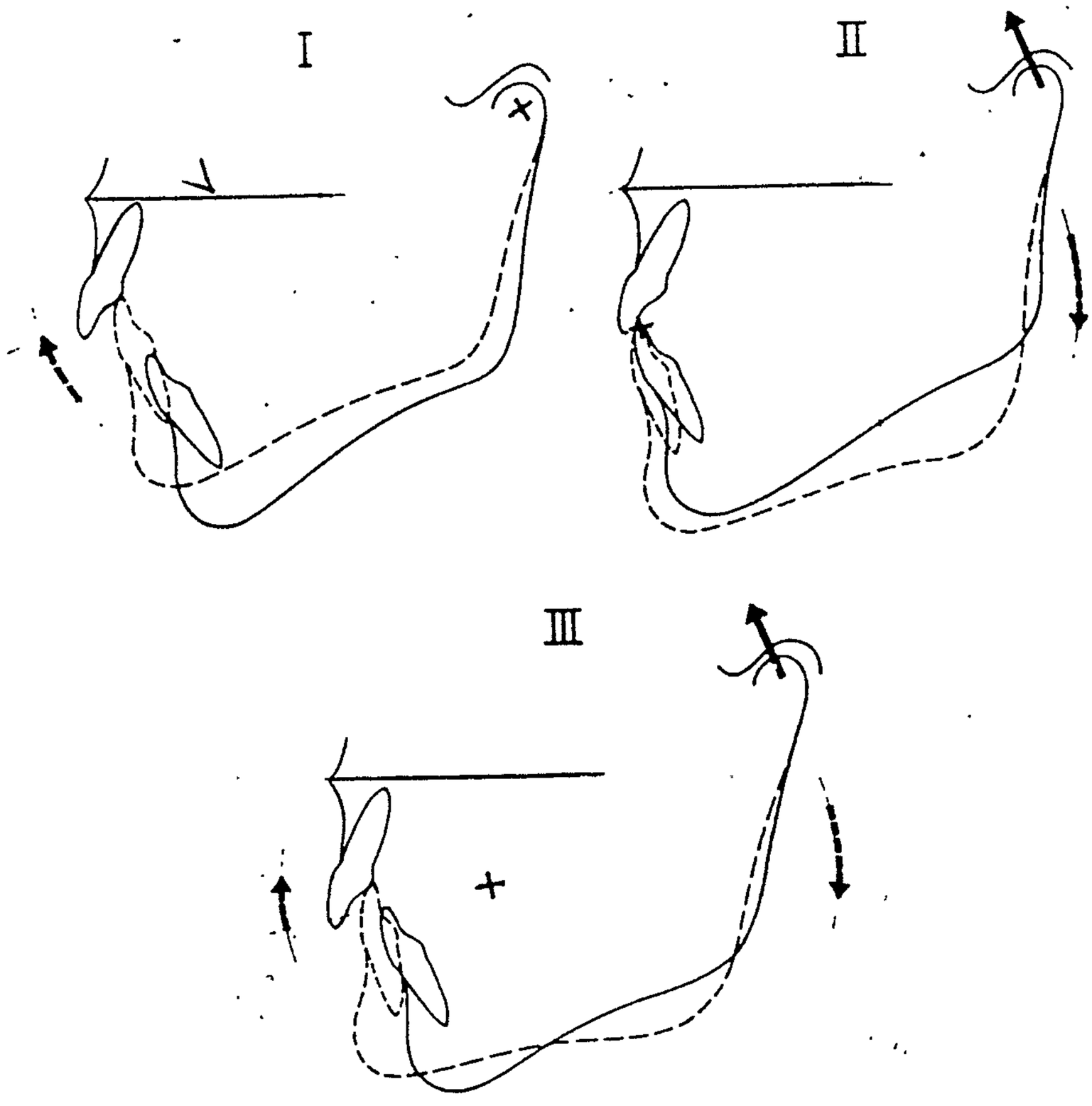
* A normal growth pattern (See Figure 1.2 II)

Type 3: In cases with a large maxillary overjet or mandibular overjet, the centre of rotation no longer lies at the incisors, but is displaced posteriorly in the dental arch to the level of the premolars. This results in the following characteristics:

* the anterior face height becomes underdeveloped, when the

posterior face height increases.

* the dental arches are pressed into each other and basal (skeletal) deep bite develops (Björk, 1969). (See Figure 1.2 III)



Forward rotation of the mandible with the centre at the joints (I), with the centre at the incisal edges of the lower incisors (II), and with the centre at the premolars (III).

Figure 1.2
Björk, A. 1969: p590.

1.3.2 Tooth Eruption and Facial Growth

Björk and Skieller (1972) state that "malocclusions are to a great extent due to incomplete compensatory guidance of eruption rather than to dysplastic deformation of the dental arches". In their 1972 study, the above authors made the following conclusions:

* rotation of the jaws in growth, influences the path of eruption of the teeth, the occlusion and tooth spacing. For example, if the centre of rotation (CR) of the mandible is located in the anterior part of the dental arch, then greater eruption of the molars than the incisors will occur.

* a stable incisal occlusion leads to a centre of rotation at the lower incisal edge and will produce the most satisfactory occlusion and an eruption pattern outlined below will most likely occur:

(a) anterior overbite is stable and does not increase with rotational growth;

(b) a forward tipping of the incisors and molars occurs;

(c) lip and tongue function are adequate to maintain a stable incisor relationship despite jaw rotation. However, when anterior occlusion is unstable the forward growth rotation of the mandible can give rise to skeletal deep overbite and distal (Class II) occlusion of the molars. (Björk and Skieller, 1972).

1.3.2.1 Effects of orofacial dysfunction: In 1953, Björk wrote that, "aetiologically" overbite can be divided into two types:

(i) dentoalveolar; (ii) basal (skeletal).

His co-worker, Skieller (1967), later wrote an article linking orofacial dysfunctions and habits to deep overbite and expanding on Björk's earlier findings. The following is a summary of both Björk and Skieller's conclusions.

(i) **Dentoalveolar Overbite:** this may arise as a result of instability in the incisal occlusion. Sucking habits including finger, thumb, and the use of a dummy (comforter) can lead to incorrect function of the tongue and lips at an age when the child is learning to speak. Such dysfunctions may persist after the habit is discontinued, even throughout the entire growth period. The dysfunction may influence development of dental arches and alveolar processes up to adulthood. (Björk, 1963; Skieller, 1967).

Skieller (1967), describes the possible mechanism whereby dentoalveolar deep overbite can arise after habits have ceased:

* the thumb sucking habit if continued until, say, 8 years of age, may result in an extreme maxillary overjet or openbite.
* after the habit has been stopped, over-eruption of the lower incisors and alveolus occurs with the loss of incisal contact, the result being a deep overbite.

Skieller (1967), concludes that this malocclusion must be described as a local anomaly and does not have its origin in a genetic pattern of jaw growth. It can develop in all facial types: large anterior face height, orthognathic (harmonious proportions) or even in a low face height and this is in general agreement with Graber and Proffit's conclusion discussed in section 1.2.1.4.

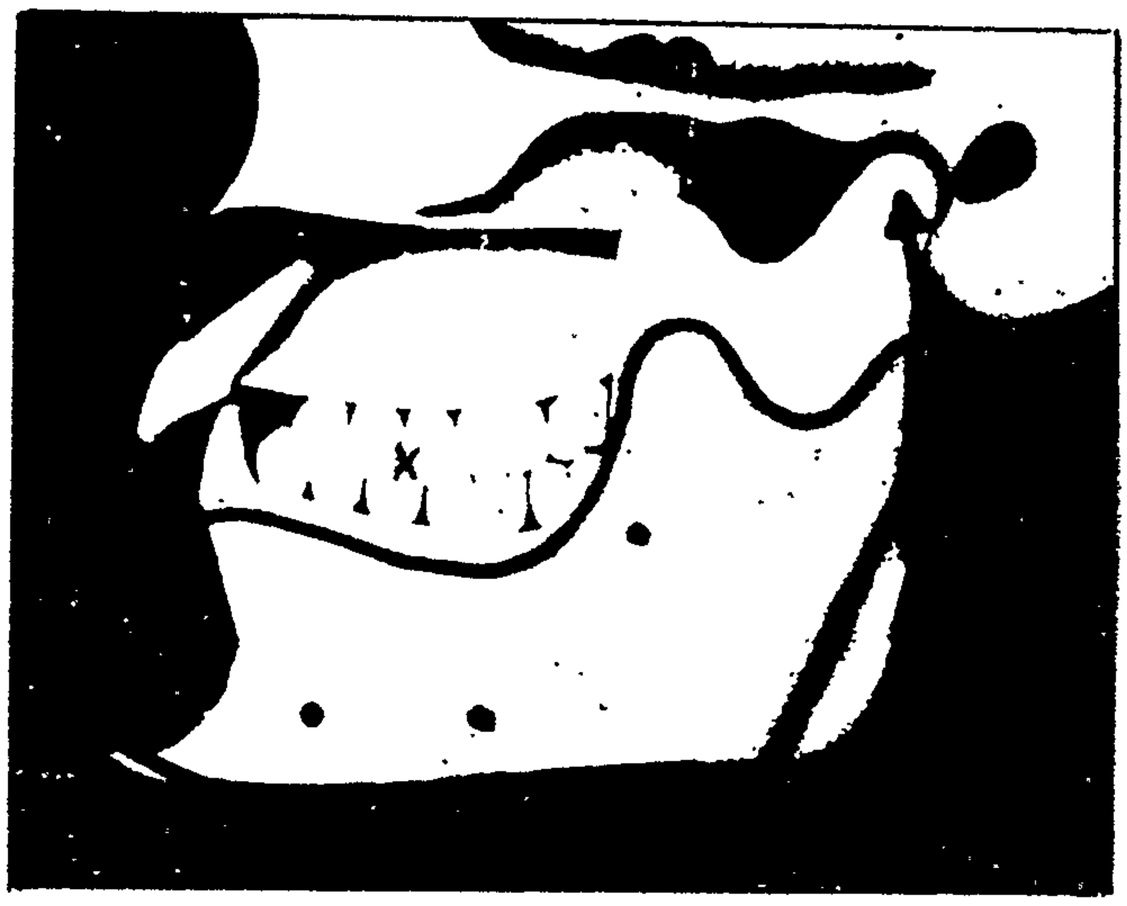
(ii) **Skeletal (basal) overbite:** is dependent on the genetic facial growth pattern. Implant studies have shown that the direction of growth at the mandibular condyles may vary from extreme vertical to a more sagital direction (Björk, 1963) and this variation in a mandibular growth pattern gives rise to individual differences in the position of the lower jaw in the face. Normally slight forward rotation of the mandible will occur during growth (Björk and Skieller, 1972). When the direction of condylar growth is extremely vertical then marked forward rotation may take place towards the maxilla. If no incisal contact is present, the centre of rotation lies posterior to the normal incisal centre of rotation, see Figure 1.3A (Björk, 1965).

Skieller (1967), also suggests that sucking habits can also contribute to the development not only of dentoalveolar deep overbite, but also to the development of basal deep overbite, adding instability in the incisal occlusion that favours the abnormal forward pattern of rotation during growth.

1.3.3 Centres of Growth Rotation and Development of Deep Overbite

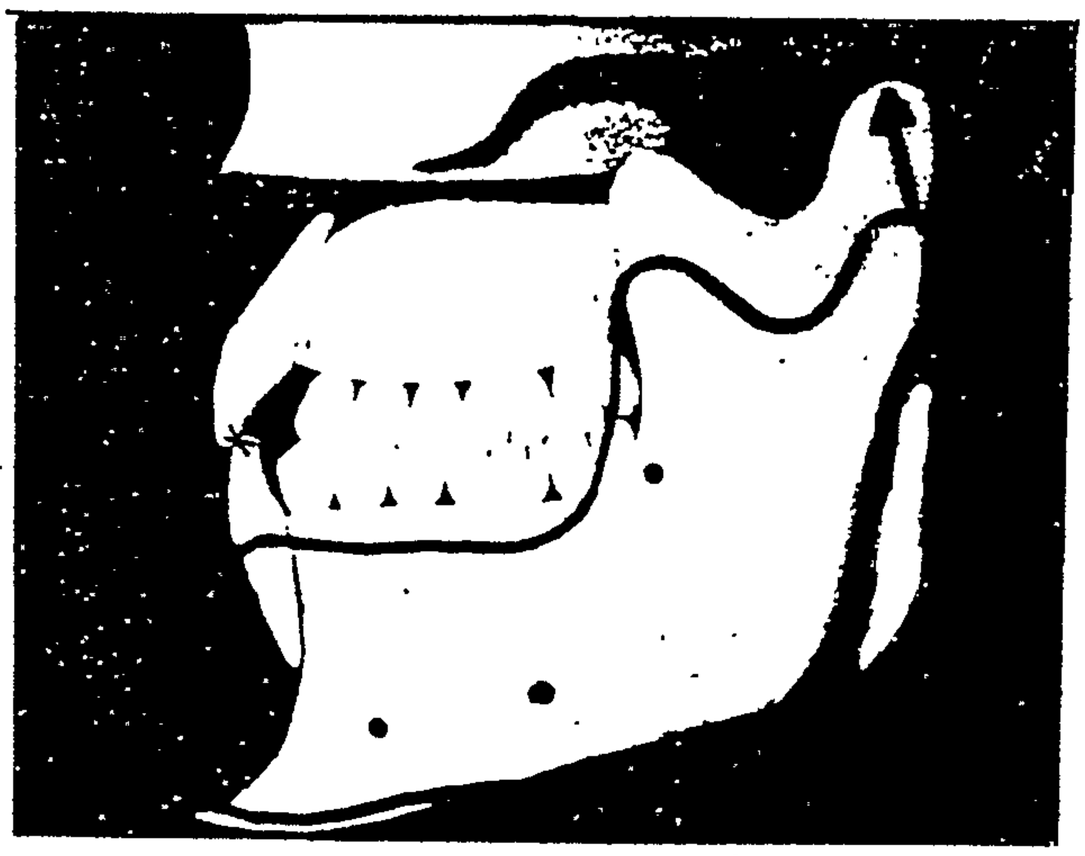
(See Figures 1.3A and B) A schematic representation of the change in centre of rotation of the mandible (with condylar growth occurring) from the lower incisal edge to the premolar region demonstrates how a deep bite may develop with growth rotation. The altered CR will result in an extreme rotation of the mandible into the maxilla creating a deep overbite. It has been suggested that thumb sucking and soft tissue dysfunction such as tongue thrust and

hypermentalis activity may contribute in some cases to the prerequisite of incisal instability. (Skieller, 1967).



When the vertical incisal occlusion is insufficient, the centre for the forward rotation of the mandible is further back.

Figure 1.3A
Skieller, V., 1967.



Normally, when the vertical occlusion at the incisors is fixed, the centre for the forward rotation of the mandible lies at the incisors.

Figure 1.3B
Skieller, V., 1967.

1.4 CEPHALOMETRIC ANALYSIS

As discussed under morphological description, several recent studies have found that the Class II molar relationship occurs in a variety of skeletal and dental configurations (Moyers et al, 1980; McNamara, 1981). A lateral cephalometric analysis is consequently of great value in these cases, not only to describe the malocclusion but more practically to determine treatment planning, both anteroposteriorly and vertically.

1.4.1 Anteroposterior Analysis

1.4.1.1 Maxillary skeletal position - a description of the maxilla relative to cranial base and cranial structures:

(i) SNA Angle: this angle, popularised by Riedel and Steiner, is used to assess the relative anteroposterior position of the maxilla. The normal is 82^{o} (Graber and Swain, 1985: pp269-279).

(ii) Point A to Nasion perpendicular (in mm). A perpendicular to Frankfurt horizontal from nasion: point A should lie within 2 mm of this perpendicular in order to be normally located. (McNamara, 1981).

(iii) "Wits" appraisal indicates the severity of anteroposterior jaw disharmony. Perpendiculars are drawn from points A and B onto the occlusal plane, these points are labelled AO and BO respectively for normal jaw relationship: AO to BO is 1 mm in males, AO to BO is 0 mm in females. For Skeletal Class II: BO is located well behind AO. The larger the linear measurement, the greater is the disharmony.

Several studies (Sassouni, 1958; Hitchcock, 1973; Jacobson,1975; McNamara, 1981) suggest a lack of confidence in the ability of angles SNA and ANB, to indicate skeletal maxillary position. Relating the jaw to cranial reference points or planes, presents inherent inconsistencies because of variation in craniofacial physiognomy, e.g. a long or short anterior cranial base or relative anterior or posterior positioning within the craniofacial complex of the anterior cranial base will influence SNA and ANB reading, (Jacobson, 1975). The nasion perpendicular to point A distance can be used as a back-up for SNA and "Wits" for ANB (McNamara, 1981).

1.4.1.2 Maxillary dentoalveolar position

(i) upper central to A-P line in normal occlusion is 3.5 mm - 6 mm. A higher reading will occur in Class II, Division 1 malocclusion with the typical overjet. McNamara (1981) states that this measurement is frequently erroneously taken as protrusion of the upper incisors rather than retrusion of the mandibular jaw and he suggests the measurement of the horizontal distance of upper incisor to point A by first measuring the distance from the most anterior point on the incisor to the nasion perpendicular. The distance from point A to nasion perpendicular is then subtracted. The advantage is a measurement independent of the mandible (the norm is 4-5 mm).

(ii) upper central to NS angle indicates the procumbency of upper incisors (McNamara, 1981).

1.4.1.3 Mandibular skeletal position

(i) angle SNB: is generally described as an indicator of the position of mandibular symphysis relative to the cranial base (norm is 79±3). A very small SNB indicates mandibular retrognathism. It has been suggested (McNamara, 1981: p184) that angle SNB is not totally reliable as a measure of skeletal position in Class II, Division 1 malocclusion because of the possible influence of muscle dysfunction affecting the position of point B.

(ii) facial angle: formed at the intersection of a line drawn from nasion to pogonion with the Frankfurt horizontal plane. Ricketts (1960) states that this should be 86^{o} at age 9 years + 1^{o} per 3 years and would be less with a skeletally retrognathic mandible. The landmarks for the Frankfurt horizontal (porion and orbitale) are difficult to locate accurately, rendering the line relatively unreliable (Proffit, 1986: pp145-146).

(iii) Y axis to NS angle: a line from S to Gnathion (Gn) effectively shows the relation of the anterior symphysial outline, although basically used as an indicator of vertical development. It is useful as an indicator of mandibular growth if the angle is greater than 70^{o} and associated with a large ANB angle, then the chin point will not be expected to move forward relative to the cranial base with growth. If the angle is less than 60^{o} a more horizontal forward growth of chin point is likely (Godfrey, 1985).

1.4.1.4 Mandibular dentoalveolar position:

* mandibular central (incisor edge) to A-P line (mm): the average has been reported as 2.3 mm in front of AP line in an ideal occlusion sample (Christie, 1977).
This measurement determines the position of the lower incisor relative to basal structures (McNamara, 1981).
* mandibular central to mandibular plane (degrees): an angular measure of the protrusion of lower incisor. It can be related to lower lip posture and mentalis muscle function; when hyperactive it results in retrusion of the lower incisors, often seen in Class II, Division 1 morphology (Graber and Swain, 1985: p78).

1.4.2 Analysis in the Vertical Plane of Space

1.4.2.1 Cephalometric description: again a distinction between skeletal deep-bite and dental deep-bite should be made (Skieller, 1967; Graber and Swain, 1985: pp78-83).
The terms "skeletal open-bite" and "skeletal deep-bite" are terms that have come to be defined as indicating skeletal proportions that form a pattern or built-in tendency towards deep-bite or open-bite. The relationship of the vertical posterior position of the mandible to the anterior incisal position should be observed. It shows a pattern towards deep overbite when it rotates upwards and forwards, the vertical dimension decreasing anteriorly.
Figures 1.4 and 1.5 show three cases: one exemplifying a skeletal open-bite and the other two, skeletal deep-bite patterns, the contrast is present at both skeletal and dental levels.

Note the following observations about deep overbites compared with open-bite: (See Figure 1.4)

* the more vertical position of the condyle and maxillary molars.

* the size of the ramus - with its greater length.

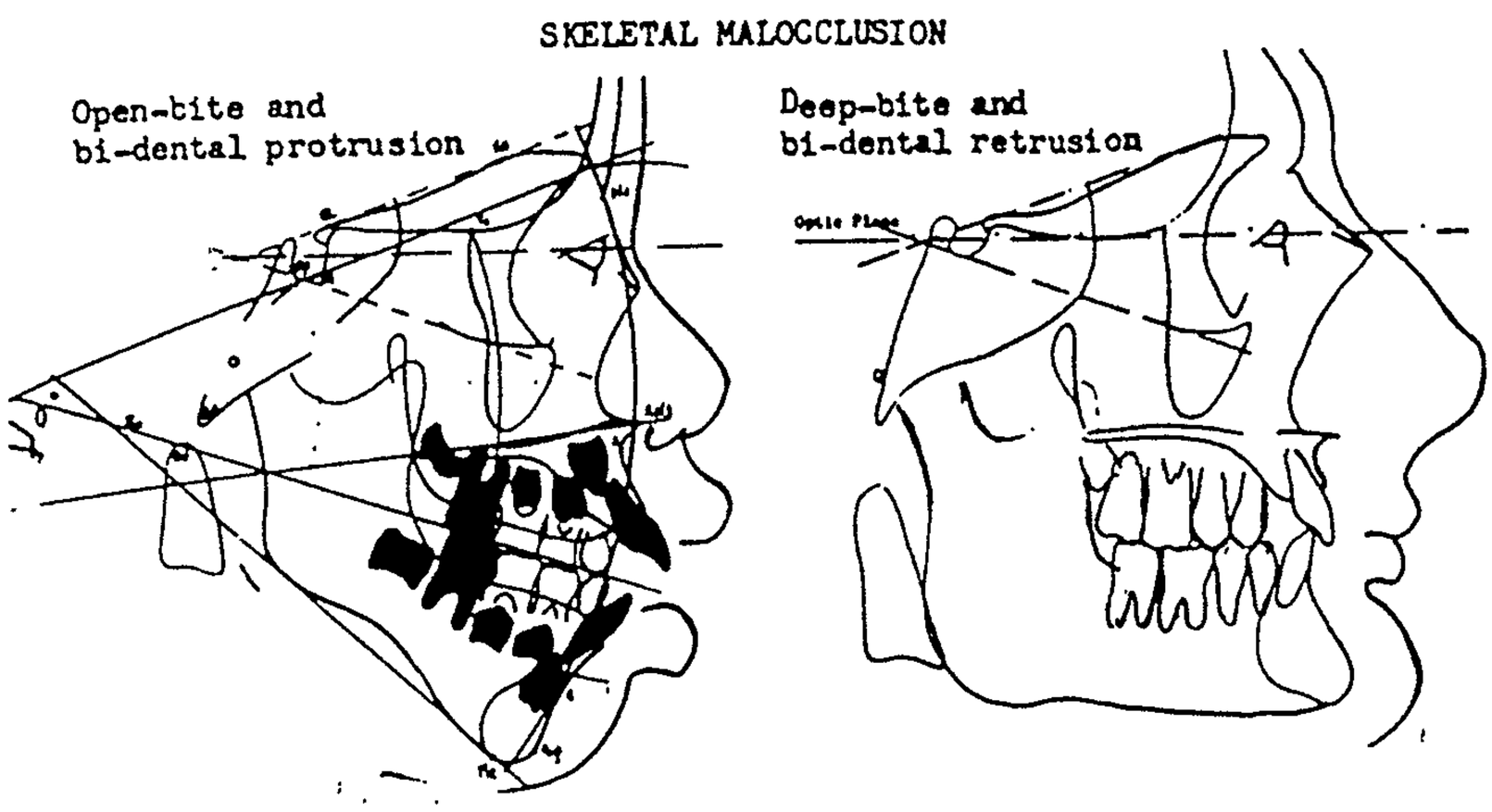
* the palatal, occlusal and mandibular planes are horizontal and nearly parallel to each other.

While in the open-bite pattern:

* the angle of the condyle is backwards.

