American Institute for Bioprogressive Education

UNDERSTANDING THE VTO: ITS CONSTRUCTION AND MECHANICS FOR EXECUTION
VOLUME ONE

by Dr. Robert M. Ricketts

UNDERSTANDING THE VTO:

ITS CONSTRUCTION AND MECHANICS FOR EXECUTION

Volume I

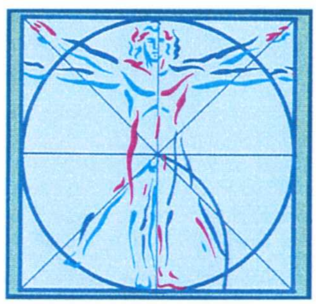
Robert M. Ricketts D.D.S., M.S.

And

Ricketts Research Library and Learning Center

Loma Linda University

Loma Linda, California



Robert M. Ricketts, D.D.S, M.S.

Director

American Institute for Bioprogressive Education

9106 E. La Posada Court

Scottsdale, Arizona 85255

Tel (480) 948-4799

Fax (480) 513-3145

E-mail rrick@adata.com

TABLE OF CONTENTS

VOLUME ONE

FOREWORD

PREFACE

CHAPTER ONE: THE ORIGIN AND ESSENCE OF THE VTO IDEA

CHAPTER TWO: THE SECOND GENERATION OF FORECASTING: THE INFLUENCE OF COMPUTER FINDINGS

CHAPTER THREE: THE MANDIBULAR GROWTH ARC FOR FORECASTING TO MATURITY: INDIVIDUALITY AND THE CRANIAL BASES

CHAPTER FOUR: THE TECHNIQUE FOR FORECASTING GROWTH FROM CHILDHOOD TO MATURITY (WITHOUT TREATMENT)

VOLUME TWO

CHAPTER FIVE: THE FORECASTING OF SOFT TISSUE

CHAPTER SIX: FORECASTING IN THE FRONTAL

CHAPTER SEVEN: THE TREATMENT DESIGN IN LONG RANGE -- TO MATURITY

CHAPTER EIGHT: MECHANICS FOR EXECUTION OF THE VTG -- THE NEW PARADIGM

CHAPTER NINE: GENERAL SUMMARY

PREDICTION, PLANNING, CONSTRUCTION and MECHANICS

by Robert M. Ricketts, D.D.S., M.S.

FOREWORD

PREFACE

VOLUME ONE

CHAPTER ONE: THE ORIGIN AND ESSENCE OF THE VTO IDEA
Introduction -- Background
The Evolution of Conceptions for Beginning With the End in Mind
Mounting and The Plaster Setup
The Cephalometric Approach
The Propositions in Planning with Cephalometrics
Natural Growth
Orthopedics
Orthodontics and Soft Tissue
Feasibility Testing
The Components of the Cybernetic Circle as a Thought Sequence
The Essence of the VTO
Problems with Treatment Designs
The Dilemma of Skeletal Change
Orthodontic Possibilities
Changes in Techniques
Extraction Rates
Borderlines
Orthopedic Interpretation and Findings
Condyle Compression and Growth
Maxillary Orthopedics
Growth Concepts Concerning Clinical Practice
Understanding of the VTO, VTG, ATO, STO
Interpretation of the VTO (Analysis of the Forecast)
Early "Forecasts"

CHAPTER TWO: THE SECOND GENERATION OF FORECASTING: THE INFLUENCE OF COMPUTER FINDINGS
New Scientific Events
Intrusion
Emergence of New Points
Pterygoid Point (Pt) and Cranial Center (Cc)
Protuberance Menti Point (Pm)
Xi Point (Xi)
The True Buccal Occlusal Plane
Computer Findings
The Change in the Format Used From 1967 to 1975
Individual Growth Forecasting
Treatment Forecasting
The Essence of the VTO
Skeletal Change in the Jaws
The Second Part of the VTO
Emplacement of Occlusion
The Steps for the Teeth
A Super-Simplistic View of Forecasting -- Mean Extension
Discussion and Summary (for Chapters One and Two)

CHAPTER THREE: THE MANDIBULAR GROWTH ARC FOR FORECASTING TO MATURITY: INDIVIDUALITY AND THE CRANIAL BASES
Introduction
The Curve of Distribution
Current Interest in the Long Term
Phases Limited
Computers
Iatrogenics
Cephalometrics: The Key Tool for Sophistication
More Than Mean Values Employed
The Genesis of the Arc
Polar Growth in the Sagittal Plane
Gnomonic Expression
Bi-Polar Behavior in the Frontal
The Three-Dimensional Context
The Mandibular Bend
The Arc Discovery
The Search for Biologic Details
Further Biologic Considerations