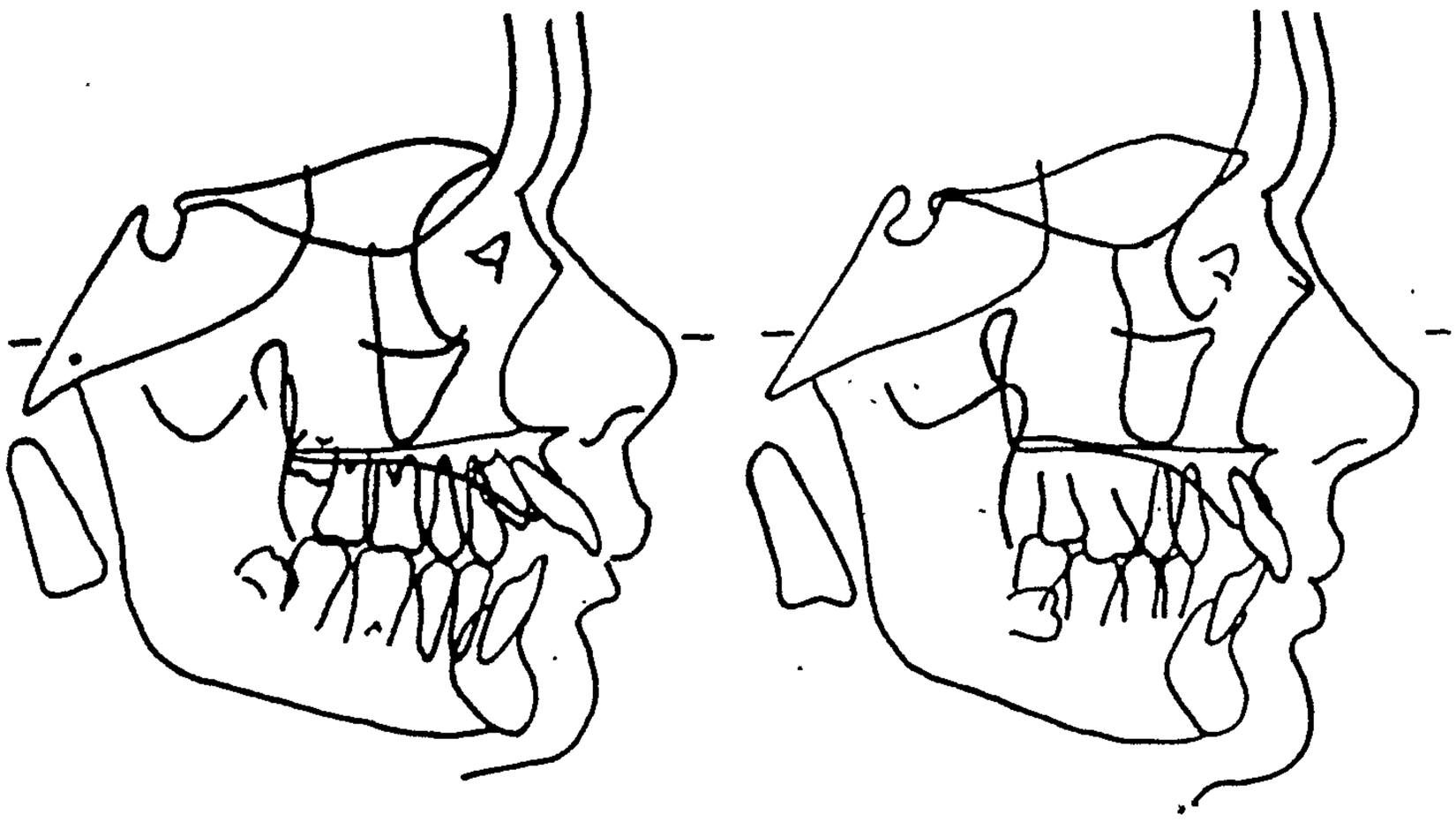
* the short ramus length.

* the sharp angulation of the palatal occlusal and mandibular planes (Sassouni and Nanda, 1964).



Tracings of two patients, one exemplifying a skeletal open-bite and the other a skeletal deep-bite. The contrast is present at both the skeletal and dental levels. Notice the ramus. In addition, in the deep-bite case, the palatal, occlusal, and mandibular planes are horizontal and nearly parallel to each other, while in the open-bite case these planes are sharply angulated. (From Sassouni, V.: The Face in Five Dimensions, Philadelphia, 1959, Philadelphia Center for Research in Child Growth.)

Figure 1.4
Sassouni and Nanda, 1964: p803.

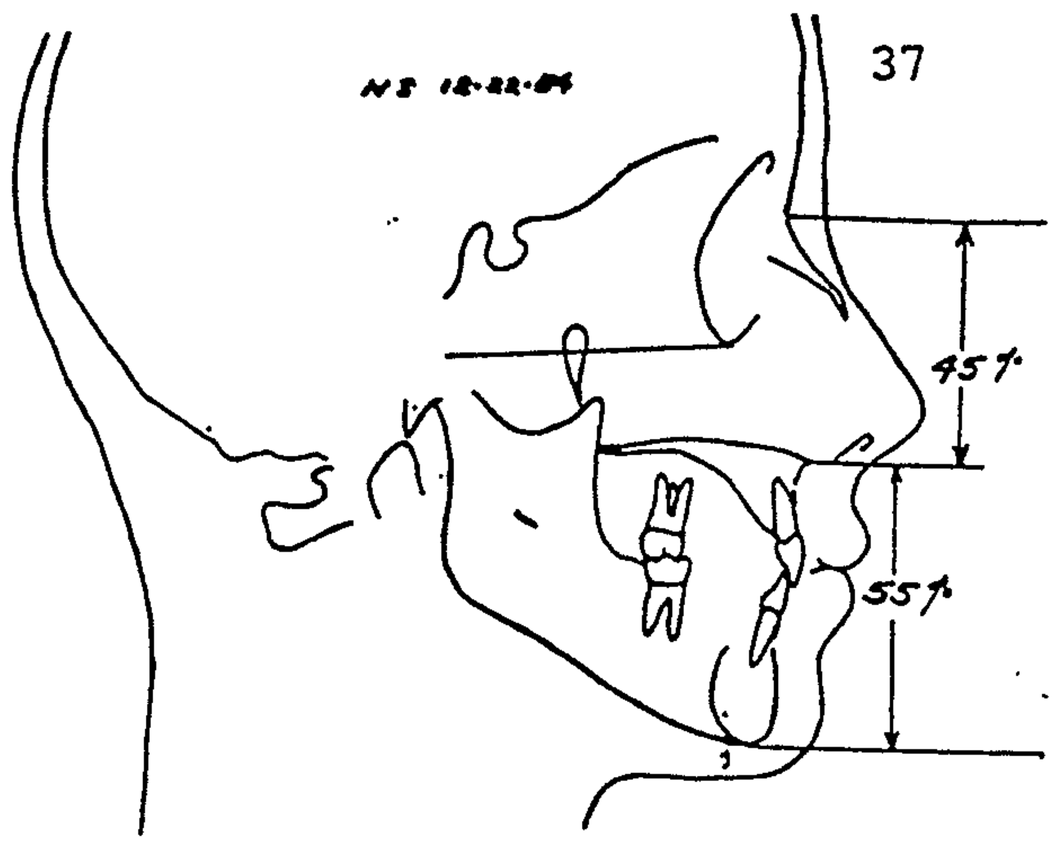


Tracings of child (A) and his mother (B), each of whom has a skeletal deep-bite pattern. Except for the premaxilla, these tracings can be superimposed almost perfectly with respect to size, shape and proportion. This is an example of total inheritance.

Figure 1.5
Sassouni and Nanda, 1964: p811.

1.4.2.2 Skeletal vertical analysis

In relating the vertical position of the maxilla and mandible to the cranium, the analysis can begin with measurement of the anterior facial height, proportionately the lower face height (lips, chin) should be 55% of total nasion-pogonion distance (Graber and Swain, 1985: pp78-83). (See Figure 1.6)



Correct proportions for normal anterior face height. (Modified from Strang, R.H.W., and Thompson, W.M.: A textbook of orthodontia, ed. 4, Philadelphia, 1958, Lea & Febiger).

Figure 1.6
Graber and Swain, 1985: p79.

Although the obvious way to determine skeletal vertical relationship is to measure anterior and posterior face height, this is not practical, the posterior dimension being difficult to measure directly. This is overcome by measurement of the relative angulation of the maxilla and mandible. The palatal, occlusal and mandibular planes are used for this purpose (Schudy, 1964).

McNamara (1981) uses the following vertical analysis:

(i) **mandibular plane angle**: the angle between the Frankfurt horizontal plane (or NS) and a line constructed through gonion and menton.

(ii) the growth (facial) axis angle: invented by Ricketts (1960). A line is constructed from basion to nasion and another from the posterior superior aspect of pterygomaxillary fissure and gnathion. Use: as an evaluation of vertical facial development

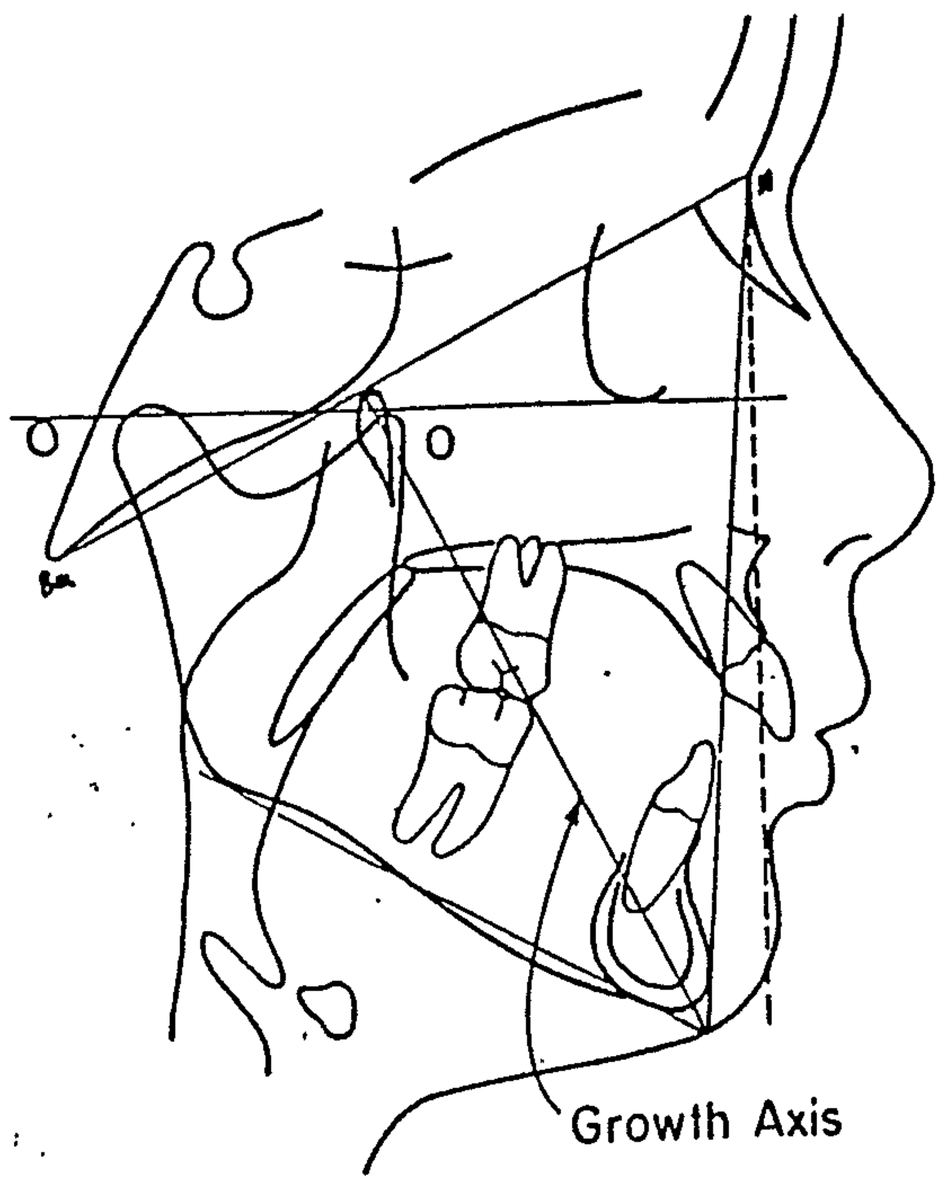
* a perpendicular geometric relationship indicates a balanced face (zero deviation).

* deficient vertical facial development has a positive value (in terms of the X axis graphically).

* excessive vertical development has -ve values, (See Figure 1.7).

This growth axis would be similar in effect to the Y axis analysis.

(iii) **lower face height:** anterior nasal spine (ANS) to menton, in a 9 year old child with balanced facial proportions, is approximately 60 mm and will increase 1 mm per year until adulthood. (McNamara, 1981).



Facial growth axis. The facial axis is constructed through gnathion and the postero-superior margin of the pterygomaxillary fissure (Ricketts, 1960 and 1981). The angle of this axis is measured as the difference from a perpendicular to the basion-nasion line (Ba-N). The clinical norm is zero as shown on this illustration.

Figure 1.7
McNamara, 1981: p187.

Note: This shows a Class II, Division 1 case with large overjet, but adequate vertical development; it has a zero facial angle.

1.4.2.3 Hyperdivergent versus hypodivergent patterns

Schudy (1964) also advises analysis of anterior and posterior face heights. He stresses the importance of two angles to assist in this:

(i) the OM plane angle (occlusal plane to mandibular plane). (15^{o} - 17^{o}, average 16^{o})

(ii) SN to mandibular plane (MP) angle. The normal is 33^{o} and indicates harmonious facial development (vertically).

The higher these two angles the greater the deficiency of posterior facial height, while the lower angles (particularly OM) are associated with deep overbites.

Schudy uses the terms:

(a) hyperdivergent (retrognathic in pattern) with high OM and SN-MP angles.

(b) hypodivergent type (prognathic) with low OM and SN-MP angles.

These two terms suggest the extremes of facial divergence. He relates this to treatment, e.g. in hyperdivergent (retrognathic mandible) cases, the molars should not be extruded or moved distally or the bite will be opened further. On the other hand, hypodivergent (deep-bite) may be treated with molar extrusion and distalization. This will aid in opening the bite (Schudy, 1964).

Schudy writes that the y axis (facial angle) is insufficiently sensitive to tell us about vertical growth or posterior dental height as related to anterior d ental height, i.e. it says nothing of the gonion angle, ramus height or height of mandibular molars, while the OM angle does this and is of more value in vertical analysis (Schudy, 1964).

1.4.2.4 Sassouni analysis. Another method of vertical analysis relies on assessment of convergence (or parallelism) of the mandibular plane, occlusal plane and palatal plane.

In skeletal open-bite tendency the planes converge rapidly to a focus just behind the face indicating a short ramus height, obtuse gonial angle - implied but not essential. In skeletal deep overbite the planes run more parallel and a longer ramus and more acute gonial angle may be present.

Harmonious vertical proportions of the facial profile exist if the face is symmetrical vertically around the palatal plane, for example:

(i) ANS to cranial base is equal to ANS to mandibular plane and PNS to cranial base is equal to PNS to mandibular plane.

(ii) the tip of maxillary central is located midway between ANS and pogonion.

(iii) the tip of mandibular central is situated midway between A and B.

(Sassouni has included a frontal radiograph in his analysis to provide a three dimensional view.)

Sassouni is of the opinion that other analyses based on a single plane of reference (e.g. nasion - sella NS or Frankfurt horizontal) are unreliable because these planes have a different slope in different individuals and also that the analysis should consider the dentofacial complex as a whole and this is best done by the geometric proportioning rather than relating structures to a particular plane.

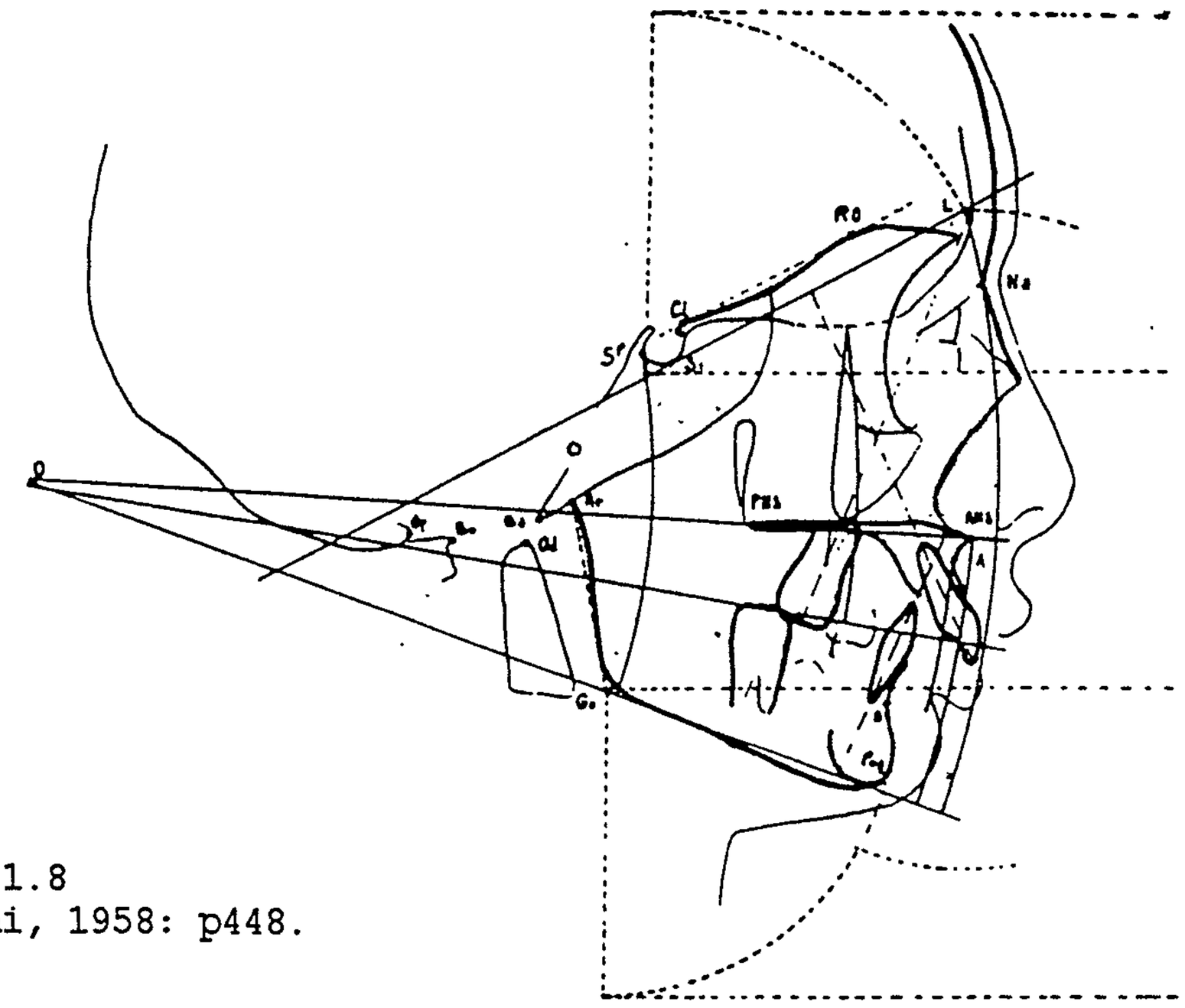


Figure 1.8
Sassouni, 1958: p448.

The Sassouni Analysis in Figure 1.8 can be described as follows:

* occlusion: Class II Division 1 deep overbite

* excessive overjet

* anteroposteriorly: compared to maxilla the mandible is 8 mm retrusive, (B is posterior to arc from A; the profile is retroarcheal i.e. ANS, upper central and pogonian are posterior to an arc from nasion). Note that the cranial base is out of convergence.

* vertical assessment: extremely deep overbite, the lower anterior face is 15 mm smaller than the upper anterior face.

1.4.2.5 Analysis of deep overbite using linear measurement

Linear measurements: Nanda (1981) states that an examination of vertical height of the face is of value. If the lower vertical

height is less than the upper vertical height (normally 1:1, see Figure 1.6) it indicates a deep-bite, while if the OM, mandibular plane to SN and other cephalometric indicators (Y axis and facial angle etc.) show a normal skeletal pattern, then the deep overbite is dentoalveolar in origin with incisal supraeruption.

The position of the molars and incisors may be assessed by linear measurements. For example, the measurement from alveolar base to the occlusal surface of molars or incisors may be compared to cephalometric standards (obtained from Michigan growth study data). An "Atlas of Craniofacial Growth" by Riolo, Moyers, McNamara and Hunter, 1974, is available.

1.4.3 Soft Tissue Analysis:

(i) a profile view of the soft tissue can be obtained from a lateral cephalometric radiograph if a "mask" is placed in the cassette to reduce "burnout" of the soft tissue. This is still only a two dimensional view and notes from clinical examination should be considered along with photographs. The clinical soft tissue examination is discussed in Chapter 2 as part of treatment planning. Class II cases will usually display a posterior divergence of total facial profile. Examination of a line dropped from soft tissue nasion to soft tissue pogonion as it relates to true horizontal plane (patients vertical axis) will indicate the following features:

* in an orthognathic face the facial angle is approximately 90^{o}.

* if the mandible is positioned posteriorly, indicated by the above facial angle being less than 90^{o}, the face is posteriorly

divergent. It should be noted that considerable racial differences exist. Northern Europeans tend to be slightly posteriorly divergent, whereas Orientals tend towards an anterior divergence. (Graber and Swain, 1985: pp67-68).

(ii) **Prominence of the lips:** is evaluated relative to the chin.

E plane: is a line drawn from the tip of the nose to the chin, the lower lip should be 1-2 mm behind the E plane in children (Ricketts, 1960).

Holdaway line: is described as a useful indicator of soft tissue balance. A line is drawn from the most anterior point of the chin across the most anterior point of the upper lip. The outlines of the nose anterior to this line and the curve of the upper lip should form a symmetric "S" curve and the sulcus of the upper lip or soft tissue curve should be 5 ± 2mm behind this line in Caucasians. When assessing facial contours and the profile, it should be remembered that the face tends to become more orthognathic with growth. Young children normally have relatively convex profiles and somewhat receding chins. With growth of the nose and both hard and soft tissues, the chin generally becomes more prominent (Graber and Swain, 1985: p68). This is not always the case in high angle backward rotation growth patterns (Schudy, 1965).

Consideration of lip/incisor relationships: this can be analysed both clinically and cephalometrically and is discussed in Chapter 4 because of its importance to the selection of treatment mechanics for overbite correction in various facial patterns. The upper central incisor edge to upper lip distance is on average 2-4 mm. If

this incisor stomion distance is large, often seen with a "gummy smile", then intrusion mechanics should be used for the deep overbite correction (Nanda, 1981).

The use of cephalometric growth prediction is important in the treatment planning of Class II malocclusion and it is discussed in Chapter 2, along with the significance of facial patterns: brachyfacial (hypodivergent), dolichofacial (hyperdivergent) and normal or harmonious vertical proportions.

1.4.4 Recent Cephalometric Analyses

As the data from recent growth studies on children has become available, construction of cephalometric reference standards has been produced, many existing cephalometric measurements have been shown to change with growth. Data from various growth studies has been assembled to produce templates representing the average 9 year old, 10 year old etc. Such templates can be used in growth prediction but need an accurate estimation of the patient's developmental age to begin with.

More recent cephalometric analyses include the Rickett s analysis which attempts to:

(i) locate the chin in space;

(ii) locate the maxilla through the convexity of the face;

(iii) locate the dentition in the face;

(iv) evaluate the profile.

The analysis uses the Frankfurt horizontal, nasion - basion line and pterygoid vertical (facial growth axis). (See Figure 1.7) It was

originally developed for the Rocky Mountain computerized cephalometric service and eleven measurements are made in all (Ricketts, 1981). Its weakness is that the normative data is based on unspecified samples collected by Ricketts. (Proffit, 1986: p152). Another contemporary analysis is that described by McNamara (1983); the anteroposterior position is evaluated with its relative position to the "nasion perpendicular", a vertical line extending down from nasion,perpendicular to the Frankfurt plane, the maxilla is normally on, or slightly ahead of this line. A comparison of maxillary and mandibular lengths is made. The lower face height is measured and the lower incisor is also related to AP. Measurements are compared to norms in the well defined "Bolton samples" which are also available in template form. (Proffit, 1986: pp152-153).

Moyers and Bookstein (1979) suggest that modern computational geometry can now handle curving constructs such as tangents, "skeletons", biorthogonal grids to provide a computer based representation of a cephalogram and which will eventually displace the ruler and protractor (sic) which have little basis in either biology or biometrics. The existing cephalometric techniques fail to capture the curving form and its changes; exclude proper measures of size for bent structures and portray growth as a vector displacement rather than a generalized

distortion. The authors suggest that future cephalometric analysis will include curvatures, tangents, Blum's medial axis ("skeleton") and biorthogonal grids.

1.5 THE SIGNIFICANCE OF CLASS II, DIVISION 1 DEEP OVERBITE MALOCCLUSION

1.5.1 In Periodontal Damage

A review of the orthodontic literature reveals a view that this malocclusion very often leads to gingival tissue damage and periodontitis and that its correction is therefore essential. (Baume, 1950; Poulton & Aaronson, 1961; Nanda, 1981). However, investigations of the relationship of overjet and overbite to periodontal disease have led to opposing views on the aetiological role of these factors in the health of the periodontium.

A recent statistical investigation on the effects of anterior overjet indicated that for the most part it was not related to periodontal destruction and this agreed with the findings of Geiger (1962). However, severe overjet (6 mm or more) showed a slightly increased level of periodontal destruction, and the authors point out that this was a very limited association (Geiger, Wasserman and Turgeon, 1973).

Gingival trauma from a Class II, Division 1 deep overbite malocclusion in a middle aged man.
Note the absence of generalised periodontal destruction. (1986)

Figure 1.9.

Anterior Overbite was not found to be associated with periodontal destruction at all levels of the dentition studied. A slight increase in severe periodontitis was found in the deep overbite patients, but this may be accounted for by the occurrences of tissue trauma. (Geiger et al, 1973) See photo - Figure 1.9.

No relationship was established between lack of lip seal and periodontal inflammation (Geiger, et al, 1973).

In summary, only severe overjet and overbite did show a very slight correlation to periodontal destruction or gingival inflammation.

However, malocclusion has been linked to periodontal disease because of direct trauma to gingival tissue in Class II deep bite cases. The abnormal gingival shape around malaligned teeth may expose the gingiva to abrasion; food impaction and lack of natural hygiene will

contribute further to the problem. Traumatic occlusion has also been cited as a specific cause of periodontal destruction. The demonstration of statistical correlation, no matter how strong, does not prove the existence of a cause and effect of the factors involved. (Poulton and Aaronson, 1961).

Another statistical study has alternatively indicated that each of the following features showed a significant relationship to periodontal status:

(a) vertical incisor overbite;

(b) posterior cuspal interdigitation;

(c) lower anterior crowding;

(d) horizontal overjet.

This study concludes specifically that such malocclusion may be an important causative factor in periodontal disease. (Poulton and Aaronson, 1961).

Impact injuries to the maxillary incisors: One of the unfortunate sequelae of Class II, Division 1 malocclusion is the greater likelihood of impact injuries to the maxillary incisors, that are often protruded or prominent relative to other facial structures. (Graber, 1972: p485).

1.5.2 The Role of Class II, Division 1 Malocclusion and Deep Overbite in TMJ Disorders and Myofacial Pain

Factors acting on the occlusion such as centric relation interference, loss of molar support, functional crossbite, Class II, Division 2 malocclusion and specifically deep incisal overbite, have

all been listed as having a TMJ "orthopaedic effect" resulting in a posterior condylar position and TMJ dysfunction. (Ricketts, 1955; Green, 1973; Stack, 1977).

Deep overbite has been cited as a factor in TMJ disorders, the deep overbite being suggested as a cause of posterior condylar displacement, disk laxity, TMJ clicking and pain. (Ireland, 1953; Ricketts, 1955). Earlier Costen (1934), Fisher, (1942) and Block (1947) attributed such symptoms as tinitus, dizziness, migraine and pain around the ears (from effects on the eustacian tube) to a "closed" or deep overbite.

There is however considerable controversy over the relationship of the malocclusion to the TMJ syndrome. Proffit (1986: p9) writes that the number of people with moderate degrees of malocclusion (50% - 70% of the population) far exceeds the number with TMJ problems (5% to 30% depending on symptoms used) and he suggests that it is unlikely that occlusal patterns alone cause hyperactivity of the oral musculature. Other studies have suggested that a distal mandibular relationship is not synonymous with posterior condylar displacement (Poselt, 1968: p39) and that in Class II, Division 1 malocclusion a slightly anterior condylar position may frequently be seen (50%*) compared with Class I (18%*). (Logsdon and Chaconas, 1975; Pullinger et al, 1987*).

A study of an asymptomatic population group including a Class II, Division 1 component, using TMJ tomograms, has shown that deep

overbite or overjet was not associated with retrocondylar position and no correlation to the measured condylar position was found. The authors conclude that a naturally occurring deep overbite is usually accompanied by successful adaptation or remodelling and does not show any notable relationship to condylar displacement. (Pullinger et al, 1987).

The relationship of malocclusion and adaptive function to the TMJ syndrome, manifested as pain in and around the temperomandibular joint, remains unclear and controversial. TMJ pain may result from pathologic changes within the TMJ but more often is caused by muscle fatique and spasm which often correlates with a history of positioning the mandible to an anterior or lateral position, or clenching or grinding of the teeth in response to stressful situations. (Proffit, 1986: p9).

The degree of controversy in the literature is apparent from this discussion; recent studies suggest a clear lack of correlation between Class II, Division 1 malocclusion and posterior condylar position (so often used to link deep overbite to the TMJ syndrome). The fact that malocclusion is so prevalent among the general population while the TMJ syndrome is comparatively rare suggests factors other than malocclusion play a significant causative role.

1.5.3 The Patient's Socio-Cultural Expectations

Jenny (1975) suggests that the demand for orthodontic treatment may

develop entirely apart from any consideration of health needs. She writes that the need and desire of members of society to achieve a culturally acceptable body image constitutes a legitimate need. If children's teeth do not naturally meet the norms for aesthetic dental appearance, then the response to socio-cultural expectations and pressures may disadvantage the child psychologically and the author recommends that the role of social acceptability levels of the malocclusion should be added to any malocclusion index, especially when a cut-off point is needed in publicly funded programs.

Shaw (1981) and Godfrey (1984) add that only a minority of malocclusions can be regarded as seriously handicapping and both authors confirm the validity of "felt need" by children and parents should still form a persuasive element in allocation of orthodontic resources.

1.5.4 Summary

The presence of deep overbite and overjet seen in this malocclusion may not be statistically related to severe periodontal disease or other health aspects (Geiger, 1973). However, some studies have found evidence of increased direct trauma to the gingiva, with some resultant periodontal destruction, in cases where lower incisors contact palatal gingiva (Poulton and Aaronson, 1961).

Susceptibility to impact trauma of protruding maxillary central incisors is also a threat to tooth and pulpal structure (Graber, 1972: p 485).

The relationship of this malocclusion to the TMJ syndrome has been discussed, there being considerable controversy evident in the literature. Several occlusal factors and specifically deep overbite have been linked to the TMJ syndrome with the suggestion that they are associated with a posterior condylar position or displacement. (Ricketts, 1955; Green, 1973; Stack, 1977). Other studies using TMJ tomograms indicate that Class II, Division 1 malocclusion frequently displays a slightly anterior condylar position rather than a posterior position. (Logsdon and Chaconas, 1975; Pullinger et al, 1987).

The fact that malocclusion is prevalent among the general population (50% - 75%) while the TMJ syndrome is comparatively rare (3%) suggests that factors other than malocclusion play a significant causative role. Apart from these health considerations Jenny (1975) states that malocclusion may reduce a child's socio-cultural expectations and may lead to psychological disadvantages. Shaw (1981) and Godfrey (1984) have suggested that the sociocultural consideration constitutes a legitimate reason for orthodontic correction.

CHAPTER 2

DIFFERENTIAL DIAGNOSIS,

GROWTH AND TREATMENT PLANNING

"A study of growth sites and growth sutures is of little value unless we know how and to what extent growth increments affect occlusion."

(Schudy F.F., 1964)

CHAPTER 2

DIFFERENTIAL DIAGNOSIS, GROWTH AND TREATMENT PLANNING

2.1 DIFFERENTIAL DIAGNOSIS

2.1.1 Horizontal Typing for Class II, Division 1

2.1.2 Vertical Typing for Class II, Division 1

2.1.3 Facial Patterns

2.2 AN OVERVIEW OF GROWTH OF THE JAWS (and its role in treatment planning)

2.2.1 Maxillary Growth

2.2.2 Mandibular Growth

2.2.3 Theories of Growth Control

2.2.4 Rotation of the Jaws During Growth

2.2.4.1 Growth rotation in the brachyfacial and dolichofacial patterns

2.2.4.2 Jaw rotation and tooth eruption

2.2.5 Planning Treatment that is Assisted by Growth (The pre and early adolescent period)

2.2.5.1 Growth modification in Class II correction

2.2.5.2 Review of the literature on growth modification

2.3 TREATMENT PLANNING FOR CLASS II CORRECTION WHEN JAW GROWTH IS SUBSTANTIALLY FINISHED (or if growth modification is unsuitable)

2.3.1 Introduction

2.3.2 Indications for Extraction Treatment

2.3.3 Planning Treatment in the Borderline Class II case

2.3.3.1 Therapeutic diagnosis

2.3.4 Extraction Versus Non-extraction

2.3.5 Extraction Sites in Relation to Crowding and the Profile

2.3.6 The Value of the A.P. line

2.3.7 Extraction and Anchorage Units/Root Surface Areas as it Relates to Retraction of Upper Anterior Teeth

2.4 TREATMENT PLANNING IN THE VERTICAL PLANE

2.4.1 Summary of Vertical Component of Growth and Rotational Changes to Chin Point

2.4.1.1 Treatment planning in backward growth rotation cases

2.4.1.2 Treatment planning in forward growth rotation cases

2.4.2 Control of Vertical Height

2.4.3 Cephalometric Description of Vertical Facial Patterns and Their Respective Treatment Planning

2.4.3.1 Hypodivergent pattern

2.4.3.2 Hyperdivergent pattern

2.4.3.3 Average or normal pattern

2.5 DIAGNOSTIC AIDS IN TREATMENT PLANNING

2.5.1 Ricketts' Visual Treatment Objective (VTO)

2.5.2 An Overview of Current Methods of Jaw Growth Prediction

2.5.3 Timing of Treatment for Class II, Division 1 Malocclusion

2.5.3.1 Indicators of the beginning of pubertal growth

2.5.4 Tooth Size Discrepancy

2.5.4.1 Bolton analysis and common discrepancies

2.5.5 Diagnostic Wax Set Ups

2.5.6 Soft Tissue Profile

2.5.6.1 Evaluation of lip protrusion

2.5.6.2 (i) Aesthetic plane; (ii) Holdaway line

2.5.6.3 Evaluation of vertical facial proportions

2.5.6.4 Notation of T.M.J. and occlusal function

-----o0o-----

DIFFERENTIAL DIAGNOSIS, GROWTH AND TREATMENT PLANNING

2.1 DIFFERENTIAL DIAGNOSIS

McNamara's (1981) study has shown that two thirds of a typical group of Class II malocclusions are associated with mandibular retrusion. However, a wide variation of abnormalities in both the horizontal and vertical development of the mandible are common. On average the study found the maxilla to be in a neutral position in relation to craniofacial structures, while maxillary protrusion is rare, with maxillary retrusion having been observed more often than protrusion. He concludes, that in designing the "ideal" treatment regime, for the "average" Class II case, appliances that alter the amount and direction of mandibular growth may be more appropriate than those that only restrict maxillary development.

Sassouni (1970) estimates that sixty four different situations may exist in Class II deep-bite pattern and the same in Class II open-bite pattern. Here he has considered skeletal variations, dental malocclusions, vertical and transverse malocclusions, crowding or spacing. These different characteristics influence the treatment planning and he concludes that it is a dangerous oversimplification to diagnose Class II, Division 1 (Angle) malocclusion in general terms and simply relate this to treatment.

Moyers et al (1980) by means of a computer based study, found several types of Class II malocclusion by defining horizontal and vertical characteristics and creating a differential diagnosis from

these computerised procedures for routine use in clinical practice. They suggest that persons of one typing not only look alike, they grow alike and will have similar treatment needs. Summary of their findings follows divided into horizontal typings and vertical typings.

2.1.1 Horizontal Typing for Class II, Division 1 (Moyers et al, 1980)

Type A: Normal Skeletal Profile
i.e. the anteroposterior position of maxilla and mandible are normal, mandibular dentition normally placed on skeletal base, occlusal plane is normal. The maxillary dentition are protruded with large overjet and overbite.

Type B: Class II - Skeletal Profile
Mid-face prominence (prognathic maxilla) with normal mandibular relationship to craniofacial structures. ANB is high, mandible of normal size.

Type C: Markedly Class II Profile
Retruded mandible (short) maxilla slightly retruded or normal. Upper incisors tipped labially or upright. Short mandible, square gonial angle, associated with flat anteriocranial base. (A severe Class II type.)

Type D: Retrognathic Profile
Associated with small mandible combined with normal or slightly prominent mid-face. The lower incisors are either upright or lingually inclined. The maxillary incisors are in extreme labioversion.

Type E: Severe Class II Profile Associated with Prominent Midface
With normal or even prominent mandible. The dentition tends to be forward on their apical base, the incisors in strong labioversion, typical of bimaxillary protrusion.

C and D 50-60% of cases; maxilla neutral, mandible retrognathic. This could contraindicate extra-oral traction as an orthopaedic force to maxilla. Should aim to optimise mandibular growth. (Functional appliances etc.)

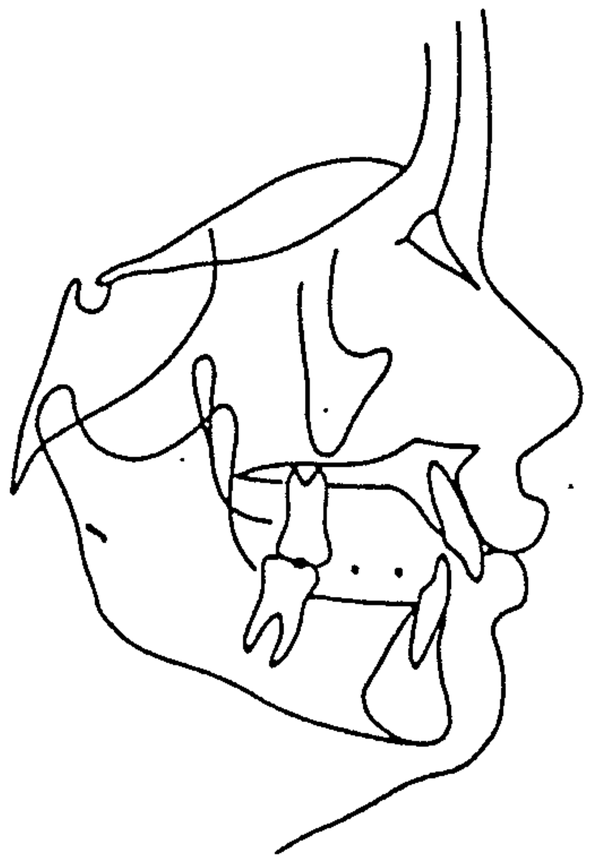
B and E make up 20% of cases with prominent maxilla, midface prognathism. Here it is logical to use EO traction as orthopaedic force to maxilla

See Figure 2.1

HORIZONTAL TYPING

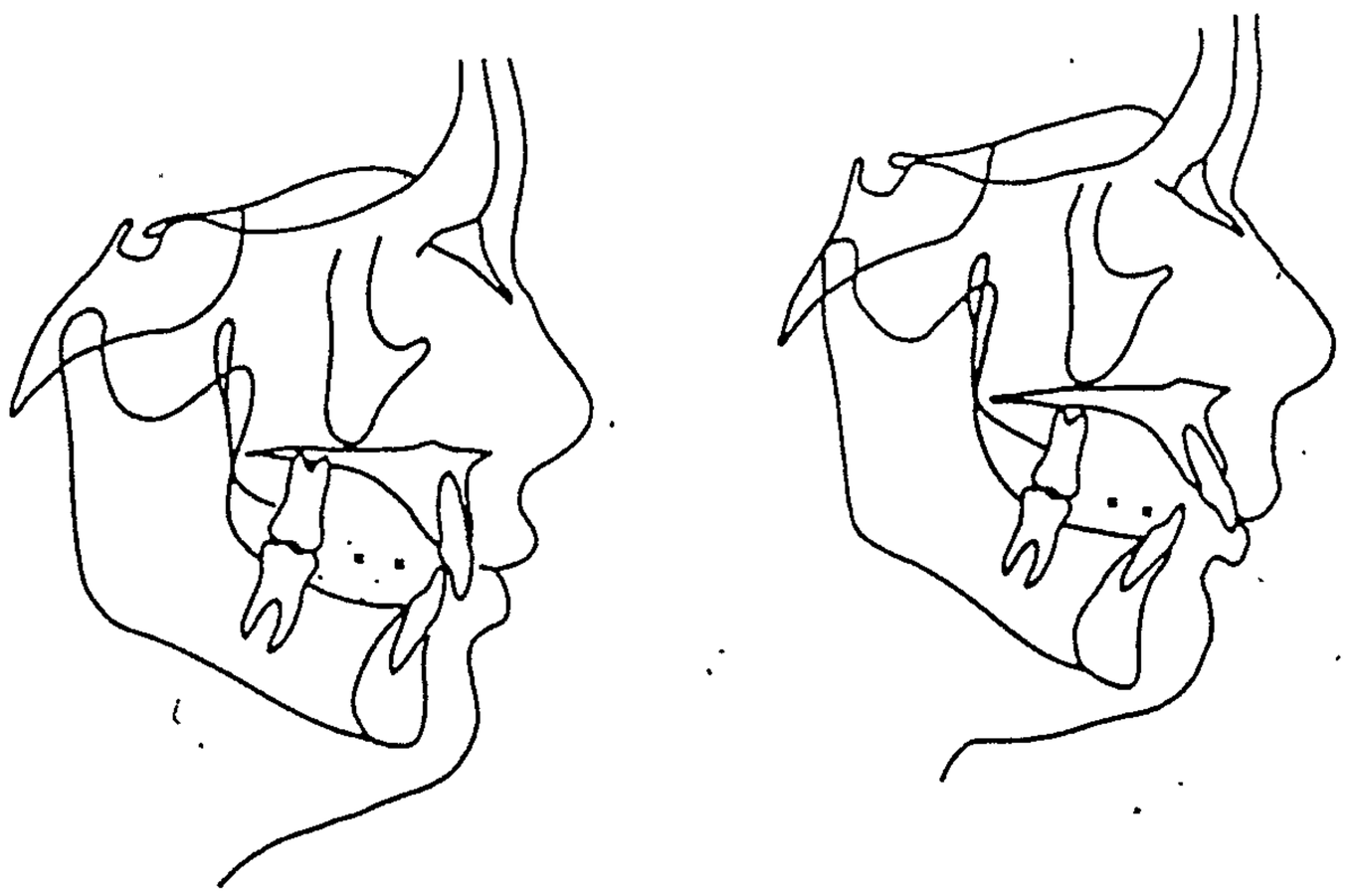
Figure 2.1 Moyers, R.E. et al, 1980: pp487-490

Differential diagnosis of Class II malocclusions



(Type A Horizontal)

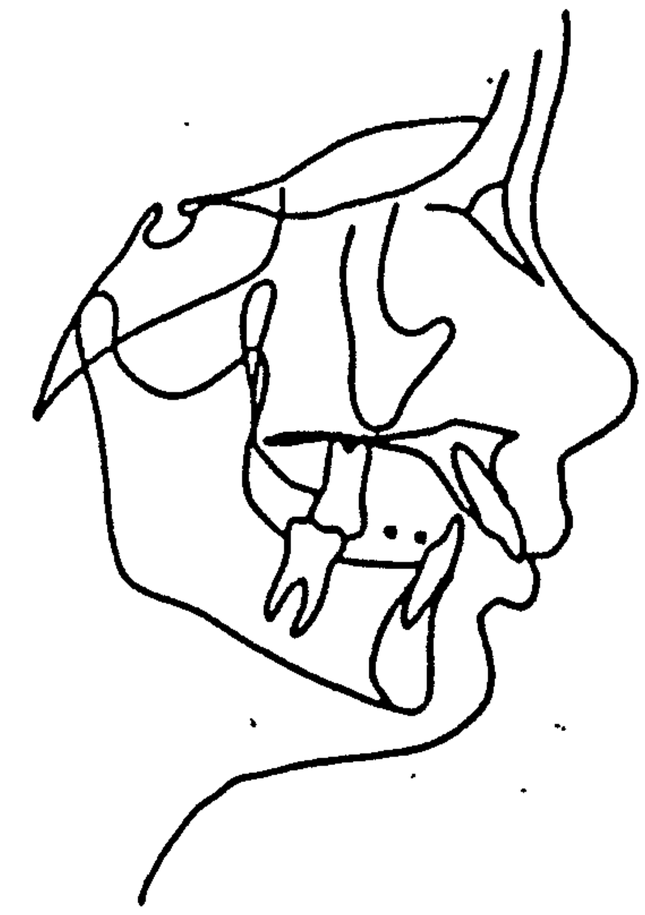
TYPE A An example of a Type A Class II malocclusion. Note that the maxilla and mandible present a straight skeletal profile, although the maxillary teeth are in labioversion. The anterior face height is only slightly greater than the posterior face height.



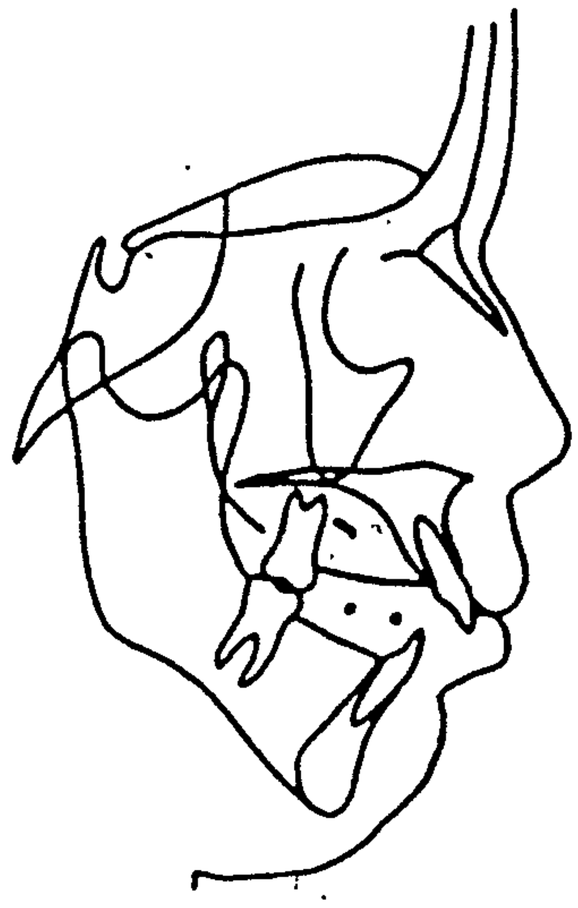
Type B-4 Class II malocclusion

TYPE B An example of Type B Class II malocclusion. Note the parallelism of the palatal, occlusal, and mandibular planes, the square gonial angle, and the resultant skeletal deepbite. (Class II,

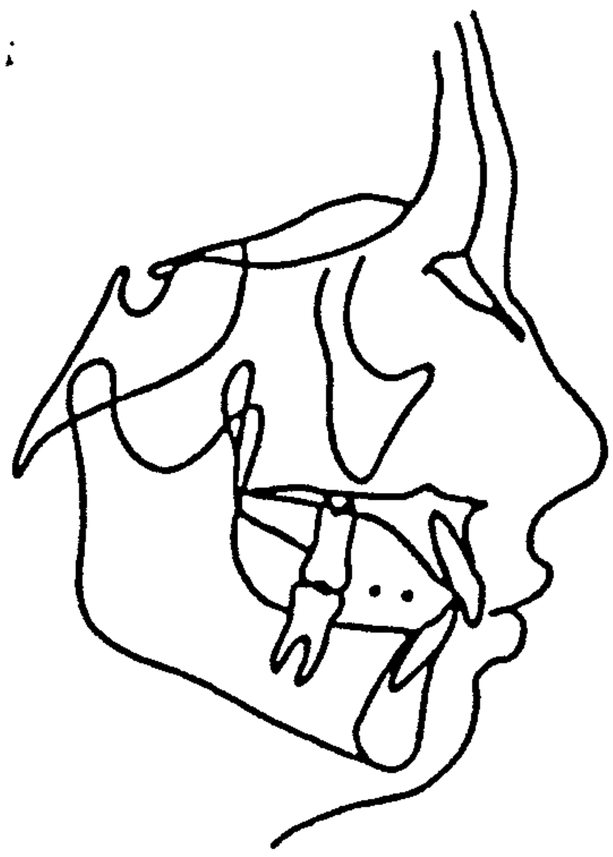
Division 2 on the left, Class II, Division 1 on the right.)