Discussion
Forecasting the Two Cranial Bases (Anterior and Posterior)
The Forecasting Logic
The Size-Gain Argument
The Patterns of Dental Development
Soft Tissue Growth and Behavior
Summary

CHAPTER FOUR: THE TECHNIQUE FOR FORECASTING GROWTH FROM CHILDHOOD TO MATURITY (WITHOUT TREATMENT)
Introduction
Discussion of Posits
Mandibular Support
Polar Behavior and Nature's Articulator: The Glenoid Fossa
Three Factors for the Fit of the Mandible and Cranium
The Cp Point (Condylion posterior) and Cs (Cond.superior)
The Anterior Border of the Ramus (Rr)
The Xi Axis
The Logic of the Sequence in Forecasting: A Five-Part Exercise
Part One: Technique for Cranial Base
Eight Steps
Part Two: Technique for Forecasting the Mandible
Seven Steps
Part Three: Fitting the Mandible to the Cranium and Upper Face
Technique for Matching the Mandible to the Cranium
Five Steps
The Skeletal Reference Lines
Part Four: Teeth
Occlusal Plane Behavior (Dental)
Technique for Occlusal Plane
Discussion
Denture Emplacement
Method of Superimposing
Compensation
Development of Lower Arch Depth – The Basic Lower Molar
Four Steps
Calculations for Third Molar Space
The Lower Third Molar
The Upper
Summary for Chapters Two, Three and Four

VOLUME TWO

CHAPTER FIVE: THE FORECASTING OF SOFT TISSUE
Profile Forecasting
Introduction
Technique for the Nose
Five Steps
Forecasting the Lips
The Upper Lip and Stomion
Four Steps (1-4)
The Lower Lip
Three Steps (5-7)
Supramentali
Three Steps (1-3)
Technique for the Chin
Five Steps (4-8)
Summary of Soft Tissue Behavior

CHAPTER SIX: FORECASTING IN THE FRONTAL
(THE TRANSVERSE DIMENSION)
Introduction
Frontal Analysis
Growth Behavior
Report on Vienna Research
Technique for Forecasting the Frontal
Discussion
Technique for Width Forecast
For the Mandible
Five Steps (1-5)
For Ramus Width
Two Steps (6-7)
For the Maxilla
Three Steps
For the Teeth
Five Steps
Another Consideration: The Divine Proportion
Treatment
Summary for Chapter Six

CHAPTER SEVEN: THE TREATMENT DESIGN IN LONG RANGE -- TO MATURITY
Introduction
The Modular Concept
Long-Range Goals (VTG)
Rebound and Recovery in Long Range
Prevention of Rotation
Maxillary Orthopedics is True Orthopedics
General Statements Regarding Orthopedics and Orthodontics In the Long Term
Factors in the Construction of the VTG
The Chin -- Long Term
Technique for Alteration of the Long-Range Forecast
For The Chin Position: Three Steps
For Point A (and the Maxilla): Three steps
Teeth: Three Steps
The Lower Molar - Arch Depth: One Step
The Lower Third Molar: One Step
The Upper Incisor: One Step
The Upper Molar: One Step
Extraction Conditions
Soft Tissue Forecasting With Treatment
Discussion
Technique for Soft Tissue
The Nose: Two Steps
The Upper Lip: Two Steps
The Lower Lip: Two Steps
The Chin: One Step
The Complete VTG Forecast
The Dilemma -- Mechanical Objectives and Growth Superimposed
The Processes with the Cybernetic Circle
Summary and Conclusions

CHAPTER EIGHT: MECHANICS FOR EXECUTION OF THE VTG -- THE NEW PARADIGM
Introduction -- The New Paradigm for Mechanics
Treatment Mechanics and Resulting Effects
Prevention of Rotation with Bioprogressive Mechanics
The Dangers of Incisor Interference
Computer Cut-off Programmed at a 2° Rotation

Discussion: The Long-range Forecast (to Maturity)
Semantics Regarding Mechanics
Definitions of Importance
Force and Pressure Controversies
Force Classification
Pressure
Differential Force of Differential Pressure?
Root Rating Scales
Suture Rating
Common Modalities
Classification of Orthodontic Techniques
Seven Types of Appliances Employed in Bioprogressive Philosophy
Orthopedic
Orthodontic
Auxiliaries
Stabilization
Shielding
Conditioning
Surgical
Summary

CHAPTER NINE: GENERAL SUMMARY
Beyond Imagination
Propositions
Interpretation
Denture Emplacement in Planning
Predicaments
Long-Range Visualization
Factors in the Forecasting
The Logic of the Sequence
Size-Gain Concepts
Mechanics
Semantics
Modalities
Advancing the Profession

PREFACE

This manual, in two volumes, is proposed as a guide for teaching. It can first be used to teach *oneself*. In that event, it will require a dedicated effort. It is best taken up a chapter -- or even one segment -- at a time until the information and procedure is mastered. A regularly scheduled program for study and discipline will help.

Secondly, it can serve as a basis for *study club* or group learning projects. It can be discussed, cursed at, poked at, and denied. However, all the ridicule and maligning it has received historically have not made the idea go away. The information and methods have continued to grow and improve over half a century.

Thirdly, it can serve as the foundation for *university* teaching at the graduate level. The author uses it in courses of instruction at various schools and in courses for interested scholars or groups. It is the framework for teaching anyone with sufficient knowledge and experience in the residency programs throughout the world.

Make no doubt about it: the capable orthodontist -- trained and employing the method routinely has a significant advantage over competitors. **It is imaging at its most reliable level.**

Comunication is the underlying benefit for the patient in this information age. In addition, it is a wonderfully rewarding experience to plan and execute treatment according to the objectives and goals set forth in the application of the VTO. Without using this method or other critical cephalometric planning programs with known standards for controls, the clinician has no way to monitor progress or to check results for the patient.

But the learning and the application of the principles inherent in forecasting at the level proposed herein are obviously not simple. This, more than anything else, probably accounts for its rejection. However, cephalometrics is a part of the specialty of orthodontics, and the effort to learn, therefore, is eminently worthy of consideration.

Precisely because it is complex, cephalometrics, along with treatment designing, is adaptable to the computer as one process of

imaging. In essence, cephalometrics may serve as a **simulation** to preview extraction or non-extraction or the prospective results of a given modality as discovered from research. Even if practiced with the computer it is obvious that the operator needs to understand the computer program and when to **modify the objective** on a practical basis. The underlying objective is for the clinician to obtain the highest level of information for the making of value judgments in planning.

With regard to the use of the computer, the individual operator is faced with choices. He or she can employ an in-house personal program which is rewarding to the ego and satisfying with accomplishment, but often requires trained and highly skilled personnel, thus proving to be expensive in the long run. The second choice, preferred by the author, is to employ a reliable computer laboratory service. This is employed just as the referral is made for X-ray laboratory services, model processing or retainer and appliance construction in other aspects of the specialty. It has been a mystery why astute clinicians have not availed themselves of such service even though reliable processing has been available for more than twenty-five years. The data has continued to improve with accumulated information and advanced technology.

While computer processing is available it is also an exciting exercise for the orthodontist to perform and compose a forecast manually. **There is no better way to learn about the individual patient** and the possibilities and limitations inherent in that single patient.

The clinician's time, however, becomes an issue. When pressed for time the operator tends to "fly by the seat of his pants". With training, a staff member can do some of the preparatory work associated with the construction of a paper plan. The objective is to "get it done"!

No matter what process is employed, the author wishes the colleague good luck in an exciting clinical adventure. The goal is a continued specialty.

R. M. R.

PREDICTION, PLANNING, CONSTRUCTION and MECHANICS

CHAPTER ONE
FIRST IDEAS

INTRODUCTION -- BACKGROUND

The rendering of orthodontic objectives on tracing paper (the Visualized Treatment Objective, or VTO) was formulated in 1950. Almost half a century later it failed to reach routine application except for about 10% of clinicians in the U.S. and perhaps double that number in certain other countries. The question is, Why is it not routinely employed 100% of the time as has been done by the author since 1950?

Perhaps it is considered too complicated because a candid view of the VTO procedure may appear to be inordinately complex. The procedure perhaps intimidates the clinician or student who then may question the value received for the effort involved. The surveys of Gottlieb et al. in 1990 indicated that in one section of the country 11% of orthodontic specialists employ the "treatment design principle", while in other sections it was less than 5%. In another survey, conducted by the author in 1987, three out of four orthodontists responding stated they **did not know how to apply the procedure** even if they had it available. Ironically, many who didn't use it still considered it trustworthy as a clinical tool.

Those not understanding any process usually fear it! The question emerged, "Was it being taught or were there even teachers to teach it?" It is obvious that a steadfast opinion still exists that "forecasting is impossible" -- as evidenced by speakers at national meetings. Without a comprehension of the method of construction and the manner in which it is to be clinically applied, the VTO consequently has been derided. Some educators state bluntly that it "doesn't work". There seems to be some miscommunication regarding its purpose because the method consists of essentially setting an objective. It is a prospective exercise. When it doesn't match the final result it is usually because (1) **the proper mechanics to produce it was not applied**, (2) an unrealistic objective was drawn, or (3) a traumatic event or an iatrogenic condition developed as a result of the treatment which altered the outcome. In other words, the objective simply was not reached.