TYPE C maxilla normal, mandible short and retruded.



TYPE D Retrognathic profile small mandible, normal or slightly prominent maxilla.



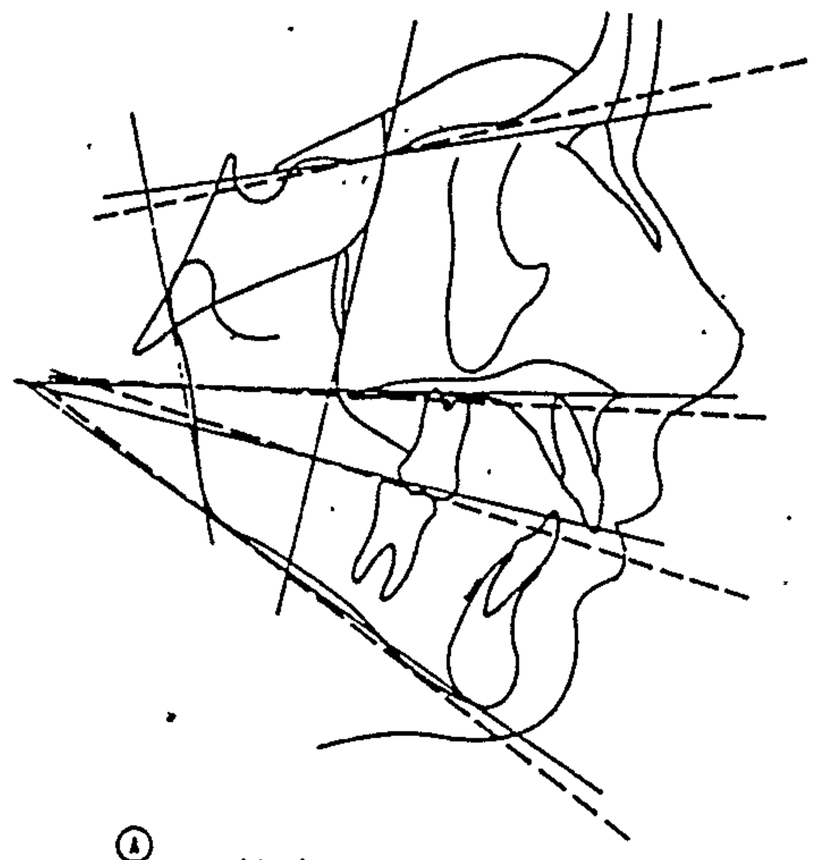
TYPE E Severe Class II profile, prominent midface, normal mandible. Dentition in bimaxillary protrusion.

2.1.2 Vertical Typing of Class II, Division 1

Here Moyers et al (1980) have identified five vertical types within the Class II grouping. (It should be noted that a horizontal type need not have vertical abnormality.)

Type 1: (High Angle Pattern,
Dolichofacial Pattern)

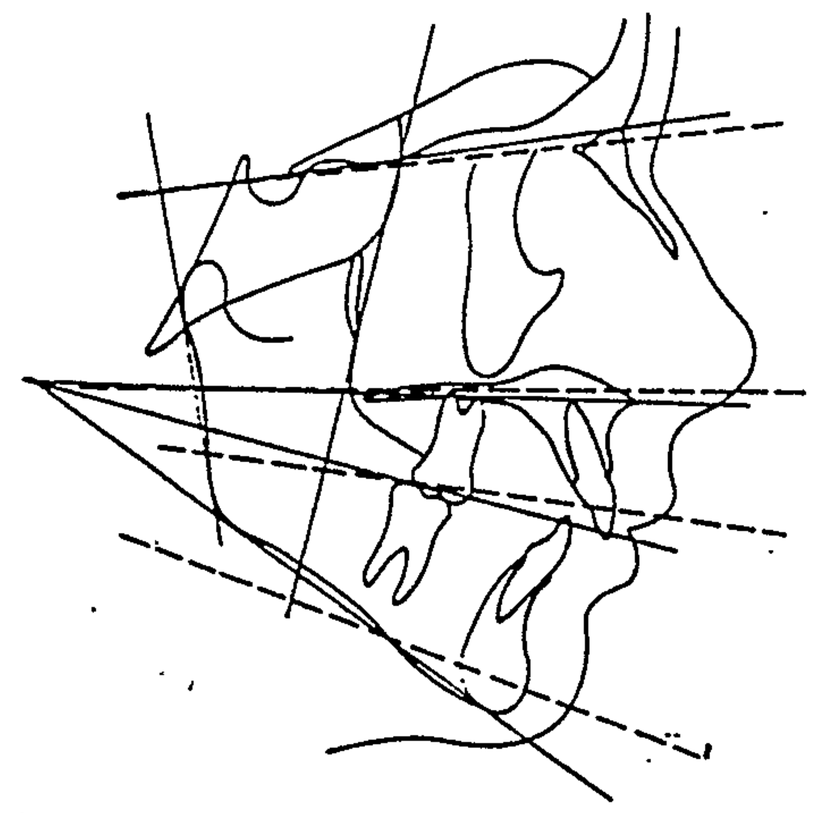
Steep mandibular plane, steeper occlusal plane, palate tipped downward. Anterior cranial base (NS) tipped upward. This pattern results in a large anterior face height in relation to the smaller posterior face height. It is variously described as "high angle case", "steep mandibular plane" case, "long face syndrome" or "dolychofacial".



① Vertical Type 1

Type 2: (Low Angle,
Brachyfacial Pattern)

Essentially a square face pattern
mandibular plane]
occlusal plane] - are low and
palatal plane] nearly parallel.
The gonial angle is close to orthogonality; the anterior cranial base is more horizontal than normal. This pattern has the incisors vertical and in deep bite although the maxillary incisors may be proclined.

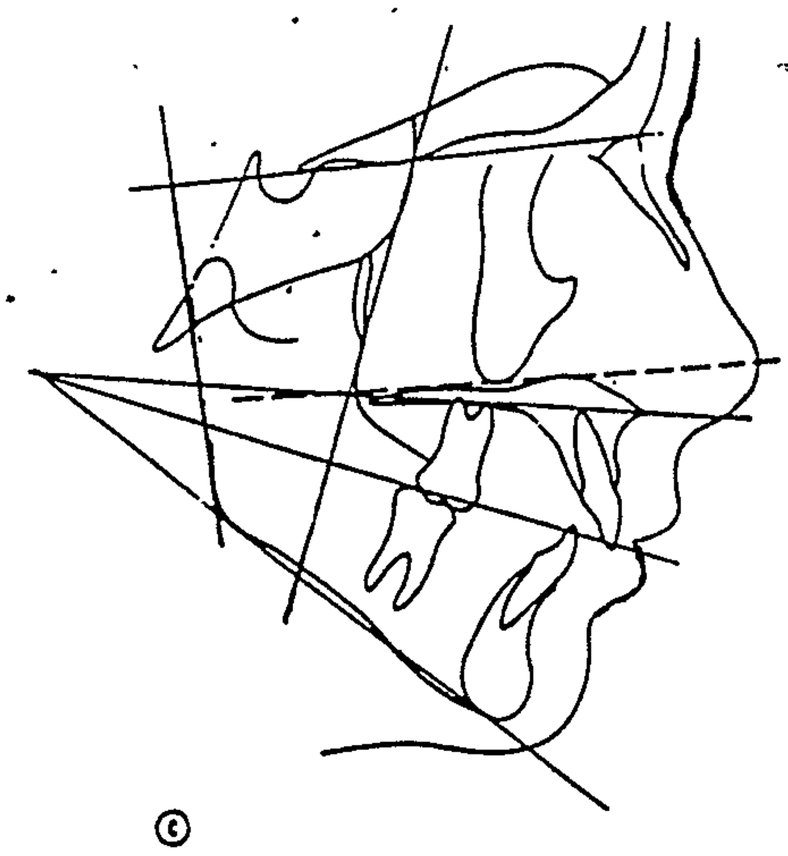


① Vertical Type 2

Type 3: (Open Bite)

Features a palatal plane tipped upward anteriorly, a steep mandibular plane, resulting in a skeletal anterior open bite.

Key:
The normal position of cranial base (NS), palatal occlusal and mandibular planes is shown by the solid line (Michigan Growth Study norms) - broken line illustrates the planes for each vertical type.



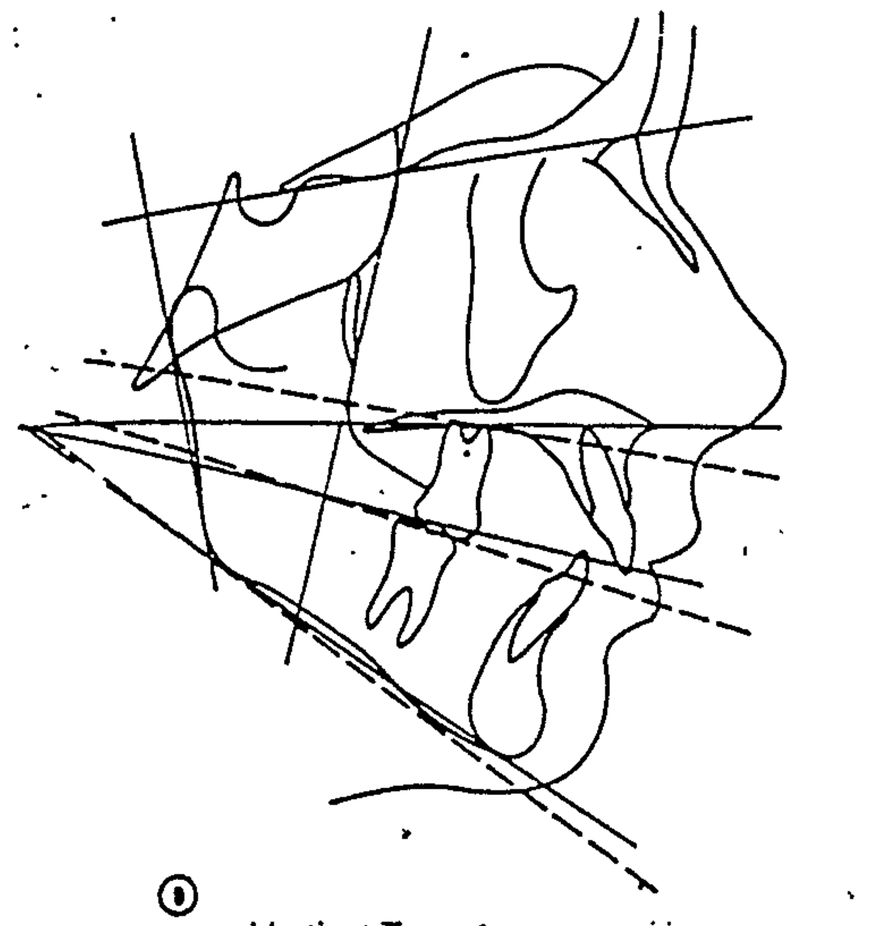
① Vertical Type 3

Figure 2.2, (1, 2, 3) Moyers et al, 1980, p482.

Figure 2.2 cont., (4, 5) Moyers et al, 1980, p483

Type 4:

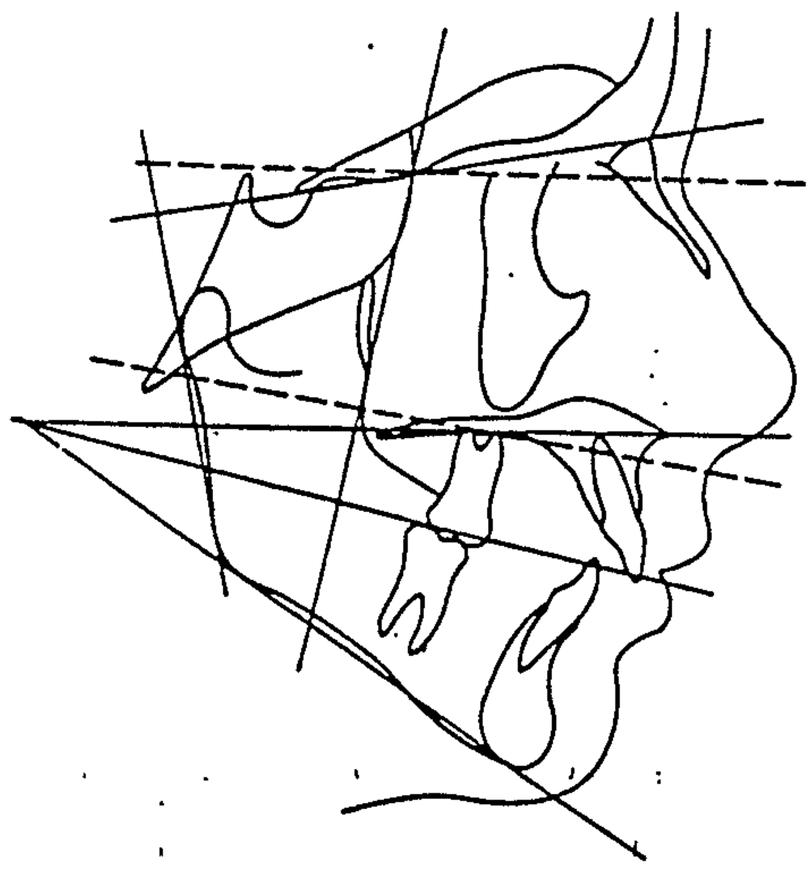
Mandibular plane, occlusal plane and palatal plane are tipped downward markedly. Features are a high lip line often on the maxillary alveolar process. The gonial angle is obtuse. This is a rare category but severe in nature, usually associated with Type B (maxillary prognathic pattern).



Vertical Type 4

Type 5: (Square Face Syndrome)

(Related to Type 2.) The mandibular and occlusal planes are normal. Palatal plane is tipped downward, gonial angle is very square. This results in a skeletal deep bite. The lower incisors are found in extreme labioversion. The upper incisors are nearly vertical (bimaxillary protrusion is seen in this category).



Vertical Type 5

Legend:

NS, mandibular plane, palatal plane: Solid line Michigan Growth Centre Norms.

: Broken lines show the five vertical types found in the study

2.1.3 Facial Patterns

These findings of McNamara and Moyers et al indicate the extent of the variation within the Class II malocclusion group.

Anteroposteriorly, it has been found that a high percentage of cases have the maxilla in a normal or neutral position in relation to the craniofacial structures, with a retrognathic mandible either retruded or short. Moyers et al found that 50% of cases fit this description while McNamara's estimate was 66%. The prognathic maxillary types were found to make up less than 20% of the cases in the Moyers et al study.

The clinical implications of these findings have been outlined by McNamara who writes that the high percentage of Class II cases associated with a normal neutrally placed maxilla would logically contraindicate extraoral traction designed to have an orthopaedic effect on the maxilla and instead suggests the selection of treatment that optimises mandibular growth.

With McNamara's study in mind, Proffit (1986: p205) has suggested the selective use of functional appliances rather than maxillary headgear, (in these cases with a normally positioned maxilla). These functional appliances will position the mandible forward and rely on stretch of soft tissues to activate growth, although there is no evidence that they will increase mandibular growth. They are often effective in the prepubescent (by 2 to 3 years) child with mild

mandibular deficiency, but normal vertical growth.

The analysis of Class II cases by Moyers et al (1980) found that in the vertical plane there were five types of patterns in their sample:

(i) the high angle dolichofacial group with a steep mandibular plane, steeper occlusal plane, a palatal plane tipped downward and the anterior cranial base tipped upwards, with a large anterior face height in proportion to posterior face height (long face or dolichofacial syndrome).

(ii) a low angle, brachyfacial type with low angles for the mandibular plane, occlusal plane and palatal plane, all of which are more parallel to each other, the gonial angle was more square and the anterior cranial base (NS) more horizontal than the Michigan Growth Study norms.

These two facial patterns had been described earlier by Schudy (1964) and Sassouni (1965) and their vital significance in treatment planning in relation to mandibular rotation and chin point changes will be discussed later in this chapter.

The three remaining types (or patterns) are less common and have been described in the Moyers et al study. They include:

(iii) an open bite pattern in which there is a normal facial pattern, but the palatal plane is tipped upward with only a slight increase of the mandibular plane.

(iv) a rare category where the mandibular plane, occlusal plane and palatal plane are tipped downward markedly. Features include a high lip line, often up on the maxillary alveolar process. It is usually a severe malocclusion often associated with the prognathic maxillary pattern (type B). (Its treatment with intrusion mechanics is discussed in Chapter 4.).

(v) the last category has normal mandibular and occlusal planes, but the palatal plane and anterior cranial base are tipped downward. Features include skeletal deep bite, lower incisors and upper incisors may be in labioversion. Bimaxillary protrusion is seen in this facial type. (Moyers, et al, 1980).

Summary:

This type of differential diagnosis of Class II skeletal cases is useful in treatment selection and planning. It has been shown that in the anteroposterior plane the maxilla is often normal in relation to craniofacial structures and it is the mandible that needs growth direction. In the vertical plane five different patterns have been confirmed, including the high angle and low angle cases that had previously been recognised in the literature, because of their marked mandibular rotational behaviour with treatment.

2.2 AN OVERVIEW OF GROWTH OF THE JAWS AND ITS ROLE IN TREATMENT PLANNING.

2.2.1 Maxillary Growth

The maxilla develops postnatally entirely by intramembranous ossification in two ways:

(i) by apposition of bone at the sutures that connect the maxilla to the cranium and cranial base, the spheno-occipital and spheno-ethmoidal synchondroses.

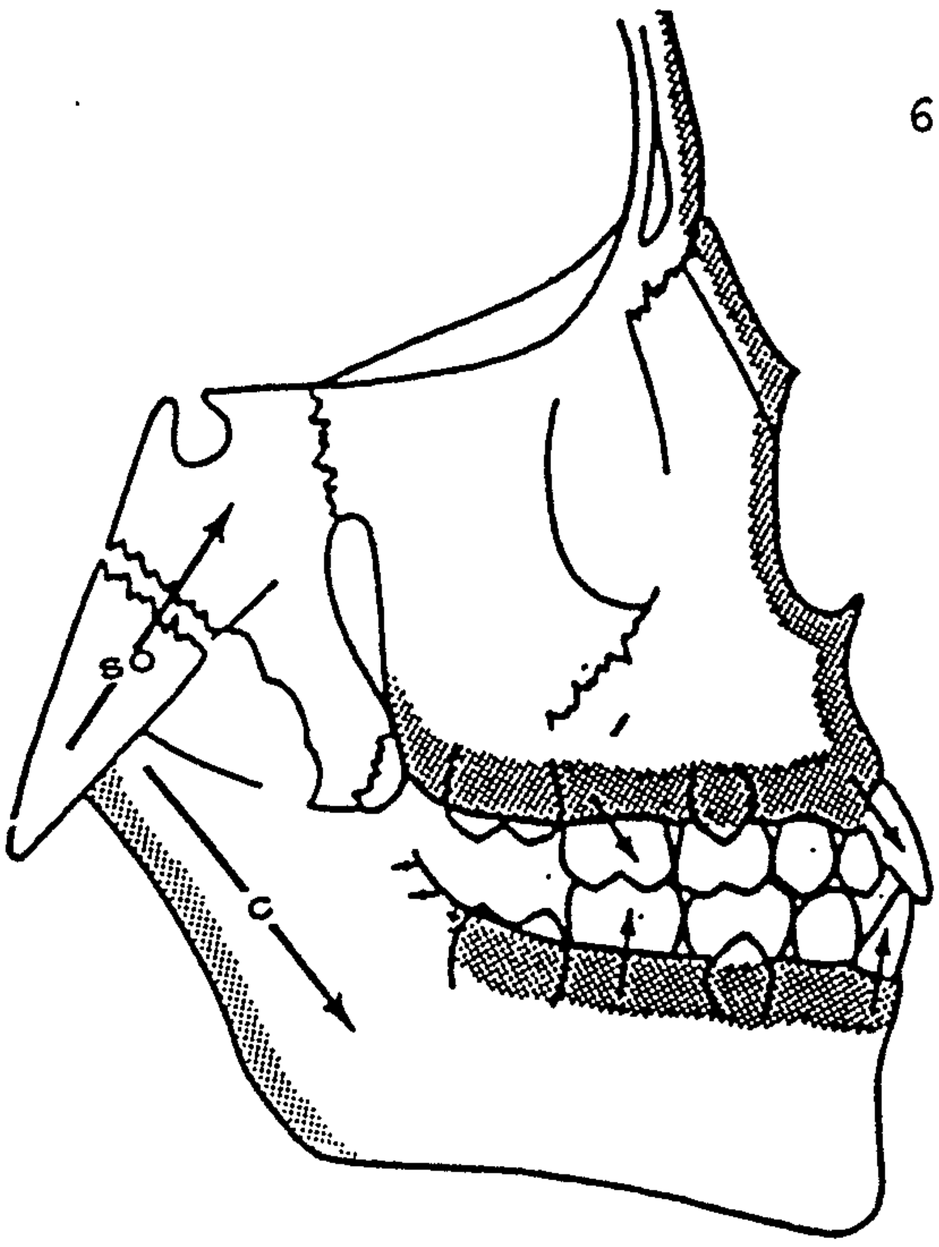
(ii) by surface remodelling.

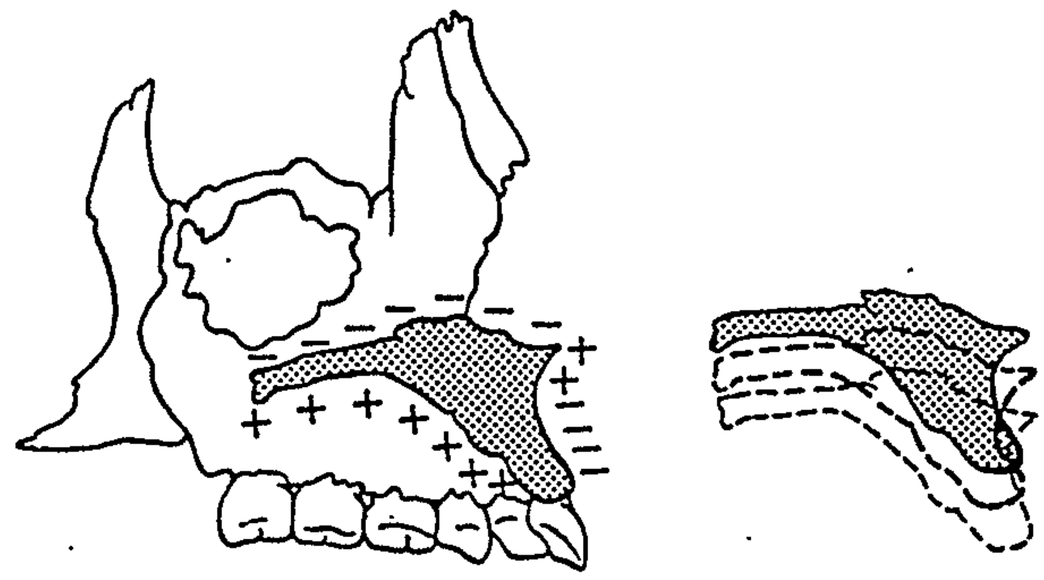
The growth pattern of the face requires that it grow out from under the cranium and the maxilla must follow it a considerable distance downward and forward relative to the cranium and cranial base. The sutures attaching the maxilla posteriorly and superiorly are ideally situated to allow its downward and forward repositioning. The proliferation of bone in these locations maintains the sutural width; the bone apposition occurs on each side of the suture, so that the bones to which the maxilla is attached also become larger. Part of the posterior border of the maxilla is a free surface in the tuberosity region to which bone is added, creating additional space into which the primary and then the permanent molar teeth successively erupt. (Enlow, 1982: p84). Remodelling of the front surfaces occurs as the maxilla grows forward and downward, almost the entire anterior surface undergoes resorption (Enlow, 1982: p84); Proffit, 1986: p30).