Yet the VTO has been used successfully on a routine basis by many of the world's leading clinicians. It would appear, therefore, that a dearth of knowledge exists with regard to how a VTO is constructed, how it is employed for testing objectives, and how it is applied for anchorage planning. Because it has been used successfully by so many clinicians, perhaps more cogent explanations are in order regarding its logic. That is the essence of this manual. The purpose of this first chapter is to discuss its origin and purpose.

THE EVOLUTION OF CONCEPTIONS FOR BEGINNING WITH THE END IN MIND

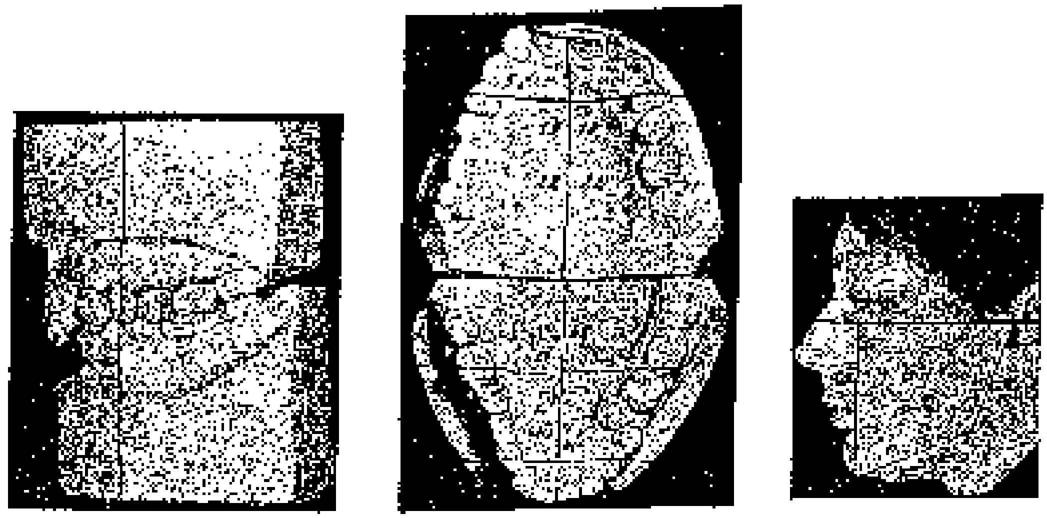
Mounting and The Plaster Setup

The gnathostatic mounting of the model as taught by Simon in 1920 was among the earliest efforts to visualize tooth and jaw relationships (Fig. 1-1A). In the 1940s, plaster "setups" were employed to enable clinicians to determine the changes desired for correction of malocclusions. The model was cut in half at the midline and one-half was set up in wax similar to a setup for a positioner. When the wax-up was compared to the untreated side, the changes required could be visualized. Often the sectioned model was analysed by estimates of the long axis of the incisors. That process became a thought form for the planning of the mechanics (Fig. 1-1B).

However, objections to the use of models alone for planning were raised. It was a static exercise in that: (1) model analysis did not bring growth into consideration; (2) procedures did not usually allow for rotational changes in the mandible; (3) no orthopedic or skeletal change was considered; (4) molars were seldom moved distally; (5) the effort was usually made to place lower incisors upright (over the existing ridge); (6) lacking soft tissue, models lacked any precise consideration of lip changes or esthetics in the result; (7) model dissection was costly in time and effort; and (8) plaster changes could be misleading due to the absence in the transverse dimension which was often not considered.

During the 1940s the static approach from model analysis was thought to be justified on the basis of the "doctrine of limitations". In fact, the influence of treatment of deep bite through extrusion of molars was thought to be only a minor influence on the mandible which was assumed usually to rebound. Extreme mandibular rotation during treatment, or the production of a long face, were "passed

A



B

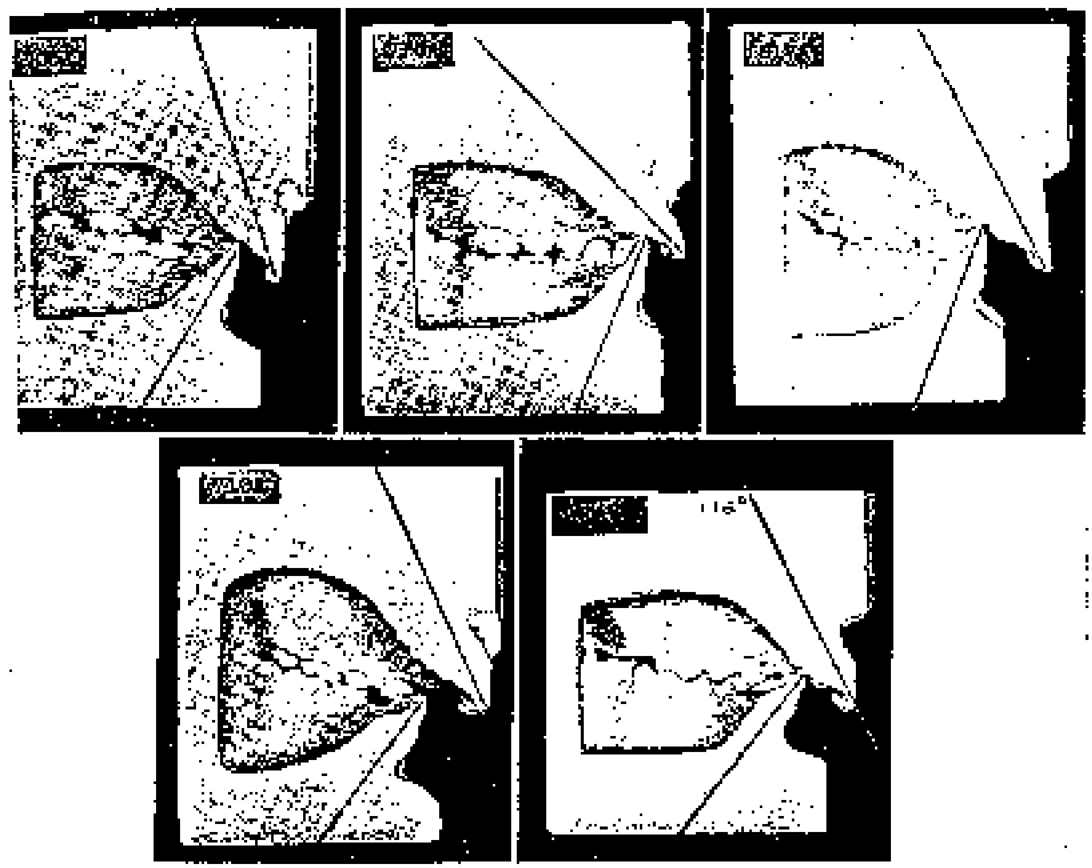


Fig. 1-1

A. From Simon (1926), showing method of relating the denture to the face via the Orbital Plane -- founding gnathostatics.

B. From Fischer (1948), showing method of splitting the gnathostatic model in order to evaluate incisor relationships.

off" or accepted to be due to "a vertical genetic growth pattern" and an unfortunate occasion. This was essentially the dilemma until 1950.

The Cephalometric Approach

Clinicians such as Downs desired information, if possible, to help anticipate in advance those patients in whom the chin would either "swing forward" or "swing backward" in the future. The frame of reference for thinking was the changes in the Facial Plane as visualized from the Frankfort Plane (Fig. 1-2).

At that time, most thinking was limited to changes only during the active treatment experience, which took about two years. Also, because patients were not treated until the permanent teeth were present, much growth already had passed. In fact, females were later found to complete essential facial growth by age 14.8 years. Long-term growth therefore held no interest.

THE PROPOSITIONS IN PLANNING WITH CEPHALOMETRICS

Natural Growth

Prognosis, by definition, is a forecast or a prediction. The first proposition or consideration of the future is one without orthodontic intervention, and growth can be estimated for a two-year period but most favorably extended to maturity. This pertains to the natural growth and development and is based on the individual's characteristics which are unique unto the patient. This is referred to as a long-range forecast (LRF).

Orthopedics

An orthopedic change is usually conceived to be a skeletal alteration, horizontally and transversely. But vertical changes are also orthopedic.

A forecast of the behavior of the skeletal facial parts is made with consideration of the influence of treatment by different modalities. This consists of: (1) a change of mandibular vertical position (relative to the untreated condition); (2) a horizontal repositioning of the mandible in the event of a condyle displacement; (3) an alteration in the mandibular form as a result of the variety of posturing techniques or of intermaxillary elastic traction (forward or backward)* which when forward most

---

* Note: When the mandible is bent forward in the course of treatment it most often may be temporary, but when bent backward or severely rotated the change has been observed to be permanent in many patients.