Depending on the specific location, translation of the naso-maxillary complex and remodelling may either oppose each other or produce an additive effect; for example, on the roof of the mouth bone is removed from the nasal side and added to the oral side, creating an additional downward and forward movement of the palate. Immediately adjacent to this the anterior part of the alveolar

process is a resorptive area, so removal of bone from the surface tends to cancel some of the forward growth that otherwise would occur with the translation of the entire maxilla and is an example of remodelling opposing growth. (Enlow,1982: pp82-84).

Enlow (1982: p84) describes a passive displacement of the maxilla created by the growth at the cranial base, described above, and an active growth of the maxillary structures and the nose. This passive displacement caused by sutural growth is an important growth mechanism during the early primary dentition years; but becomes less important as growth at the synchondroses of the cranial base slows at about age 7 years with completion of neural growth (Coben, 1966; Proffit, 1986: p81) and during the entire period between ages 7 to 15 years about one third of total forward maxillary movement is due to passive translation, the rest is the result of active growth of the maxillary sutures in response to stimuli from enveloping soft tissue. For example, as a result of surface apposition or resorption, the maxilla grows downward and forward as bone is added in the tuberosity area posteriorly and at the posterior and superior sutures. This results in greater downward and forward growth (25% greater) than the forward movement of anterior surface of the maxilla which undergoes surface remodelling, (See Figure 2.3), except for a small area of the anterior nasal spine. (Enlow, 1982: p42).





(a) Coben S., 1966, p9.

(b) Enlow D.H., 1982, p43.

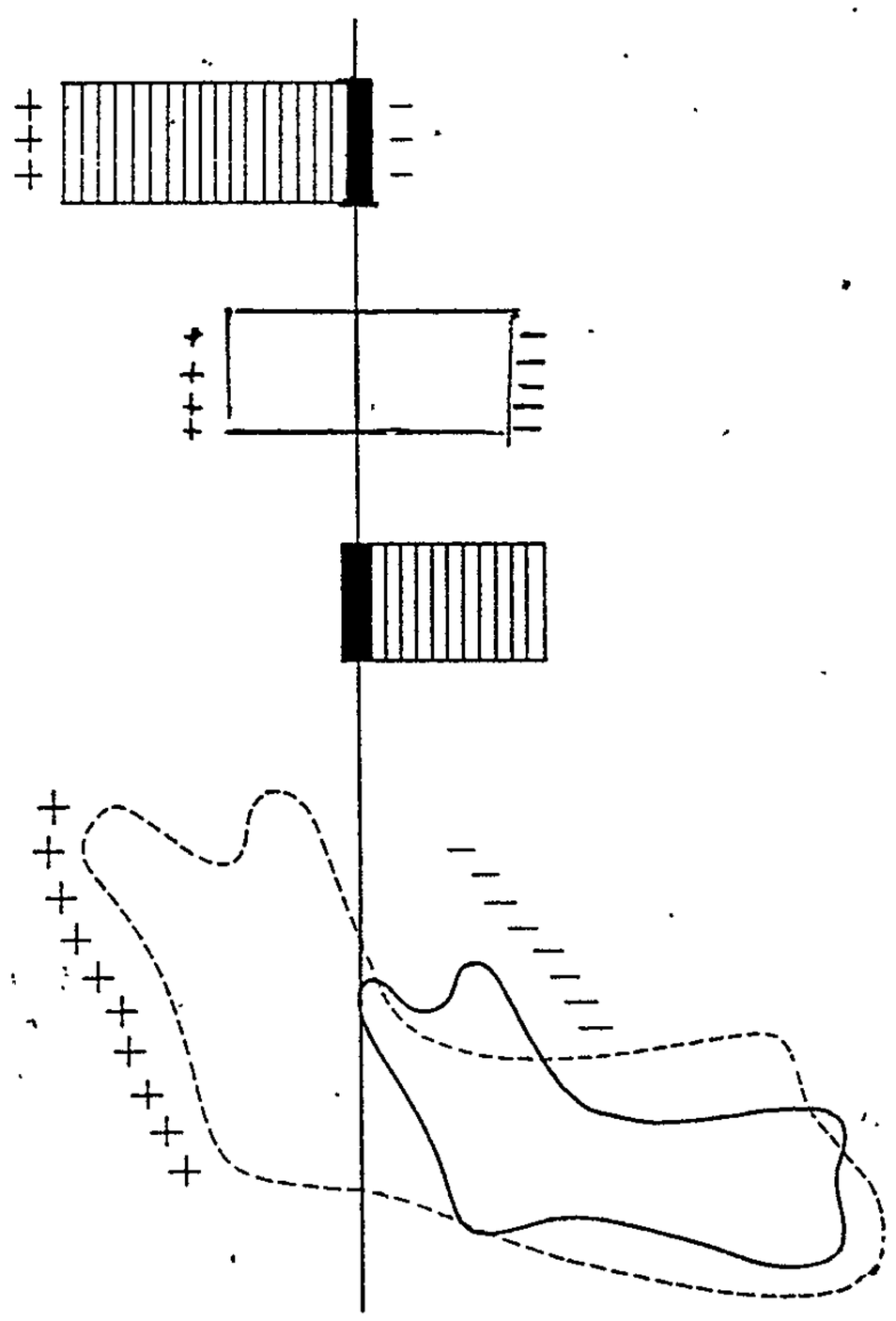
Figure 2.3:
(a) Postnatal craniofacial growth systems from age 7 (second decade). Cartilaginous growth: SO, Spheno-occipital synchondrosis - active through puberty, C, reflection of condylar mandibular growth - active to facial maturity; nasal septum - growth completed. Spheno-ethmoidal circummaxillary suture system: Sutural growth no longer primary system of upper facial development., Surface apposition-modelling resorption development (stippled area). Now major method of upper facial development and alveolar growth.

(b) Shows remodelling of the hard palate and bony maxillary arch with areas of bone resorption and bone deposition marked.

2.2.2 Mandibular Growth

Both endochondral and periosteal growth activity play an important role in growth of the mandible. The condyle has a surface coverage of cartilage at the temperomandibular joint and although it is not like the cartilage at an epiphyseal plate or synchondrosis, hyperplasia hypertrophy and endochondral replacement do occur there. All other areas of the mandible are formed and grow by direct surface apposition and remodelling.

The overall pattern of growth with the cranium as the reference area is such that the chin moves downward and forward, with the principle sites of growth being the posterior surface of the ramus and the condylar and coronoid processes, there being little change along the anterior part of the mandible. (See Figure 2.4).



As the mandible grows in length, the ramus is extensively remodelled, so much so that bone at the tip of the condylar process at an early age can be found at the anterior surface of the ramus some years later. Given the extent of surface remodelling changes, it is an obvious error to emphasize endochondral bone formation at the condyle as the major mechanism for growth of the mandible.

Figure 2.4
Redrawn from Enlow D.H., Handbook of Facial Growth, 1982: p43.

The chin translates downward and forward as the growth occurs at the condyle and posterior surface of the ramus. The mandible grows longer by periosteal apposition of bone on the posterior surface of the ramus, and the ramus grows higher by endochondral replacement at the condyle accompanied by surface remodelling. The chin itself is almost inactive as a growth site. The backward movement of the ramus is an ideal example of remodelling resorption, i.e. the mandible grows longer by apposition of new bone on the posterior surface of the ramus, while at the same time large quantities of bone are removed from the anterior surface.

In infancy the ramus is located in about the region of the primary first molar. Progressive posterior remodelling creates space for the second primary molar and then for sequential eruption of the permanent molar teeth (Proffit, 1986: pp31-33).

Data from Riolo et al (1974: An Atlas of Craniofacial Growth, Ann Arbor, Michigan), indicate that the mandible grows at a steady rate before puberty. The average ramus height increase is 1 - 2mm per year and corpus length increases 2 - 3mm per year. This type of cross sectional data tends to smooth out the pubertal growth spurts which do occur in mandibular growth.

The accentuation of the chin prominence actually results from resorption of the bone just above the chin point, between it and the alveolar base and also from the forward translation of the chin with

mandibular growth.

2.2.3 Theories of Growth Control

Exactly what determines the growth of the jaws still remains unclear and a subject of considerable research and study. Proffit lists two "major" theories that are currently viewed as being able to explain the determinants of craniofacial growth:

(i) cartilage is the primary determinant of skeletal growth while bone responds secondarily and passively; and

(ii) the soft tissue matrix in which the skeletal elements are embedded is the primary determinant of growth and both bone and cartilage are secondary followers.

The major difference in the theories is the location at which the genetic control is expressed. The first theory or "cartilage theory" suggests that genetic control is expressed in the cartilage, the bone responding passively. This indirect genetic control is called "epigenetic". The second theory or functional matrix theory of Moss (1968) assumes that genetic control is mediated to a large extent outside the skeletal system and that growth of the bone and cartilage is controlled epigenetically occurring in response to soft tissue growth. Moss and Salentjin (1969) also suggested that volumetric growth of the oronasopharyngeal functioning spaces was the primary factor in facial skull growth, its objective being maintenance of an airway.

Proffit (1986: p33) writes that it becomes apparent that the more indirectly growth is controlled the greater the opportunity for environmental influences to affect it and he believes the determinants of growth may be found in some synthesis of the cartilage and functional matrix theories.

Distinguishing between a site of growth and a centre of growth may be useful in treatment planning.

A site of growth is merely a location at which growth occurs, (e.g. mandibular condyle).

A growth centre is a centre at which independent or genetically controlled growth occurs. (Enlow, 1982: p26).

Sutures and periosteal tissues are generally not primary determinants of craniofacial growth as evidenced by the failure of these sutural areas to grow independently when transplanted. Also it can be seen that growth sutures will respond to outside influences, for example, rapid maxillary expansion at the midpalatal suture will result in new bone formation and overall enlargement. Alternatively, if a suture is compressed (e.g. extraoral orthopaedic traction) growth at the site is impeded, thus sutures are areas of growth that react to outside influence and the maxillary sutures are sites of growth, but not independent growth centres.

Experiments in which the condyle was removed or transplanted do not

indicate that the condylar cartilage is a growth centre. (Proffit, 1986:p37). Other studies by Lund (1974) show fractures of the condyle in a child do not lead to growth impairment. Proffit argues that if the condyle was an important growth centre it could be expected that severe growth impairment would follow the condylar fracture and he concludes that growth at the mandibular condyles is analogous to sutural growth at an epiphyseal plate and not an independent growth centre. (Proffit, 1986: pp36-37). Growth experiments (in animals) do indicate that cartilaginous nasal septum in animals may be independent growth centres, their partial removal resulting in deficient forward growth of the animals nasomaxillary complex. There are few if any similar examples reported in humans. However, this loss of growth in animals does indicate that septal cartilage may have innate growth potential unlike the condylar cartilage or maxillary sutures (Sarnat, 1976).

The functional matrix theory put forward by Moss, would place the genetic determinant of growth neither in bone nor cartilage, but in the adjacent soft tissues where growth occurs in response to functional needs and is mediated by the soft tissue in which the jaws are embedded. This theory may best be illustrated by the growth of the brain (Moss, 1968) and conditions such as hydrocephaly in which accumulated cerebral fluid leads to a build-up in intercranial pressure and reciprocal growth of the cranial vault will occur. As discussed earlier Moss and Salentjin (1969) theorize that the major determinant of growth of the maxilla and mandible is the enlargement

of the nasal and oral cavities which grow in response to functional needs.

Summary

* Growth of the cranial base is a result of endochondral growth and bony replacement of the synchondroses, which have independent growth potential.

* Growth of the maxilla occurs from a combination of sutural growth and direct remodelling; the maxilla is "translated" downward and forward as the face grows and new bone fills in at the sutures; the role of the nasal septum in translation of the maxilla remains to be confirmed and growth of the surrounding soft tissue would appear important.

* Growth of the mandible occurs by both endochondral proliferation at the condyle and apposition and resorption of bone at the surfaces. It is likely that the mandible is translated in space by growth of muscles and related soft tissue. (Graber, 1972: pp61-71; Enlow, 1982: pp26-33; Proffit, 1986: pp27-38).

2.2.4 Rotation of the Jaws During Growth

The introduction of cephalometrics in the 1930s-1940s, facilitated the longitudinal study of craniofacial growth and it was soon employed to test the different concepts concerning the mechanism responsible for growth of the head. The technique of superimposing a longitudinal series of radiographs on constructed landmarks at the cranial base led to the acceptance of the "forward-downward" growth

concept of the face (Broadbent, 1937). More recently the literature mentions the concept of "rotation". The forward-downward growth of the face has been loosely converted into "forward rotation" and an opening or backward rotation added. However, concepts of the "swinging" chin and many centres of rotation have made heads spin (sic) (Dibbets, 1985).

As stated in Chapter 1, Björk (1955) first introduced the term "growth rotation". He concluded from his metal implant studies that the rotation observed by superimposing consecutive tracings, revealed a mandibular rotation, relative to its original shape, which he related to a marked resorption of the lower border of the mandible in the gonial region which emphasised the unchanging mandibular plane angle to nasion-sella. A more recent work by Björk, A. and Skieller, V. (1983) explains the mandibular growth changes by dividing them into three component parts.

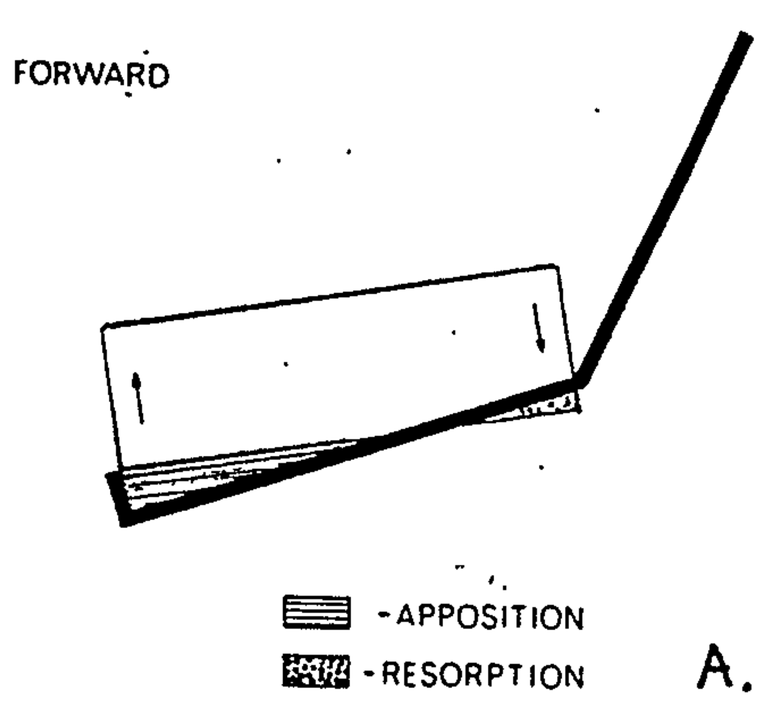
(i) **Total Rotation:** rotation of the mandibular corpus, measured as a change in inclination of an implant line in the corpus, relative to the anterior cranial base.

(ii) **Matrix Rotation:** a rotation of the soft tissue matrix (defined as the tangential mandibular line) relative to the cranial base, there being a centre of rotation at the condyles.

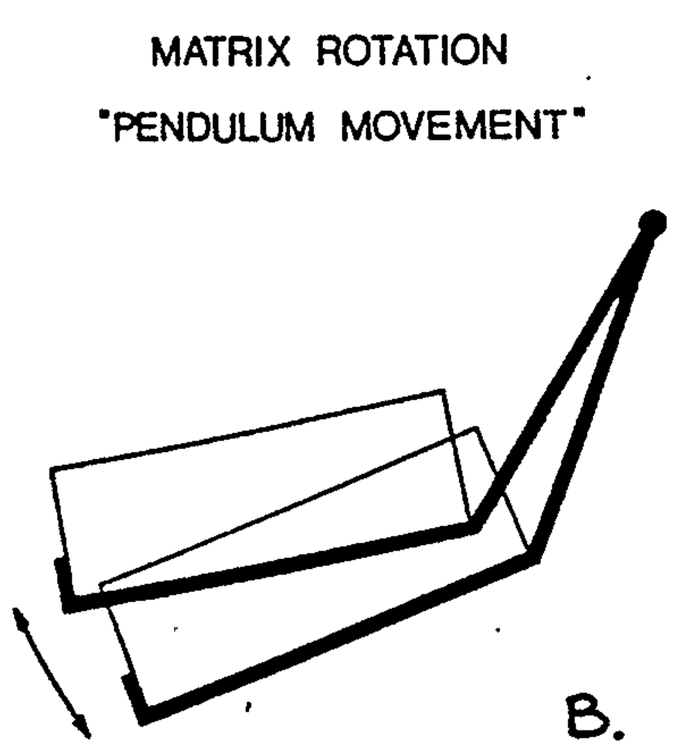
(iii) **Intramatrix Rotation:** is the difference between the total rotation and matrix rotation, expressed as remodelling at the lower border of the mandible. The centre of rotation is somewhere in the corpus.

Björk and Skieller's later description of this internal rotation of the implant line of growth refers to it as the total rotation consisting of two components, the matrix rotation (of outer bony processes and attachments) which occurs around a centre at the condyle and the intramatrix rotation centred within the body of the mandible. By convention, the rotation of either jaw is considered "forward" and given a negative sign if there is more growth posteriorly than anteriorly. (See Figure 2.5A). While the rotation is "backward" and given a positive sign if it lengthens anterior dimensions more than posterior ones, bringing the chin downward and backward. (See Figure 2.7)

Figure 2.5 A and B
Björk and Skieller, 1983: pp4-5.



A.
The intramatrix rotation represents a rotation of the mandibular corpus inside its matrix with the centre somewhere in the corpus and not at the condyles. The anterior part of the corpus is lifted up from the matrix, leading to apposition below the symphysis and the anterior part of the lower border. The posterior part of the corpus is pressed downward into the matrix, resulting in resorption.



B.
In backward rotating cases the matrix rotation may, as in forward rotation, show a pendulum movement with the centre at the condyles.

In summary the bony mandibular corpus and its soft tissue covering and bony processes (the matrix) are considered as independent tissue systems capable of independent rotation both forward or backward, the composition of the total rotation may change in each individual at any time during the entire period of development. (Björk and Skieller, 1983).

It is stated that for an average individual with <u>normal vertical facial proportions</u> there is about a -15^{o} of mandibular rotation from 4-20 years of age (25% matrix rotation and 75% from the intramatrix rotation). Proffit (1986: p84) states that this 15^{o} of rotation is accompanied by only a $2-4^{o}$ reduction in the mandibular plane angle representing the external view of the mandible; the reason for this is the surface changes which compensate for the rotation by resorption or apposition of bone on the lower border of the mandible. (See Figure 2.5A). Björk and Skieller (1983) indicate that for forward rotation there is a posterior resorption of the lower border of the mandible while for backward rotation there is anterior resorption and posterior apposition. On average with forward rotation there is 15^{o} of intramatrix rotation and 11^{o} to 12^{o} of matrix, backward rotation resulting in a 3^{o} to 4^{o} decrease in mandibular plane angle during childhood to adolescence.

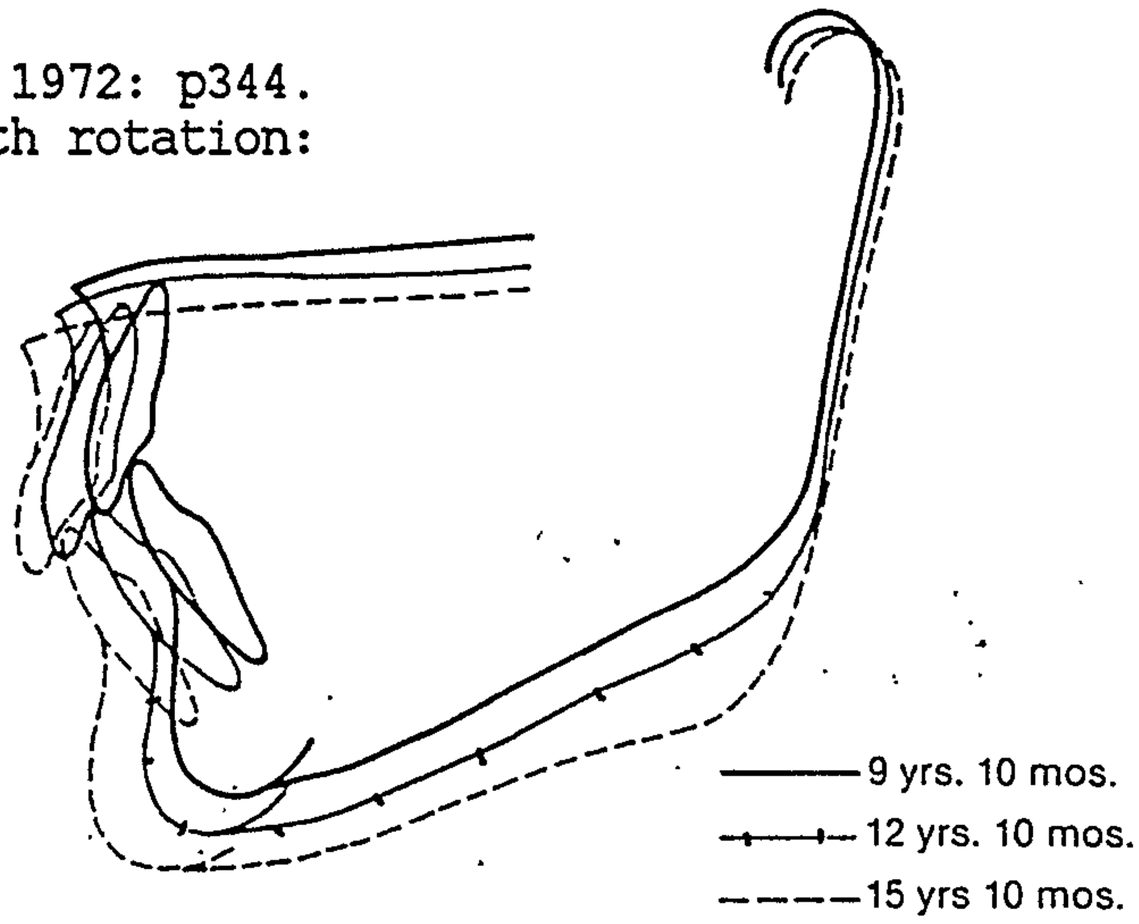
An explanation for the complicated mechanism of mandibular growth rotation may primarily be found to be closely associated with both the direction and the amount of growth at the condyles which may be part of a genetically determined growth pattern in the development of the bone and muscle systems (Björk and Skieller, 1972).

The maxillary rotation: It is perhaps less easy to assess the maxillary growth, however, if implants are placed above the maxillary alveolar process an intramatrix core of maxilla is seen to undergo a small and variable degree of rotation forward or backward, a small amount of forward rotation is the more usual pattern. Varying degrees of resorption of bone on the nasal side and apposition of bone on the palatal side occur along with a variation in the amount of eruption of the incisors and molars. In a **normal skeletal pattern**, an external rotation in the opposite direction to the intramatrix rotation occurs, so that the two rotations cancel out and the net change in jaw orientation is usually zero. (Björk and Skieller, 1976).

2.2.4.1 Growth rotation in the brachyfacial and dolichofacial patterns. Björk and Skieller (1983) have also described variations from the slight forward mandibular and maxillary rotation seen in the normal vertical cases. For example, in the brachyfacial patterns characterized by a short anterior face height, an excessive forward rotation of the mandible occurs with growth resulting from both an

increase in the normal internal rotation and a decrease in matrix (external) rotation resulting in a lack of compensation. The result is a nearly horizontal palatal plane and mandibular morphology of the "square jaw" type, low mandibular plane angle and a square gonial angle, a deep bite malocclusion and crowded incisors usually accompany this type of rotation. (See Figure 2.6). This is similar to Moyers et al vertical Type 2. (See Figure 2.2[2])

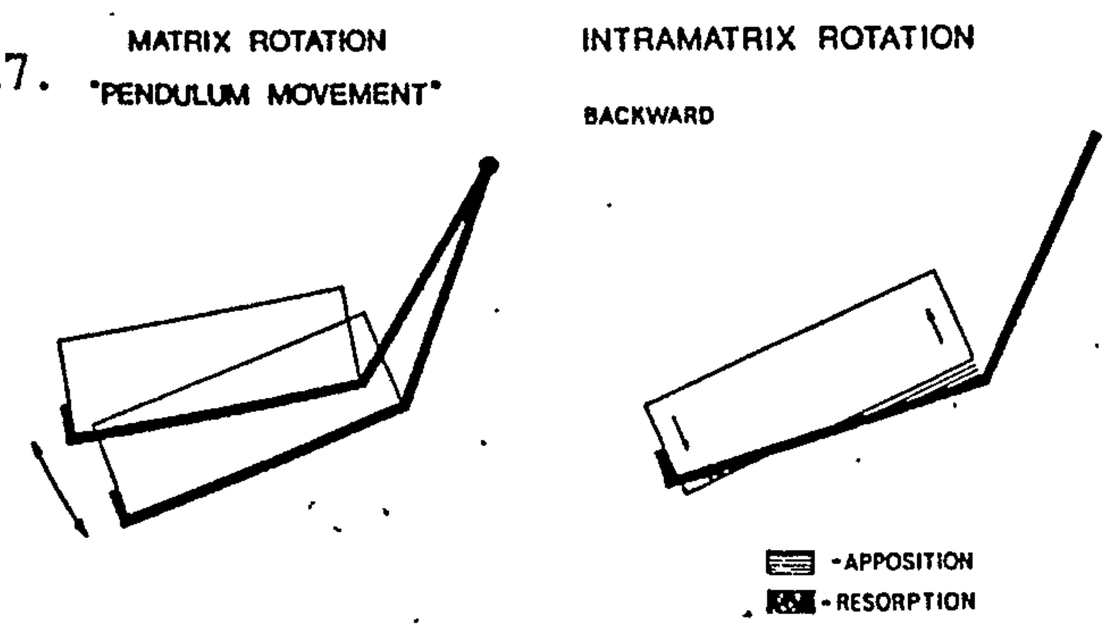
Figure 2.6
Björk and Skieller 1972: p344.
Brachyfacial, growth rotation:



Cranial base superimposition shows the characteristic pattern of forward jaw rotation in an individual developing in the "short face" pattern. The forward rotation flattens the mandibular plane and tends to increase overbite anteriorly.

In "long face" dolichofacial patterns with excessive anterior face height, the palatal plane rotates down posteriorly, often creating a negative rather than the normal positive inclination to the horizontal. The mandible showing an opposite backward rotation with an increase in the mandibular plane angle, brought about by either a lack of normal forward internal (intramatrix) rotation or even a backward internal rotation. The total backward rotation is primarily matrix rotation centred at the condyle and not intramatrix rotation (See Figure 2.7). This type of growth rotation will be associated with mandibular deficiency causing a retrognathic profile (the chin rotates back as well as downward) with either an anterior open bite or occasionally the incisors will continue to erupt until contact. (See Figure 2.8)

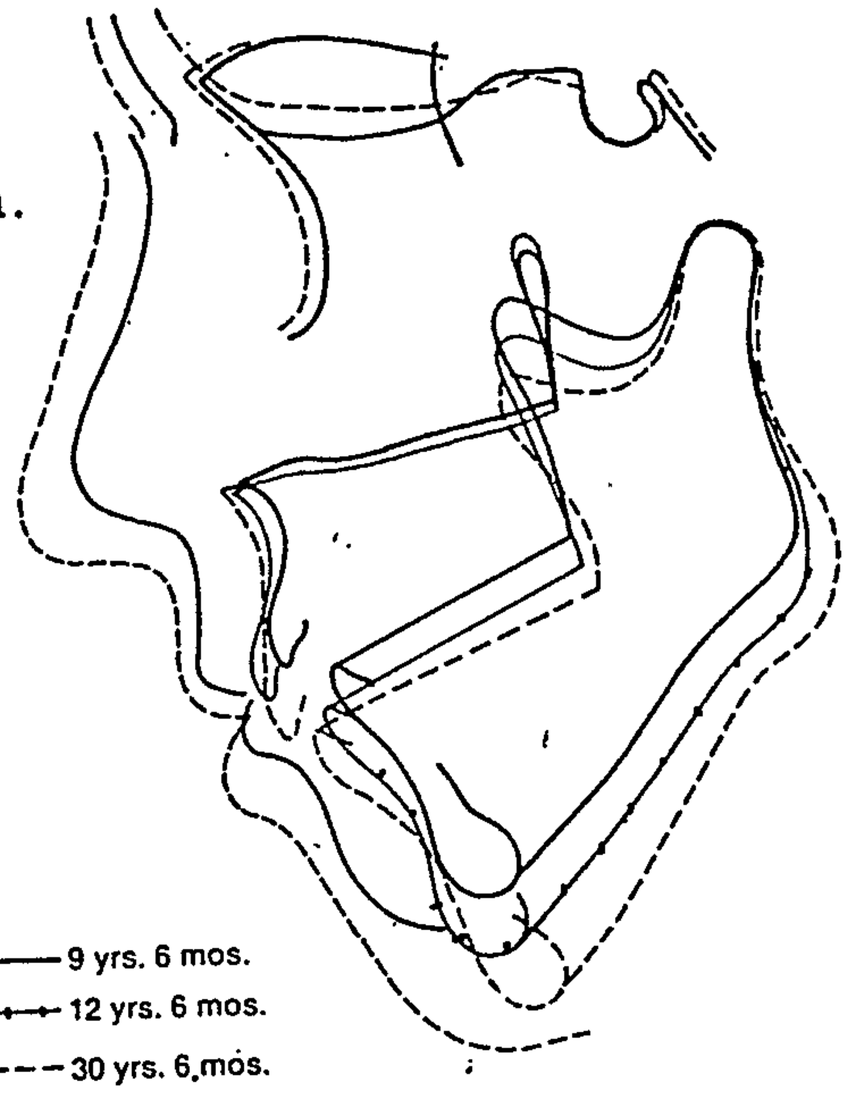
Figure 2.7
Björk and Skieller,1983: p27.



In backward rotating cases the matrix rotation may, as in forward rotation, show a pendulum movement with the centre at the condyles.

Backward intramatrix rotation resulting in resorption below the symphysis and apposition below the angle. Apposition may occur at the chin point. The Centre of rotation is situated in the corpus.

Figure 2.8
Björk and Skieller, 1983: p29.
Dolichofacial pattern of growth rotation.



The pattern of jaw rotation in an individual with the "long face" pattern of growth (cranial base superimposition). As the mandible rotates backward, anterior face height increases, there is a tendency toward anterior open bite, and the incisors are thrust forward relative to the mandible. (From Björk, A., and Skieller, V., 1983: p29.

2.2.4.2 Jaw rotation and tooth eruption

As discussed earlier the growth of the jaws creates space for posterior tooth eruption. Rotation of the jaws can also influence the direction of eruption and ultimate position of the incisor teeth.

Eruption path of maxillary teeth in normal growth pattern: The maxillary teeth normally erupt in a downward and slightly forward direction. However, if backward maxillary rotation occurs the anterior teeth are directed more posteriorly, relatively uprighting them and decreasing their prominence.

Eruption of mandibular teeth is upward and slightly forward. The normal internal rotation of the mandible carries the jaw upward in front, the rotation altering the path of eruption of the incisors tending to direct them more posteriorly.

Björk and Skieller also report a decrease in arch length that occurs normally from 10 to 21 years resulting from the internal jaw rotation which tends to upright the incisors, while the molars migrate further mesially during growth than do the incisors and this is more noticeable in the mandible than the maxilla because it has slightly greater rotation. The clinical significance of this process is covered later in a discussion on retention (Chapter 5).

The excessive forward rotation associated with brachyfacial pattern cases, may result in overlapping of the incisors and lower lingual

displacement with the development of deep overbite, often associated with Class II,Division 2 described in Moyers et al, Type B. In the dolichofacial pattern the rotation in the mandible will carry the incisors forward producing a dental protrusion. An open-bite will develop as anterior face height increases, unless the incisors over-erupt to an extreme distance. (Björk and Skieller, 1972).

2.2.5 Planning Treatment that is Assisted by Growth (the pre and early adolescent period)

Continued substantial growth in a patient offers an opportunity to correct the Class II relationship either entirely by growth modification or to combine the useful components of the growth vectors to assist in Class II dental correction with extraction of teeth.

Proffit (1986: p201) stresses the importance of distinguishing a non-skeletal Class II relationship from the skeletal relationship. Growth modification is not needed in the normal facial type such as Moyers et al Type A (See Figure 2.1) where the teeth only have been displaced relative to the jaws, which are themselves in a normal relationship.

Other important factors to consider in growth modification treatment planning are:

(i) the Class II skeletal morphology in the horizontal plane.

(ii) the skeletal problems in the vertical plane.

(iii) jaw growth prediction may be of value; current methods and

their reliability will be discussed in sub-section 2.5.2.

(iv) indicators of the beginning of the pubertal growth spurt which are listed and discussed in sub-section 2.5.3.

2.2.5.1 Growth modification in Class II correction:

There must be a substantial amount of growth remaining and the growth modification needs to be commenced before the pubertal growth spurt. Although jaw growth certainly continues after puberty its magnitude is rarely sufficient to allow correction of significant skeletal jaw discrepancies. (Coben, 1966; Proffit, 1986: p201).

Case diagnosis and treatment planning in growth modification:

Class II correction for skeletal cases will require a cephalometric analysis to establish the anteroposterior and vertical relationship of the dental jaws to craniofacial structures.

(i) Consider the anteroposterior relationship: McNamara (1981) has reported that up to 66% of Class II cases have the maxilla in a neutral or normal position while the mandible is retruded. A smaller proportion, perhaps 20% have a protruded maxilla with normal mandible. (Moyers et al, 1980).

(ii) Consider the vertical relationship: Pearson (1978) has stated that growth patterns may assist treatment in some cases or actually increase the treatment difficulty; for example, a backward growth rotation of the mandible in Class II cases usually results in an increase in the anterior face height and a more posterior chin position, while a forward growth rotation may assist Class II

correction.

For Class II skeletal cases with mandibular deficiency (short or retruded): As stated earlier the majority of Class II cases have a component of mandibular deficiency and treatment methods designed to stimulate mandibular growth seem logical rather than attempts at orthopaedic force on the normally placed maxilla. (McNamara, 1981). It has been suggested that the use of functional appliances to influence mandibular position is more logical. Diagnostic indicators for selection of functional appliances:

* the patient should be prepubescent by 2 to 3 years (i.e. 8 to 9 years of age in girls, 10 to 11 years in boys).
* normal or slightly forward maxillary development
* normal vertical face, in particular not dolichofacial, high angle cases
* normally positioned or retrusive lower incisors, but definitely not protrusive, lower incisors. (Proffit, 1986: pp204-205).

For Class II skeletal cases with a forward maxilla: Since the growth pattern of the maxilla is such that it is translated downward and forward, growth at the suture of the maxilla has been described as a reactive process and not independently active. The use of force applied across the sutures to modify excessive maxillary growth in Class II correction is well established in the literature (Moore, 1959; Coben, 1966; Enlow, 1982: p276) and extraoral force to the

maxilla has been used since the late nineteenth century.

The vertical facial pattern is important to treatment planning. For example, if cervical traction is used, producing a downward vertical force component, then the molars will extrude causing a backward mandibular rotation and distal chin point positioning in the more "high" angle dolichofacial cases and this is less than helpful in Class II correction. However, the direction of traction may be changed to avoid extrusion and to intrude the molars. In the low angle brachyfacial patterns cervical headgear may be acceptable to assist in bite opening (Schudy, 1965;Pearson, 1978) and this is discussed more fully later.

The ideal case for extraoral traction in growth modification treatment: bearing in mind that extraoral force to the maxilla inevitably produces both orthodontic and skeletal orthopaedic effects, the following diagnostic indicators should be noted:

* excessive horizontal growth of the maxilla, with or without excessive vertical changes
* reasonably good mandibular dental and skeletal morphology
* to be effective start treatment before prepubertal growth spurt.

2.2.5.2 Review of the literature on growth modification

Coben (1966) found that during growth, maxillary distal traction can tip or bodily move upper molars distally, or it can hold, retard or redirect the forward eruption and migration of the upper molars,

while mandibular condylar growth continues to carry the lower dentition downward and forward out of the Class II relationship. Coben also adds that surface bone apposition on the sub-nasal surface of the maxilla can be retarded or halted with extraoral force or Class II elastic force.

It is during the pubertal growth period that the greatest advantage is made in attaining Class II correction, because at this time there is a general increase in the downward and forward growth of the mandible, but if there is little mandibular growth, or if it is impressed vertically, it becomes increasingly difficult to establish a Class I relationship and the treatment plan may have to be altered to include extraction of teeth (Coben, 1966).

The object of functional appliances, often as an adjunct to full banding, is to make maximum use of growth modification in the mixed dentition period. In severe skeletal cases further treatment will most likely be required, both for further skeletal and occlusal correction and the functional appliance is indicated in the deficient mandible, Class II cases (Proffit, 1986: p204). However, there is no definitive evidence that functional appliances actually increase the size of the mandible. Coben (1966) writes that there is no substantiating evidence of there being any ability to stimulate mandibular growth mechanically beyond its genetic potential, and most methods of functional therapy employ maxillary arch anchorage in some manner and the success of functional appliances may be found in maxillary retardation. This idea is supported by Lindquist, writing in Graber and Swain (1985: pp592-593), and Proffit (1986: p203). It

has been suggested that the soft tissue elastic force caused by stretch of the tissues, when the mandible is held forward with these appliances, causes restraint on the maxilla and usually some tooth movement. Whatever the action, cephalometric study does show some growth stimulation, although this may be simply an acceleration of growth rather than an actual size increase. (Proffit, 1986: p205).

Moore (1959) states that two factors are of primary importance in the successful treatment of Class II malocclusion, namely, growth and mechanical therapy. Moore investigated the effectiveness of several treatment factors which he divided into maxillary factors and mandibular factors.

Table 2.1 and Table 2.2 summarise these treatment factors that were substantiated by Moore's study while Table 2.2 also shows the therapies that are best used to maximise growth potential and eruption factors in the edgewise appliance correction of Class II, Division 1 malocclusion.

TABLE 2.1
Moore, 1959: p324.

Maxilla	
I	Inhibit normal forward movement of denture
II	Control eruption pattern
(a)	Guide unerupted teeth into a more posterior path of eruption
(b)	Maintain molar position vertically
III	Move denture posteriorly
IV	Create space in which to move teeth by selective extractions
Mandible	
I	Growth - horizontally and vertically
II	Control eruption pattern
(a)	Tip occlusal plane up posteriorly
	1. Stimulate molar eruption
	2. Depress anterior segment of teeth
III	Move denture anteriorly
IV	Create space in which to move teeth by selective extractions.

TABLE 2.2

Moore, A., 1959: P351
Treatment Procedures

OBJECTIVES	MAXILLA	MANDIBLE
Growth (consider age and sex of patient)	Occipital anchorage Elastic traction	Pray ! ! !
Eruption	Elastic traction Mechanical arch form Control of pre-molars (banded) Bite Plate	Elastic traction Mechanical arch Control of pre-molars (banded) Bite plate
Tooth movement	Posterior force Occipital anchorage Elastic traction Mechanical arch form (tipping)	Anterior force Elastic traction Mechanical arch form
Space in which to execute tooth movement	Extraction (mechanical arch auxiliaries to produce desired movement)	Extraction (mechanical arch auxiliaries to produce desired movement)

Stages of Class II molar correction in non-extraction cases

The transition from Class II molar relationship to Class I is described by Moore as a gradual transition often over a period of twelve months. After six months the molars when in occlusion are still in Class II relationship, but at rest position as a result of either mandibular growth or inhibition of the normal forward movement of maxillary dentition, it is found that the molar relationship has become end to end.

After 9-10 months the cuspal inclined planes begin to influence the molar relationship and the molars begin to assume a Class I

relationship and at 12 months,Class I molar relationship may exist at both rest position and in occlusion. The change resulted gradually, only a final slight shift being needed to cause the inclined planes to shift their relationship, making it more comfortable to bite forward rather than posteriorly. If posterior traction on the maxillary denture had been discontinued at, say, the tenth month, full correction of the molar relationship would not have been retained or even fully achieved. Moore makes the point that it is not adequate to just achieve Class I molar relationship at rest and in occlusion, it must be retained by continued use of extraoral traction and/or Class II elastics. (Moore, 1959).

2.3 TREATMENT PLANNING FOR CLASS II CORRECTION WHEN JAW GROWTH IS SUBSTANTIALLY FINISHED (or if growth modification is unsuitable).

2.3.1 Introduction:

Moore (1959) found that extraction of teeth can be a factor in successful treatment of Class II malocclusions. However Proffit (1986: p212), and Proffit and Ackerman(writing in Graber and Swain, 1985: p94) state that the use of tooth extraction enables the correct molar and incisor relationships to be achieved, but the underlying Class II jaw relationship remains and the descriptive term "camouflage treatment" is used by these authors for extraction-based treatment of the Class II relationship. They both write that the displacement of teeth, relative to the bony bases, will achieve good occlusion and is compatible with reasonable facial aesthetics in the mild to moderate Class II cases. However, with the severe

cases, retraction of the upper incisors will lead to an increasing prominence of the nose and unaesthetically obtuse nasolabial angle that will signal the effective limits of retraction (or camouflage treatment).

Proffit (1986: p214) writes that extraction treatment in Class II correction is most useful in patients in the early permanent dentition years who are past the pubertal growth spurt, but still have some growth remaining.

2.3.2 Indications for Extraction Treatment

* Too old for successful growth modification

* Will not co-operate with headgear or functional appliance use. Reasonably good alignment of teeth (so that extraction space would be available for controlled anteroposterior displacement and not used up to relieve crowding).

* Good vertical facial proportions especially not brachyfacial, low angle pattern (Schudy,1964: 1973; Proffit, 1986: p214).

2.3.3 Planning Treatment in the Borderline Case, i.e. where the choice between non-extraction (growth modification) and extraction therapy is unclear.

Most authors tend to agree that growth modification is desirable, but it must be commenced just prior to the adolescent growth spurt in order to gain adequate differential growth. (Coben, 1966; Pearson, 1978). However, the mandibular growth must also be in a forward rotational pattern to assist in the Class II correction. A

backward rotation may hinder Class II correction resulting in a more distal chin position and although this can be controlled to some extent using intrusive highpull headgear (Pearson, 1978) it can not be achieved with functional appliances (Proffit, 1986: p204). Growth prediction accuracy for these rotational patterns is uncertain at present, (it will be described later), and rather than rely on a growth prediction alone, Ackerman and Proffit (1970) have suggested the following approach.

2.3.3.1 "Therapeutic diagnosis": As a general principle, if the patient exhibits good skeletal growth and co-operates well, it should be possible to obtain Class II correction without extractions. On the other hand if growth, co-operation, or both, are poor, extractions and "camouflage" would be the best approach. (Ackerman and Proffit, 1970). The question to be answered is what to do about cases that cause doubt and uncertainty about the treatment plan? The visual treatment objective (V.T.O.) and growth prediction is the path taken by Ricketts et al (1979). Growth prediction has been found to work satisfactorily for the average patients, but not so well for the skeletal problems that often occur in this malocclusion. Ackerman and Proffit have suggested the use of the patient's initial treatment response as an aid to treatment planning in that it allows a better evaluation of growth response and co-operation with treatment.

Methods: Implement a conservative (non-extraction) treatment plan, scheduling a re-evaluation of the patient after 6 to 9 months,

typically a Class II patient might be placed on a functional appliance or extraoral traction to the maxilla with minimal use of fixed appliances for tooth movement. If a good response is achieved then this treatment plan is continued. If a poor response is observed, whether through poor co-operation or poor growth, the modification therapy may be dropped in favour of extractions and/or fixed appliances.

2.3.4 Extraction Versus Non-Extraction

In Class II malocclusion with such a wide variation in the morphological pattern, there is a need to individualize treatment planning and in particular decisions on extractions; consideration being given to facial aesthetics, stability of the dentition, overbite control, habits and morphogenetic limitations. Often each of these considerations will point to the same treatment plan. For example, a case with a slight openbite, with some crowding in a somewhat protrusive profile, points to extractions in the treatment plan. However, often there is some conflict in satisfying each of the considerations named above. For example, in a Class II, Division 1 case, with moderate lower crowding and a complete or deep overbite; here the crowding may call for extraction, while the low mandibular plane angle and deep overbite flash warning signals against any extractions. A full look at other considerations is needed, e.g. profile, lower lip position and lower incisor repositioning, tongue, tooth size ratios, may help to point the way to the preferred treatment plan (Rubin, 1969).

Rubin (1969) describes another case full of hazards, built into the skeletal morphology; that of the markedly retrognathic profile, e.g. facial angle of 78^{o}, high mandibular plane angle of 38^{o} and noticeably retrognathic mandible with short posterior ramus height. In these cases growth will not be an aid and may be detrimental if treatment allows backward mandibular rotation. Schudy (1965) advises the planning of treatment as if no growth were present (as in an adult) and makes no effort to achieve Class I occlusion. If no lower crowding is present, then the extraction of upper first premolars enables the correction of anterior overjet. Correction of any supraeruption of incisors could be carried out with intrusive mechanics; vertical molar anchorage may be needed with high-pull headgear to prevent any reciprocal extrusion. In these cases posterior headgear traction causing any posterior movement of maxillary molars or prolonged use of Class II elastics only adds to the skeletal problems with chin point moving further back via backward mandibular rotation precipitated by molar extrusion. In the backward rotating high angle cases Roth has suggested that extraction of teeth will assist treatment by allowing the forward movement of posterior teeth, effectively knocking the props out between molars (sic). He adds that care must be taken not to extrude the buccal teeth and he advises the use of light force mechanotherapy. (Roth, in Graber and Swain, 1985: p701).

2.3.5 Extraction Sites in Relation to Crowding and the Profile

A view popularised by Margolis and Tweed was that the most effective

extraction strategy to relieve crowding is to extract the premolar teeth closest to the site of crowding. However, this site can lead to over-retraction of the anterior teeth unless scrupulous anchorage control is achieved. Where retraction of upper anterior teeth should be minimal, in order to preserve an orthognathic or flat profile and to maintain facial balance (rare in Class II Division 1), then extraction of second premolars or first molars should be made. (Graber and Swain, 1985: p94). Conversely, if the profile is convex and would benefit by some degree of flattening, the extraction of upper first premolars to facilitate upper anterior retraction and extraction of second lower premolars to enhance lower anterior root anchorage units and minimise their retraction. This latter combination has been suggested for Class II Division 1 treatment by Proffit (1986: p424).

If crowding and overjet is minimal and facial balance good, then extraction of permanent upper second molars soon after eruption will allow alignment provided third molars are present. (Note that banding of lower second molars will be needed to avoid their over-eruption.) Headgear may be used on the first molars for distal traction of the remainder of the dentition. (Graber and Swain, 1985; Proffit, 1986: p423).

The extraction site: is also a factor of anchorage control; posterior sites provide much less potential for incisor retraction than more anterior extraction sites. Extraction of second molars, for example, provides about 2 mm of additional space for decrowding the arch, which allows no space for any incisor retraction. By

moving the extraction site forward, thereby increasing the posterior anchorage units, the retraction of anterior teeth may be expected. (Graber and Swain, 1985: p94).

Mechanotherapy can be varied to maximize or minimize the retraction of incisors by increasing posterior anchorage with extraoral traction or Nance holding arch etc. or the incisor retraction may be minimized by uprighting springs, intrusive sectional archwires etc. or the use of protraction headgear to close posterior space. (Bench et al, 1978; Ricketts et al, 1979: pp299-301).

2.3.6 The Value of the AP Line (Diagnostic Line) in Treatment Planning.

Many writers, including Tweed, Ricketts and Downs, recognised the importance of lower incisor position on the facial profile. However, their description concentrated on angulation; Williams (1969) stressed that in either treated or non-treated persons with harmonious or well-balanced lips, it will be found that the incisal edge of the lower incisor is at or close to the AP line. (See Figure 2.9) Godfrey (in tutorial at the University of Sydney), following on from Williams adds that incisor roots should be located centrally in the alveolar ridge which, in turn, should be located over the mandibular basal bone, in order to maintain stability after treatment.