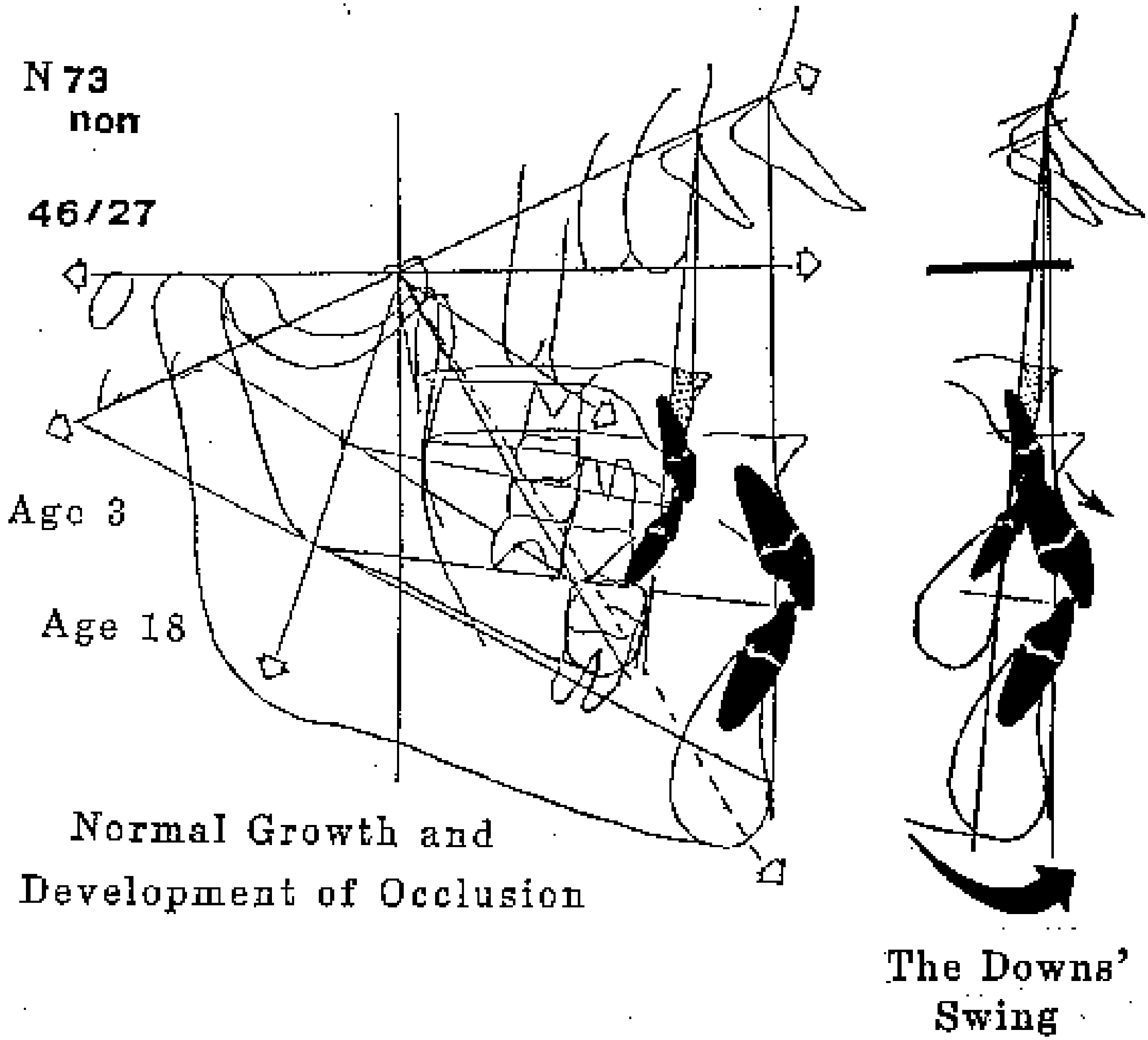


Fig. 1-2 From Ricketts (1990), showing updated behavior of the Facial Axis and depicting the concept of W.B. Downs for the swing of the chin via the change in the Facial Plane from Frankfort Plane.

often may be temporary and when backward is often permanent; (4) changes induced in the midface complex or the upper jaw. Thus, the second concept consists of designed skeletal objectives.

Orthodontics and Soft Tissue

The third proposition is actually the setting of dental and soft tissue objectives, as based on the conceived possibilities. It also is based on the preferences of the individual clinician. Hence, "Doctor limits" are practiced.

Feasibility Testing

After construction of a VTO, the application of the "PPF" test is recomended. Each objective is considered in terms of ***possibilities*** (P), or the most ***practical*** course of treatment for the result(P), but finally ***feasibility***, or the most likely result to be successful under the existing circumstances (F). In the end, a decision for treatment planning and anchorage sequencing are the benefits to be derived.