The AP line has become widely used in treatment planning and Williams has carefully outlined its value. Firstly, consider the two points A and P which move independently during growth and treatment.

The movement of point P is changed by growth within the mandible; it may also be changed with treatment from backward or forward rotation. Point A can be influenced by orthodontic treatment, e.g. in treatment of Class II, Division 1 it may be transposed to a posterior position. There are two procedures available to move the incisal edge of the lower incisor to the predetermined position relative to the AP line:

(i) differential arch length adjustment;

(ii) modification of anchorage by the appliance.

A. Patient with incisal edge of lower incisor on AP line and good lip balance and harmony of soft tissue in lower third of face.

B. Patient with normal occlusion and poor lip balance and absence of soft-tissue harmony in lower third of face. This is associated with a position of the incisal edge of the lower incisor too far posterior to the AP line.

Figure 2.9
Williams, 1969: p461.

The use of AP plane in extraction decisions.

With a treatment goal of placing the incisal edge of the lower incisor on or 1 - 2mm ahead of AP, Williams lists five tests to decide if any arch-length adjustments are appropriate. If the case passes all of these tests, then it is non-extraction; if it fails to pass all, it will be regarded as needing some degree of arch-length reduction.

William's five tests for non-extraction treatment.

(i) Is there crowding in the lower arch? If crowding exists, will it be necessary to relocate the incisal edges too far ahead of the AP line.

(ii) Will levelling the curve of Spee in the lower arch move the incisal edge too far ahead of AP line? 1mm of depth of curve of Spee needs 1mm of arch length to correct. Alternatively the formula developed by Baldridge (1962) can be used: Forward movement of lower incisor = 0.488D - 0.255 where D is the maximum depth of curve of Spee.

(iii) Will correction of the Class II molar relationship consume so much lower molar anchorage that the incisal edge of the lower incisor is moved too far ahead of AP line?

(iv) In the treatment, will the effort to reduce apical base differences towards a normal range, in which retraction of upper incisors and canines and their roots, consume so much lower molar anchorage that the incisal edge of the lower incisor is moved beyond AP line?

(v) Will mandibular growth carry point P so far forward as to

leave point A behind relatively, with the lower incisor too far ahead of AP line?

These tests are designed to eliminate the risks of expansion of the mandibular arch (unless it is collapsed). Over-expansion of the intercanine width or excessive protrusion of lower incisors will lead to post retention relapse in most cases. Graber, Riedel etc. (This is fully discussed in Chapter 5 in relation to Class II, Division 1 treatment stability.)

If slight lower arch length deficiency exists then the space may be adequately provided by enamel stripping of the incisors and posterior teeth, if reasonably well flared mesiodistally, or by extraction of the four first molars. The medium level demand for space is the classic removal of four first premolars. Extreme space demand would be met by removal of four first premolars and four first molars or four first premolars and two second molars using headgear and distal traction on the first molars to provide incisor retraction space and Class II molar relationship correction. (Williams, 1969).

Williams suggests that in non-extraction treatment cases, intraoral force is a highly critical procedure and favourable mandibular growth is needed or a loss of lower anchorage is acceptable in order to resolve the Class II molar relationship.

Non-extraction offers the smallest upper incisor and point A retraction potential and involves the most dependence on forward movement of point P through mandibular growth.

2.3.7 Extraction and Anchorage Units/Root Surface Areas as it Relates to Retraction of Upper Anterior Teeth

* In molar extraction: a greater potential exists, than in non-extraction, for upper incisor and point A retraction, with four first molar extractions. Consideration of root surface areas gives a ratio between the lower anchorage units and anterior upper units to be retracted of 100 to 400 ("Freeman's values"**). It can be expected that the second molars will move four times as far forward as the upper incisors retract. Molar extraction provides the smallest potential for anterior retraction of upper incisors although slightly greater potential than non-extraction. The appearance of these cases is similar to non-extraction cases once the third molars erupt into a normal functional occlusion.

* Premolar extraction: Four first premolar extractions provide a more favourable root surface ratio, of 100 to 90, which favours the posterior teeth and provides the greatest anterior retraction potential of the upper incisors and point A.

* Second premolar extraction: is an alternative if anchorage is not so critical and the profile is to be protected.

* Extraction of four first premolars and four first molars: offers greatest potential for anterior retraction. The Freeman root surface ratio is 100 to 135. (This ratio does not include the second premolars.) Here the second molars move forward slightly more than the anterior teeth will retract. Since there is so much extraction space provided, the retraction of point A has maximum potential.

**(Freeman, D.C. Quoted by Williams, R. 1969)

These root areas ratios must be considered with some reservation because the anchor units may be relatively larger (if stationary anchorage) and therefore relatively smaller periodontal pressures than the affected root areas (in tilting or tipping back of incisors). Williams (1969) indicates the value of anchorage consideration in selecting extraction sites and relates this to the degree of anterior retraction needed. ("Freeman's values" of root surface area relate to anchorage in the Begg Technique with its emphasis on tipping of teeth.)

In Class II, Division 1 correction it has been suggested that extraction of maxillary first, and mandibular second premolars rather than first premolars, thus altering the anchorage value of the two segments and can simplify the mechanics needed for differential space closure with continuous arch edgewise techniques. (Proffit, 1986: pp424-425).

Broussard (1979) also suggests this approach in Class II cases with a deep curve of Spee as it eliminates the deepest level of the curve and results in a more stable levelling of the lower occlusal plane.

2.4 TREATMENT PLANNING IN THE VERTICAL PLANE

The following is a summary of growth in the vertical plane and the mandibular growth rotations that cause positional changes of the chin and is taken from Schudy's articles of 1964 and 1965 in which he contrasts vertical growth and anteroposterior growth and relates this to treatment effects on three different facial patterns.

2.4.1 Vertical Component of Growth and Rotational Changes to Chin Point

Schudy (1964) stressed the importance of vertical growth as it relates to anteroposterior growth, and how the total effect of growth in these two directions produces different facial types and different amounts of vertical overbite.

The following growth areas contribute towards vertical growth and facial height:

(i) growth at nasion and in corpus of maxilla, produces an increase in the distance, nasion to anterior nasal spine, and causes the maxillary molars and posterior nasal spine to move away from sella-nasion plane.

(ii) growth of maxillary posterior alveolar process, the molar teeth move away from the palatal plane.

(iii) growth at mandibular posterior alveolar process causing molar teeth to move occlusally; growth of the anterior alveolar height does not affect facial height, but it is expressed in overbite increase.

Schudy goes on to explain that dorsal migration of the glenoid fossa is a very real factor in face height development; it may tend to cancel out the growth of the condyles and may be an assistance to vertical growth in deep-bite cases while it would shorten posterior height and tend to increase anterior open-bite cases. (Schudy, 1965).

Clockwise (backward or opening) rotation of the mandible is the

result of more posterior vertical maxillary growth than condylar growth. This would result in a centre of rotation being set up with a clockwise mandibular rotation taking pogonion backwards. Here we see vertical growth exceeding horizontal (condylar growth). The pogonion will fall behind the forward growth of the upper face and the mandible rotates backward, steepening the mandibular plane.

2.4.1.1 Treatment planning in backward growth rotation cases:

* ANB angle would not necessarily decrease with treatment, as chin point moves distally
* class II molar correction is not aided by this pattern of growth (lack of horizontal component)
* the vertical overbite, if deep, is lessened and its treatment and retention are very much facilitated while open-bite tendency will worsen with treatment.
* mandibular plane to SN if high will become steeper with treatment and the chin will tend to move backward.

(Schudy, 1954; Creekmore, 1967).

2.4.1.2 Treatment planning in forward growth rotation cases:

This results from more condylar growth than the combined vertical maxillary growth.

* the pogonion will move forward
* a flattening of the mandibular plane angle will occur which tends to increase the vertical overbite and will hinder its correction and retention with treatment.

* if the gonial angle is small the greater the degree of rotation for each mm of forward movement of pogonion.

* a low mandibular plane to SN angle indicates a forward growth of chin position. (Schudy, 1965 and Pearson, 1978).

2.4.2 Control of Vertical Height:

Molar height may not only control the vertical position of the chin, but also to an extent the anteroposterior position. This has a definite application to treatment of Class II malocclusions, for example, in cases with an already high mandibular plane angle, then excessive vertical growth or extrusion of the molar teeth would prevent forward positioning of the chin and prevent Class II anteroposterior correction with a worsening of the profile (it becoming more retrognathic). (Schudy, 1964).

Schudy (1965) states that if condylar growth cannot be stimulated by orthodontic treatment, then vertical growth assumes greater importance as a treatment factor in Class II correction. For example, if vertical growth can be inhibited it will have the same effect as stimulating condylar (horizontal) growth by actually guiding the chin forward rather than backwards.

Creekmore (1967) compared the forward movement of the chin in treated and untreated cases. He found that orthodontic treatment retarded the forward growth of the chin. The cause of this reduced forward chin movement has been explained by the molar extrusion with Class II elastics and/or cervical traction resulting in a greater backward rotation of the mandible and chin. Schudy postulates from

this study that posterior alveolar growth can be stimulated or retarded depending on the treatment priorities, whether it is necessary to correct the anteroposterior discrepancy without bite opening (e.g. in open-bite cases) or whether some backward rotation may be acceptable. He concludes that the posterior alveolar process of the mandible should be used to make a greater contribution to both overjet and overbite correction by differential inhibition or stimulation of vertical growth.

Dibbets (1985) describes Schudy's work as important, but it fails to consider all the information provided by Björk's implant studies. Its concept of clockwise and counterclockwise growth rotations of the mandible are simply relating the position of the mandibular plane to the cranial base. As a consequence the phenomenon Schudy describes actually relates to the pattern of growth of the head. Dibbets maintains that in effect this is one part only of Björk's observations (matrix rotation) and does not include total or intramatrix rotation (remodelling of the mandible).

2.4.3 Cephalometric Description of Vertical Facial Patterns and Their Respective Treatment Planning

Schudy (1965) defines three types of facial morphology in the vertical plane, which need differential treatment planning:

2.4.3.1 Hypodivergent Pattern: where vertical growth has been determined as being deficient resulting in deep overbite (See Figure 2.10B).

Description

* Anteroposterior growth has exceeded vertical growth.

* Posterior facial height has exceeded anterior facial height, alveolar height may be deficient posteriorly.

* Occlusal/mandibular plane angle (OM) and mandibular plane to sella-nasion (SN) angle are low tending towards parallelism. (This is a low angle brachyfacial pattern).

Treatment Planning

Overbite will be very difficult to correct:

(i) band mandibular second molars to assist in arch levelling and anchorage control with use of Class II elastics.

(ii) molar teeth will stubbornly resist occlusal extrusion.

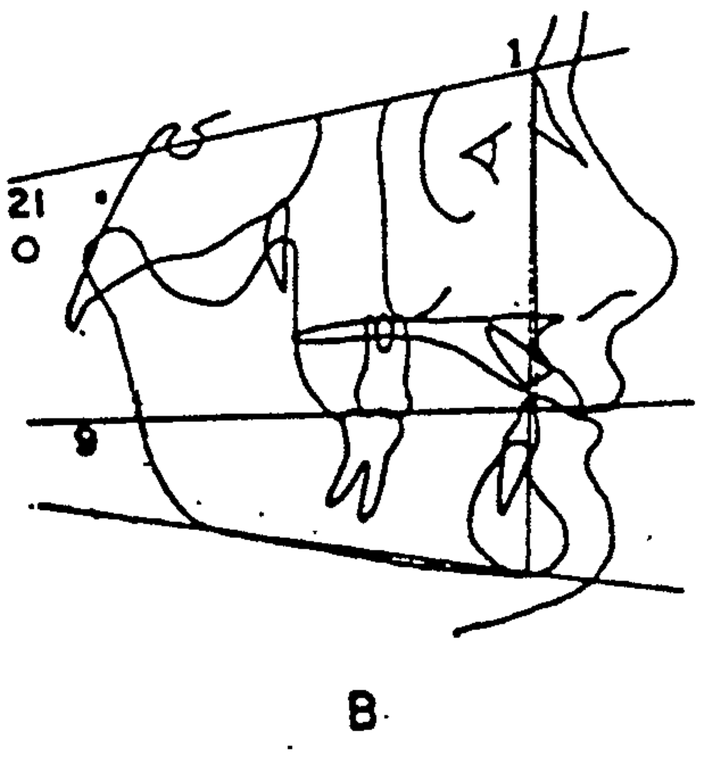
(iii) maxillary molars should be moved distally as much as possible.

(iv) avoid extractions if possible as extractions will aid bite deepening.

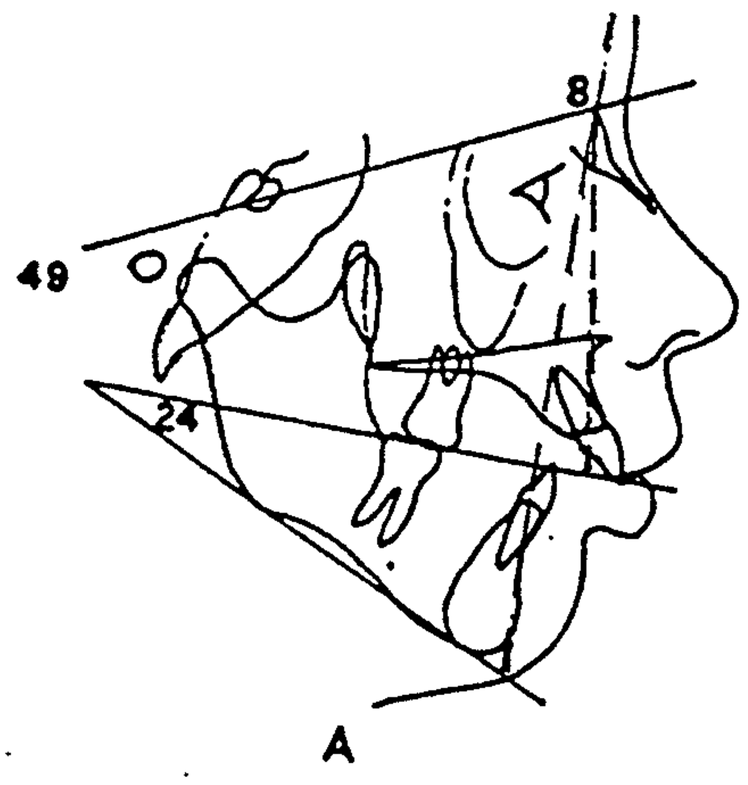
(v) retention of corrected overbite will be very difficult and should be extended until growth is complete. (See Figure 2.10B)

Figure 2.10 (A,B,C)

A,B Schudy,1965: p41



B



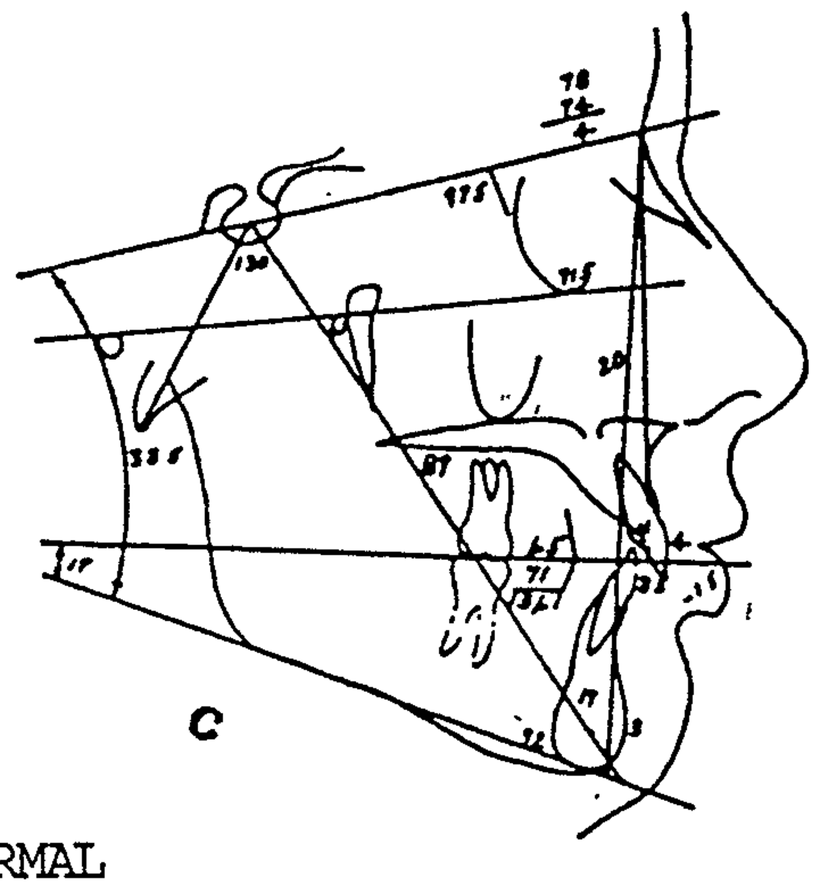
A

A. HYPERDIVERGENT

B. HYPODIVERGENT

Showing two opposite facial types. A. A hyperdivergent individual in which vertical growth is excessive and/or condylar growth is deficient. B. A hypodivergent type where vertical growth is deficient.

C. Schudy, 1964: p90



C

NORMAL

C. Average facial proportions which usually present no particular problems in treatment.

2.4.3.2 Hyperdivergent pattern (retrognathic profile)

Description:

* anterior facial height is excessive and out of proportion to posterior facial height.

* a prominent mid-face with retrognathic mandibular profile may be present. This is confirmed by the "high" OM angle and SN to MP angle.

* anterior facial height is excessive compared to posterior facial height.

* there is an open-bite tendency

* pogonion will not move forward with growth and may even move backwards a little, worsening the profile. (See Figure 2.10A)

Treatment Planning

(i) Do not allow mandibular incisors to move lingually.

(ii) The mandibular molars must not be moved occlusally with Class II elastics.

(iii) Do not move maxillary molars occlusally or distally.

(iv) A high-pull headgear to inhibit maxillary alveolar growth in the molar region.

(v) Any improvement of the ANB angle will not come from forward growth of the mandible, but from posterior movement of point A.

(vi) Extraction of two teeth in the maxillary arch will facilitate most aspects of the treatment planning (if no lower crowding exists).

(vii) Extraoral high-pull force against the maxillary arch may be needed during retention if growth is not complete.

2.4.3.3 Average or normal vertical growth pattern

* The ratio of anteroposterior growth and vertical growth of the face is harmonious, revealed by normal OM and SN - MP angles.

* Posterior facial height is in harmony with anterior facial height.

* Overbite correction is easy to correct with edgewise appliance and Class II elastics and it does not tend to relapse, (See Figure 2.10C).

Skieller (1967) describes the need to distinguish skeletal and dentoalveolar deep overbite in planning treatment:

In deep overbite cases, consideration must be given as to whether anterior face height is too low and should be increased and whether or not a continued forward rotation of the mandible is expected during growth. She describes dentoalveolar and basal (skeletal) deep bites and their treatment planning.

Dentoalveolar overbite: generally develops early and is not accompanied by reduction in the anterior face height (Schudy's normal vertical relationship). It is best corrected by intrusion of incisors with fixed appliances.

Basal Overbite: in most cases it is necessary to re-establish the face height. Treatment that promotes eruption of the teeth in the posterior segment is advocated with full banding or functional appliance treatment. In extreme anterior (forward) rotating cases a bite plate must be used until growth at the condyles has ceased.

The most suitable treatment timing is at the pubertal growth spurt, for all growth adapting appliances, and Skieller advises early treatment in the extreme anti-clockwise rotation cases in order to prevent deep basal overbite development.

Treatment of basal overbite after puberty or in patients with small vertical growth of the face, is achieved by stimulation of posterior eruption and growth of the alveolar process.

Growth of condyles will often continue for some years after completion of sutural growth of the upper face. This may result in relapse of the deep bite with further forward rotation if these cases are not retained until growth is complete. (Skieller, 1967).

Treatment Changes to the Mandibular Plane and Growth Considerations

Schudy (1965) addresses the problems of steepening of the mandibular plane that occurs with treatment and its tendency to return (relapse) to its original position:

* if growth is complete then the mandible will permanently remain at the steeper inclination.

* relapse will occur if growth continues after retention,i.e. continued condylar growth will cause a flattening of the mandibular plane with an increase in overbite. Growth of the condyles is the last part of the face to reach completion and is especially late in males. (This will be re-examined in the section on stability and retention (Chapter 5).

N.B. The effective treatment strategies concerning Class II mechanics, E.O.A. and extraction alternatives are discussed further in Chapters 3 and 4.

2.5 DIAGNOSTIC AIDS IN TREATMENT PLANNING

In Class II,Division 1 treatment, the anteroposterior jaw discrepancy is attended by retraction of the maxillary incisors and possibly protraction of the mandibular incisors. Specification of the desired positioning of the incisors in each arch in advance, will define the extent to which the extraction spaces are to be closed by retracting the incisors versus moving the posterior teeth forward. In turn, this specification of incisor position will make it possible to plan the degree of posterior anchorage conservation needed, the mechanism for space closure, the extent of interarch elastic wear and other factors relevant to mechanics selection. (Proffit, 1986: p216). The incisor position desired at the end of treatment can be expressed cephalometrically and was incorporated in the Steiner analysis (1953) with the use of a table of appropriate positions for the incisors as a function of ANB size, thereby indicating the position for the incisors needed to produce any given degree of correction for jaw discrepancy. The cephalometric analysis advocated by Ricketts et al (1980: p35) incorporates a visualized treatment objective (VTO) as a treatment planning aid in addition to its diagnostic component and it goes beyond Steiner's analysis by including growth prediction to indicate the expected final position of both skeletal and dental structures.

2.5.1 Ricketts' Visual Treatment Objective (VTO)

The VTO starts with a cephalometric tracing of the patient's skull followed by a predicted growth outline which is superimposed on the

original cephalometric tracing.

The actual predictive method (usually over 2 years) is complex and considers a large range of factors, some of these are described as follows:

* there is a method of projecting an arc of mandibular growth (rotation), this may open or close depending on the effects of mechanotherapy and also facial pattern, e.g. the facial axis is opened 1^{o} if the case is dolichofacial and closed 1^{o} if the case is brachyfacial.

* growth is shown by a lengthening of the basion - nasion line 2mm/year.

* lengthening the mandibular condyle axis and corpus 2mm/year.

* the maxilla is predicted to move down and forward two thirds that of the mandible (Ricketts et al, 1979: p38).

Guidelines for the effect of various treatment procedures are available:

* 1^{o} opening of the facial axis can be expected for each: 3mm of molar correction, 4mm of overbite reduction, and/or 5mm of convexity reduction.

* the following is a list of maximum ranges of point A change with various mechanics.

	MECHANICS	MAXIMUM RANGE
(1)	Extraoral force	- 8mm (reduction)
(2)	Class II elastics	- 3mm
(3)	Activator	- 2mm
(4)	Torque	- 1 to - 2mm

(Ricketts et al, 1979: pp38-44)

The correction of the Class II relationship may use a combination of headgear and Class II elastics etc. The actual mechanotherapy chosen helps produce a third outline of the various treatment effects on the predicted tracing.

A visualized treatment objective combines the changes that would be produced by normal growth in the absence of treatment with the changes in jaw relationship and tooth position that are expected to result from the treatment selected.

Proffit (1986: pp216-217) writes that the VTO relies heavily on a growth predictive method that works satisfactorily for average patients, but not in growth patterns outside the normal range such as Class II malocclusions. There is therefore still a considerable degree of uncertainty at the adolescent or preadolescent stage when the growth forecast is made, (Ackerman and Proffit, 1970; Björk and Skieller, 1983). Proffit goes on to suggest the use of a "therapeutic diagnosis" advocated by Ackerman and Proffit (1970) to provide a better evaluation of growth response and co-operation. This latter method is also advocated in Graber and Swain (1985: p94). Certainly the VTO has support in the literature; Roth, for example, states that he uses the VTO concept with minor modification to suit certain treatment mechanics and that VTO allows the clinician to determine precisely what must be achieved by the treatment in a quantitative fashion (Roth,writing in Graber and Swain, 1985: p671).

2.5.2 An Overview of Current Methods of Jaw Growth Prediction

As mentioned earlier (2.2.5) orthodontic treatment involves a combination of tooth movement and facial growth changes. The growth direction and whether or not it is favourable could therefore be a valuable aid in orthodontic treatment planning.