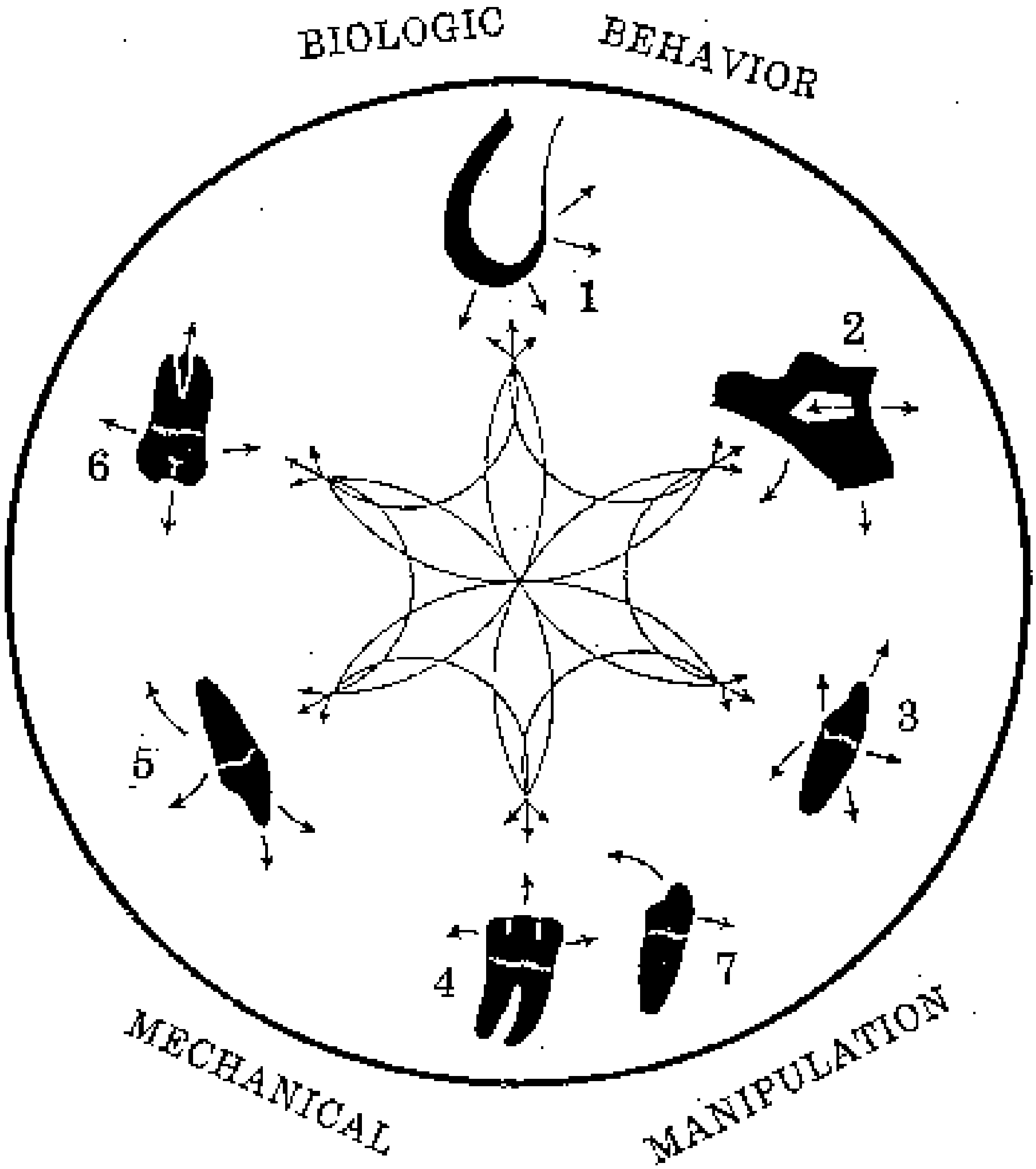
THE COMPONENTS OF THE CYBERNETIC CIRCLE AS A THOUGHT SEQUENCE

Whether or not the VTO is constructed, the resolving of a patient's problem follows a logical sequence. Each component carries a contingency in relation to the other parts. The first two components are skeletal. They are the first consideration before planning denture emplacement. Once this is realized, the idea of a preview of jaw relations and denture emplacement is no longer a mystery.

The goals for four dental areas are the four segments, the anterior and posterior of each arch. These are represented by the lower incisor, lower molar, upper incisor, upper molar. These come secondarily and are fed back onto the two anticipated skeletal structures,

These six key structures were arranged into a "cybernetic circle" representing a feedback relation for purposes of demonstrating the concept (Fig. 1-3). A seventh key, represented by the lower first premolar, concerns transverse considerations and arch form as an influence on molar location.