Bjork's Structural Method of Growth Prediction:

Björk has contributed significant information which provides a glimmer of light on our ability to understand, and to a limited extent predict, what type of mandibular growth rotation may occur, (through his metal implant studies 1963, 1969, 1972).

Björk's structural method of growth prediction from a single lateral skull cephalogram is tabulated below. The seven structural features developed as a result of the remodelling process that occurs with mandibular growth may not always be seen in one cephalogram; the more features that are observed the greater the reliability of the prediction. (Björk, 1969).

The prediction of a forward or backward rotator would assist greatly in treatment planning, Table III attempts to list indicators of these respective patterns.

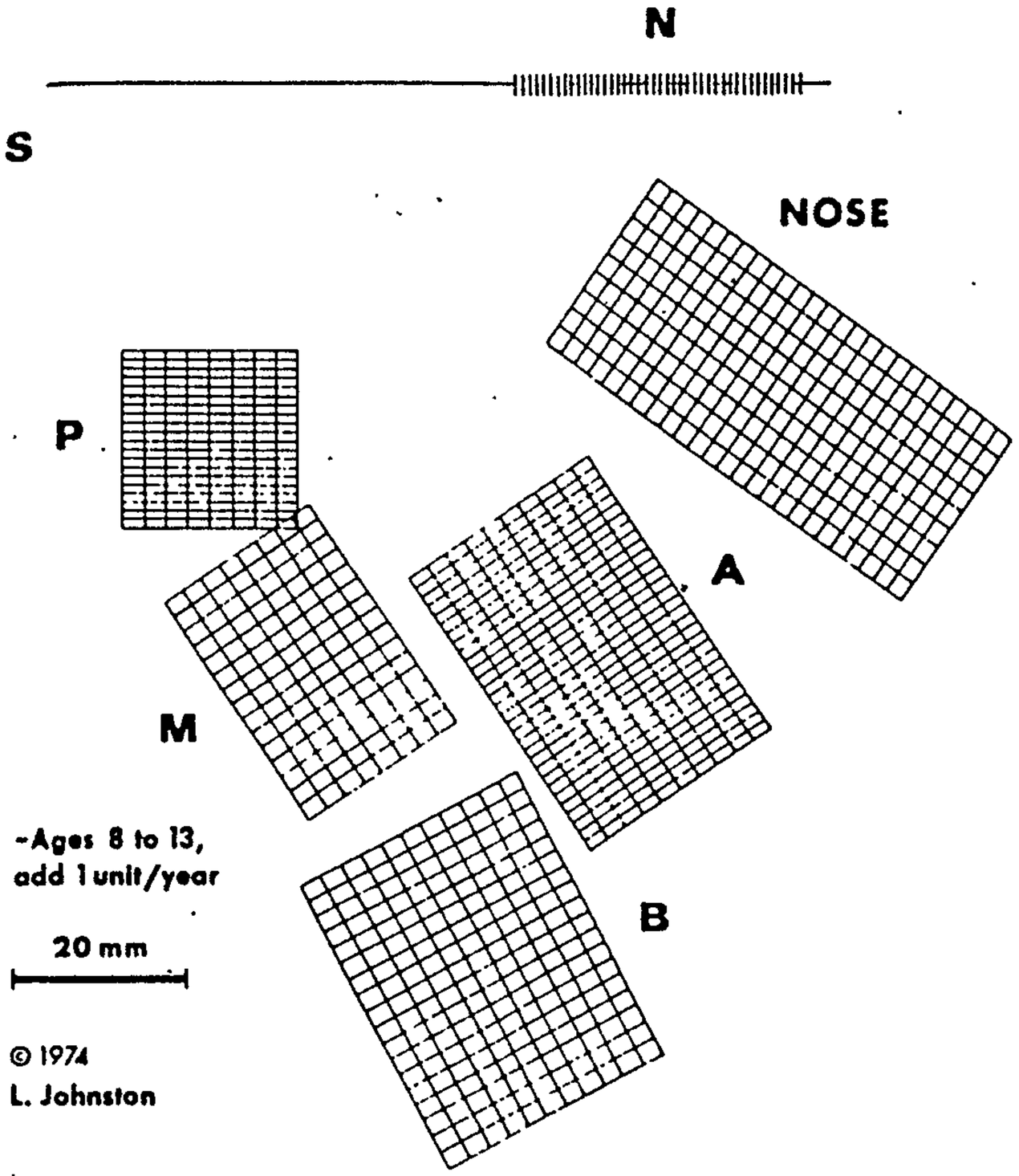
TABLE 2.3
Björk's structural method of prediction of forward or backward mandibular growth rotators.
Pearson, 1978:p33
(Taken from Björk,1969)

I.	Inclination of the condylar head	Forward Rotator (See Fig.2.10B) Curves forward	Backward Rotator (See Fig.2.10A) Straight or slopes up and back
II.	Curvature of the mandibular canal	Curved	Straight
III.	Shape of the mandibular lower border	Curved downward	Notched
IV.	Inclination of the symphysis (Anterior aspect just below "B" point)	Slopes backward	Slopes forward
V.	Interincisal angle	Vertical or obtuse	Acute
VI.	Interpremolar or intermolar angles	Vertical or obtuse	Acute
VII.	Anterior lower face height	Short	Tall

Other contemporary methods of jaw growth prediction are essentially mean-change expansions of the existing skeletal patterns. Johnston (1975) accepts this situation and, as a result, recommends a simple "forecast grid" based on a mean-change expansion along the existing pattern provided by one lateral cephalograph of the skull. He readily concedes that there is no individualization possible for the prediction, in that all patients are assumed to grow along the existing (cephalometric) pattern with annual mean growth increments

taken possibly from a different genetic grouping or a polygenetic group (See Figure 2.11).

Figure 2.11
Johnston, 1975: p254.



Forecast grid. S, Sella; N, nasion; P, posterior nasal spine; NOSE, tip of the nose; M, any point on the crown of the maxillary first permanent molars; A and B, subspinale and supramentale. A tracing of the landmarks is superimposed along S-N and registered at S. The points are then advanced downward and forward one unit per year.

Computerised prediction is now a possibility - the Rocky Mountain Data Systems Inc. (RMDS). This computer forecast uses the Ricketts short-range prediction methods (2 year) which effectively assumes patients vertical patterns will grow more vertically and patients with horizontal patterns will grow more horizontally plus other information from the facial pattern seen on a cephalometric lateral x-ray (See Section 2.5.1).

While the RMDS predictive method can not estimate the change in pattern for any specific child, it is argued that it provides a graphic representation of the most probable pattern of growth and serves to provide the clinician with information that may help sort out the various treatment alternatives frequently being used as part of the visual treatment objective. (Ricketts et al, 1972).

Schulhof and Bagha (1975) carried out a statistical evaluation of the Ricketts, Lyle Johnston and the RMDS computer program, growth prediction methods. Their results showed that although it provides a useful prediction, the Johnston grid was least accurate of the three methods, while the RMDS computer program was found in this study to be 21% more accurate than the Ricketts short range method and 56% more accurate than the Johnston method. The writers conclude that refined computer methods which take into account the individual facial patterns will not be more accurate than other methods in the 70% of patients that constitute the normal growth pattern range. They do show an advantage in the 30%, i.e. those that make up the abnormal patterns. The authors feel that further refinement with computer prediction may provide greater predictive accuracy.

However, another study of computer prediction by Greenberg and Johnston (1975) found that the commercial computer-based forecasts were roughly equivalent in accuracy to those affected by addition of mean constants and were no better than the assumption that no change in growth pattern would occur. The authors concluded that the simple Johnston "grid forecast" was as much use to the clinician.

It is not acceptable to rely on the constancy of growth pattern. Björk and Skieller (1983) have shown that facial growth increments are not uniform in either direction or rate; even the paths of eruption of the teeth are variable. Thus none of the present growth predictive methods are totally reliable for an individual growth prediction. However, the Björk structural method of prediction is widely accepted as a somewhat useful predictive tool, while the computer-based approach (RMDS) has been found more accurate in the abnormal growth cases and has found a level of acceptance among orthodontists.

2.5.3 Timing of Treatment for Class II, Division 1 Malocclusion

Coben (1966) states that: "As long as you treat children, growth is as much a factor in treatment of Class II as the appliance itself. While the appliance is being manipulated, to regulate the teeth, growth is also working for you or nullifying your treatment efforts". All investigators agree that growth is a major factor to be used in correcting Class II relationships or to control to one's advantage rather than disadvantage, throughout treatment.

Graber and Swain (1985: p34) state that skeletal orthodontic

problems are best treated during the period of growth acceleration. Predicting the nature and timing of the onset of pubertal growth is important in planning Class II, Division 1 orthodontic therapy. Pubertal growth acceleration (body growth, including jaw growth) is directly related to sexual maturation and the onset of rapid sexual development.

Proffit (1986: p202) suggests that growth modification to treat the Class II relationship should start 2 years before puberty to gain the required differential growth of the jaws. Therefore treatment should begin at about 8 or 9 years in girls and at 10 or 11 years in boys (on average).

2.5.3.1 Indicators of the beginning of pubertal growth

* In females - menarche onset.

However the beginning of menstruation also indicates that the greatest part of her skeletal growth has already occurred. Thus it can only be used retrospectively as an indicator that the beginning of growth spurt has passed. Other factors relating to growth spurt are breast development, pubic hair appearance. (Graber and Swain, 1985: p39).

* In males - voice change and various markers of sexual maturation, pubic hair, etc. The acceleration of general body growth that occurs at puberty is directly and causally related to sexual maturation. (Hagg and Taranger, 1982).

* dental age: is not a good indicator of the beginning of growth spurt (Graber and Swain, 1985: p39; Hagg and Taranger, 1982).

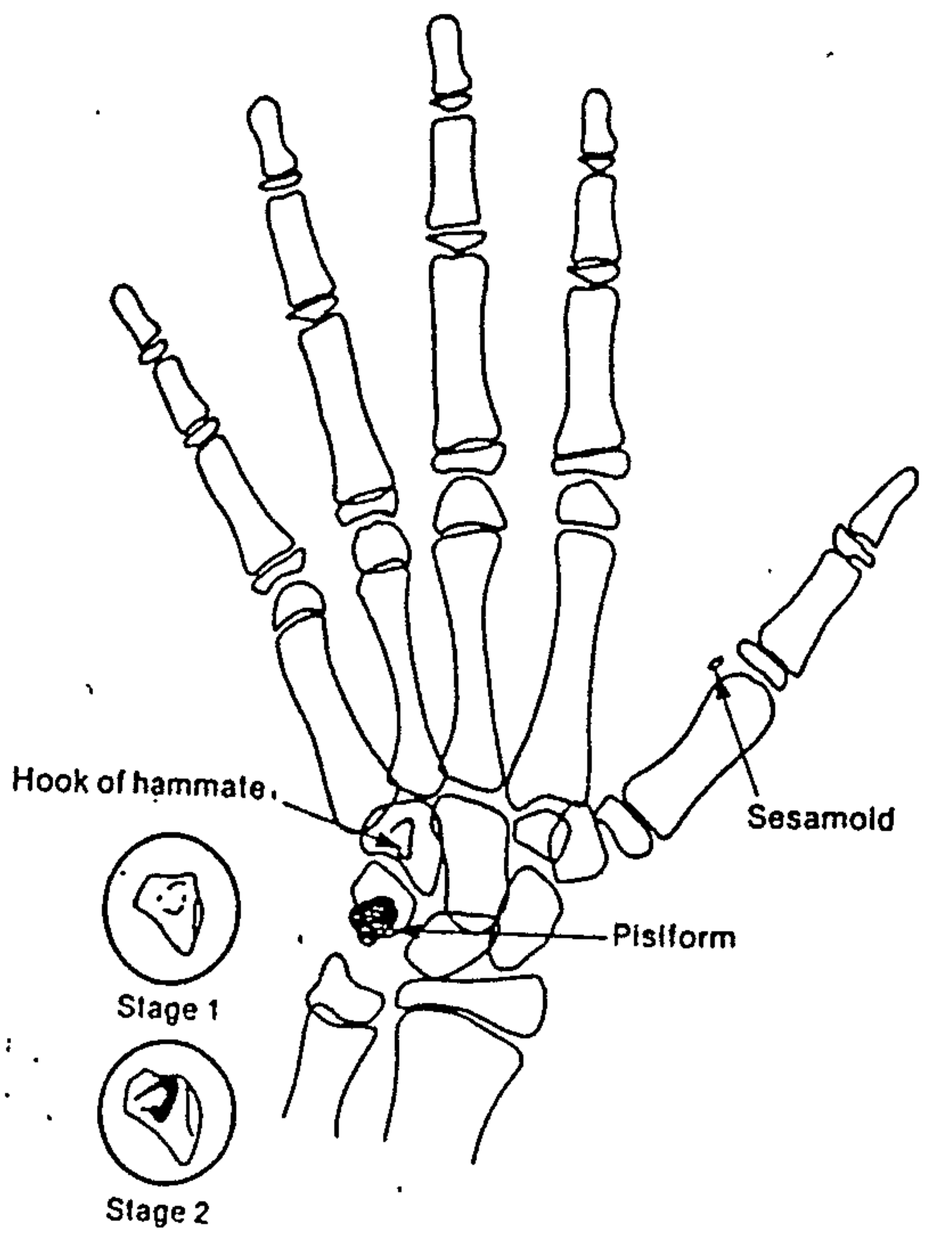
* skeletal age: correlates well with the physical growth status. The ossification stage of the carpal bones has been employed. A wrist film with a standard cephalometric x-ray or a dental x-ray machine is satisfactory (Figure 2.12)

Indicators of pubertal growth spurt with wrist x-ray:

* start of ossification of adductor sesamoid

* hook of the hammate (appearance of).

Figure 2.12
Graber and Swain, 1985: p39.



Important ossification events relating to the onset of puberty.

A statistical investigation into the reliability of the indicators of pubertal growth spurt was recently carried by Hagg and Taranger (1982). Their findings are summarised below.

(i) On average the pubertal growth spurt began at 10 and 12 years, ended at 14.8 and 17.1 years in girls and boys respectively. In both sexes, peak height velocity (PHV) occurred 2 years after onset, i.e. 12 years in girls and 14.1 years in boys on average. In both sexes, the early maturers had reached the end of the growth spurt before the late maturers had reached onset.

(ii) Dental development, assessed by means of dental emergence stages was not a useful indicator.

(iii) The peak and end, but not the onset of pubertal growth spurt, could be determined by means of indicators taken from the skeletal development of the hand wrist. However, they state that menarche and voice change are the most suitable indicators for use in clinical orthodontics.

2.5.4 Tooth Size Discrepancy

In good occlusion, the teeth must be proportional in size. If large upper teeth are combined with small lower teeth ideal occlusion cannot be achieved. Approximately 5% of the population have some degree of disproportion among sizes of individual teeth and this is termed tooth size discrepancy. The most common cause of this discrepancy is an anomaly in the size of the upper lateral incisors, but occasionally all the upper teeth will be too large or too small to fit properly with the lower teeth. (Proffit, 1986: p138).

2.5.4.1 Tooth size analysis/Bolton analysis (Bolton, 1962)

* The mesiodistal width of each permanent tooth is measured. A standard table is then used to compare the summed widths of the

maxillary to mandibular anterior teeth and also the total width of all upper to lower teeth excluding second and third molars. (See Table 2.4)

* A quick check of anterior tooth size discrepancy can be done by comparing the size of upper and lower lateral incisors and unless the upper laterals are larger a discrepancy will exist. If the discrepancy is less than 1.5mm it is not significant, a larger discrepancy must be considered in treatment planning. (Proffit, 1986: pp138-141).

* The ratio of the sum of the widths of the 12 mandibular teeth to the 12 maxillary teeth provides a ratio or percentage which is ideal at 91.3% for the overbite/overjet relationship.

e.g. $\frac{\text{Sum of widths of mandibular 12 teeth}}{\text{Sum, of widths of maxillary 12 teeth}} \times \frac{100}{1} = 91.3\%$

TABLE 2.4

Graber and Swain, 1985: p65.

Expected tooth size relationships.

Maxillary anteriors	Mandibular anteriors	Maxillary anteriors	Mandibular anteriors	Maxillary anteriors	Mandibular anteriors
40.0	30.9	45.5	35.1	50.5	39.0
40.5	21.3	46.0	35.5	51.0	39.4
41.0	31.7	46.5	35.9	51.5	39.8
41.5	32.0	47.0	36.3	52.0	40.1
42.0	32.4	47.5	36.7	52.5	40.5
42.5	32.8	48.0	37.1	53.0	40.9
43.0	33.2	48.5	37.4	53.5	41.3
43.5	33.6	49.0	37.8	54.0	41.7
44.0	34.0	49.5	38.2	54.5	42.1
44.5	34.4	50.0	38.6	55.0	42.5
45.0	34.7				

Modified from Bolton, W.A.: Am.J.Orthod. 48: 504,1962.

Differences of more than 2mm from these relationships indicate the probability of a tooth-size discrepancy.

* If the ratio exceeds 91.3% the discrepancy is due to excessive mandibular tooth structure. The amount of excess (using the "Bolton table") is the difference between the actual and correct mandibular measurement.

* If the ratio is less than 91.3% there is excessive maxillary tooth width (Moyers, 1973: p362).

Depending on the magnitude of the discrepancy, stripping of the teeth or increasing mesiodistal width with composite build-ups is a possibility for correcting tooth size discrepancy (Field, 1981). Another possibility is asymmetric extraction.

Common Discrepancies

Bolton-type (or teeth-to-teeth) discrepancies often necessitate a compromise in the finished case. To reduce these discrepancies:

* aim at selecting teeth to be extracted which establish a quantitative balance with basal bone and which are as nearly alike as possible and which leave the patient with healthy, non-damaged teeth.

* congenital absence, malformation and tooth loss prior to treatment, may be seen and are a major teeth-to-teeth discrepancy.

* discrepancies among the anteriors may also jeopardise stability and may be associated with post retention spacing between uppers or imbrication and rotation of the lower anteriors.

The existence of spacing between upper anteriors or else the buccal segments are not in Class I, but edge-to-edge, after treatment,

indicates that the upper six anteriors are not wide enough to maintain proximal contact and good buccal interdigitation. Often the laterals are the problem, frequently being variable in size and shape or congenitally missing .

In Class II, Division 1 cases, the upper and lower incisors frequently do not undergo normal attrition, similarly the cingulum areas are not worn or they may be excessively prominent or ridged. This could cause rotations and collapse of the lower anteriors following treatment. In normal occlusion these ridges are gradually worn down with function. Equilibration of these ridges, reshaping of scalloped incisal edges should be considered where needed in the treatment plan. (Swain,1952) Also it is possible, using present composite materials to reshape teeth, in terms of arch length and thickness discrepancy. (Zachrisson, 1984)

2.5.5 Diagnostic Wax Set Ups (Swain, 1952; Graber and Swain, 1985: pp92,93).

These are a useful diagnostic aid in the decision on whether to extract or not and on which combination of teeth to extract for a particular case.

Starting with plaster models articulated:

(i) leave the end molars as they are;

(ii) cuts should be made beneath, but not through the contact points which should be broken not sawn;

(iii) the lower anteriors should first be set upright or near to it and on the ridge;

(iv) select extractions which leave the dentition with the following qualities after extraction:

* the remaining dentition is in quantitative balance with basal bone.

* the teeth should be collectively alike in size and shape.

* individually healthy and in healthy periodontal condition.

(v) For Class II, Division 1 deep-bite cases, ensure that space is provided for levelling the curve of Spee, if the decision is non-extraction. (Rubin, 1969)

The levelling of curve of Spee: often deep in Class II, Division 1 cases, where non-extraction treatment is being considered, then you should expect the lower incisors to be pushed forward as the arch is levelled. Usually 1mm of curve depth requires 1mm of arch space when levelling the curve of Spee. (Graber and Swain, 1985: p93)

2.5.6 Soft Tissue Profile

Disproportionate and asymmetric facial features could be a major contributor to the facial aesthetic problems. The goal in treatment should be to improve facial harmony. The following examination should be made:

Frontal View: of the face should be examined for bilateral symmetry. A small degree of bilateral facial asymmetry exists in nearly all normal individuals, the major area of asymmetry is a chin or nose that deviates to one side. Also the relationship of the dental midline of each arch to the skeletal midline of the jaws should be checked. (Proffit, 1986: p128)

Profile View: will reveal anteroposterior and vertical tooth

relationships as well as facial aesthetics.

Methods: There are three goals of lateral facial form analysis:

(1) are the jaws proportionately positioned in the anteroposterior plane?

(2) is the face profile approximately vertical or does it slope either anteriorly or posteriorly (divergent)? Within reasonable limits a divergent face is not necessarily disproportionate. For example Asians tend to have anterior divergent faces and other ethnic groups may have a more posteriorly divergent face. (Proffit, 1986: p130).

(3) profile convexity or concavity reveals jaw disproportions and this is detected by dropping two lines, one from the bridge of the nose to the base of the upper lip, and the second extending from that point on the lip downward to the chin. A convex profile indicates a skeletal Class II jaw relationship but it does not indicate if the maxilla is forward or the mandible retruded. (Proffit, 1986: p130).

2.5.6.1 Evaluation of lip protrusion

Lip protrusion can be evaluated by observing the distance that each lip projects forward from a true vertical line through the concavity at its base, i.e. a different reference line is used for each lip. The evaluation is carried out with the patient's lips relaxed making note of the following:

* the extent to which the lips are separated and any strain to bring the lips together.

* when the lips are protrusive and separated at rest by more than 3-4mm it can be concluded that the lip protrusion results from incisor protrusion (and should improve with incisor retraction). If the lips are protrusive but close over the teeth without strain, minimal changes to lip position will follow incisor retraction.

* lip protrusion is strongly influenced by racial and ethnic characteristics. (Proffit, 1986: pp130-131).

2.5.6.2 (i) Aesthetic plane; (ii) Holdaway line

(i) Ricketts (1957) has described the use of the aesthetic plane,(E line) a line drawn between the end of the nose and the chin, the lips are measured anterior or posterior to this line. The ideal lip position for European (females) was to have the lower lip 2mm and the upper lip approximately 4mm posterior to the line; the male was slightly more retracted in relationship to the nose and chin. Ricketts reports that clinical observation suggests that the lower lip should be on the "E" line in children of the age range 7 to 12 years to result in a pleasing adult lip profile. Riedel, in an investigation, also found that children in the mixed dentition showed a poor facial balance if lips were forward of the "E" line. (Riedel, 1950).

(ii) Holdaway line gives an indication of nose size to existing lip position. The line joins chin point across the anterior point of the upper lip and extends across the nose. The sulcus or curvature of the upper lip beneath the nose should fall 5 ± 2mm behind the

line in Europeans. (Graber and Swain, 1985: pp68-69).

Graber and Swain add that when assessing facial contour and the profile, it must be remembered that the face tends to become more orthognathic with growth. Young children normally will tend to have relatively receding chins and convex profiles, with maturity the nose and chin become more prominent, by downward and forward growth and remodelling above the chin point.

The lip/incisor relationship and its important role in selection of mechanotherapy is discussed further in Chapter 4.

2.5.6.3 Evaluation of vertical facial proportions and mandibular plane angle

The proportioning of the facial profile into thirds, i.e. the vertical height of the midface, from supraorbital ridges to the base of the nose should equal the height of the lower face (Proffit, 1986: p128). While the lower face (lips and chin) should be 55% of the total nasion-pogonion distance (Graber and Swain, 1985: p79). The inclination of the mandibular plane to a true horizontal line is visualised readily by placing a mirror handle along the lower mandibular border. A steep mandibular plane angle correlates with long anterior facial dimensions, while a flat mandibular plane angle correlates with a short anterior facial height and deep bite malocclusion. (Proffit, 1986: p132). Both facial photographs and the lateral cephalogram can be helpful in assisting chin-lip relationship.

2.5.6.4 Notation of TMJ and occlusal function:

Palpate the temporomandibular joint (TMJ) as a routine part of the examination; note any pain, noise or limitation of opening. Note if there is any shift laterally or anteriorly when a child closes its jaw (a shift will occur with unilateral crossbite).

Notations of occlusal interferences: balancing interferences, presence or absence of canine protection in lateral excursions; with a view of simply checking their correction on completion of treatment. (Proffit, 1986: pp131-133).