In computer jargon, an alteration from a standard procedure is called a "conditional statement". Each is weighed in magnitude in a "feedback loop" for the production of the final design. Thus, cephalometrics is a potentially a most powerful clinical tool!



CYBERNETIC CIRCLE

FOR PLANNING

Fig. 1-3 From Ricketts (1970), showing the sequence of designing for objectives. It starts with the mandible (#1), and secondarily the maxilla (#2), from which the new APo Plane is drawn. The lower incisor is positioned (#3) as the key to denture emplacement (#4 - #7).

THE ESSENCE OF THE VTO

The "VTO" consists of a "paper setup of objectives" for visualizing the changes desired for the individual patient. Produced on either tracing paper or data processing paper, the result can be visualized and pre-assessed rather **than only imagined in the mind's eye** (or not even considered at all). This cephalometric procedure is "dynamic". Physiologic changes or maxillo-mandibular skeletal alterations are superimposed on natural growth of the patient's individual matrix. This is highly revealing!

In truth, renderings are designed so that (1) the necessary anchorage provisions can be made, (2) the needed orthopedic change can be calculated, (3) the required tooth movements can be visualized, and (4) the resulting soft tissue profile alterations are displayed as a "blueprint". It is essentially a "simulation" exercise.

For interpretation, an analysis of the VTO itself is broken down into four-position summary display (for each jaw and each arch). **This is the standard for contemporary communication.** Through such a "summary change analysis" the prospective movements of the jaws, teeth, and soft tissues are visualized (Fig. 1-4). It is, in fact, like an architectural rendering and indeed becomes a blueprint. The blueprint serves in the construction industry for an engineer to plan the necessary supplies for the construction. Thus the orthodontist is first an architect and subsequently an engineer. In order to execute the plan the operator now becomes a builder or the mechanic. In the end the orthodontist becomes an artist.

Problems With Treatment Designs

If the orthodontist does not believe something can be done, how can he plan for it?

The Dilemma of Skeletal Change

The traditional limitation dictated that the orthodontist should plan to treat the teeth to positions to conform to the existing convexity. In other words, he should treat the anterior teeth to harmonize "to the convexity" or plan to place teeth into "compensated" positions. Another idea is to achieve "neutral" or "**reciprocal**" positions of the teeth. In about 1950 the idea was taught that "torque" of the upper incisor roots could modify the alveolar process at Point A only about 2 mm. At that time it was believed that only a moderate convexity change or horizontal basal correction could become a part of the orthodontic objective, as based on the techniques studied.

But a second issue concerned dental protrusion. The orthodontist could either accept an individual protrusion or make the reduction of that protrusion a definite objective of the therapy. This was the basis of the argument between Angle and Case in the 1920s, and it emerged in the 1940s with Brodie and Tweed.

By 1954, however, it was found that in growing children skeletal correction of the whole mid-face complex with extraoral traction was accomplished. This included alteration of the entire nasal floor or hard palate! (Fig. I-5). **Midfacial skeletal change, therefore, became a definitive orthodontic objective.** Change for the maxilla, and later temporary alteration of the mandible, became a component of the VTO construction (usually rendered for two years). [See manuals on Extraoral Therapy and on Sectional Mechanics.]

Treating for **orthopedics** by establishing maxillo-mandibular relationship and then treating for esthetic harmony became the objectives.

Orthodontic Possibilities

It is obvious that many in teaching institutions and "traditional orthodontists" overreacted to arch length deficiencies, particularly in the lower arch. Expansion in the lower arch was adamantly condemned because of the theory of a "predestined ridge". Experience with orthodontic treatment regimes witnessed the lower incisors to be, so to speak, "dumped" forward into (1) an esthetically protrusive strained lip position, (2) an unhealthy state, and (3) an unstable condition. Some of the treatment techniques in fact did that.

Changes in Techniques

However, findings slowly changed those limitation concepts. Many of the limitation conclusions were accepted prior to the advent of:

a) growth forecasting with cephalometrics,
b) sectional and segmented mechanics,
c) the change in results offered by cortical anchorage,
d) the shift to .018" bracket,
e) the application of lighter forces and the whole pressure concept,
f) the earlier and progressive orthopedic use of extraoral mechanics,
g) the findings from the use of bumpers,
h) the three-dimensional control with concatenated wires,
i) the benefits of mandibular posturing technique,
j) the drama of changes in the transverse dimension,
k) the freedom of lower arch development with third molar germectomy,
l) the change in muscle influenced by myofunctional therapy.

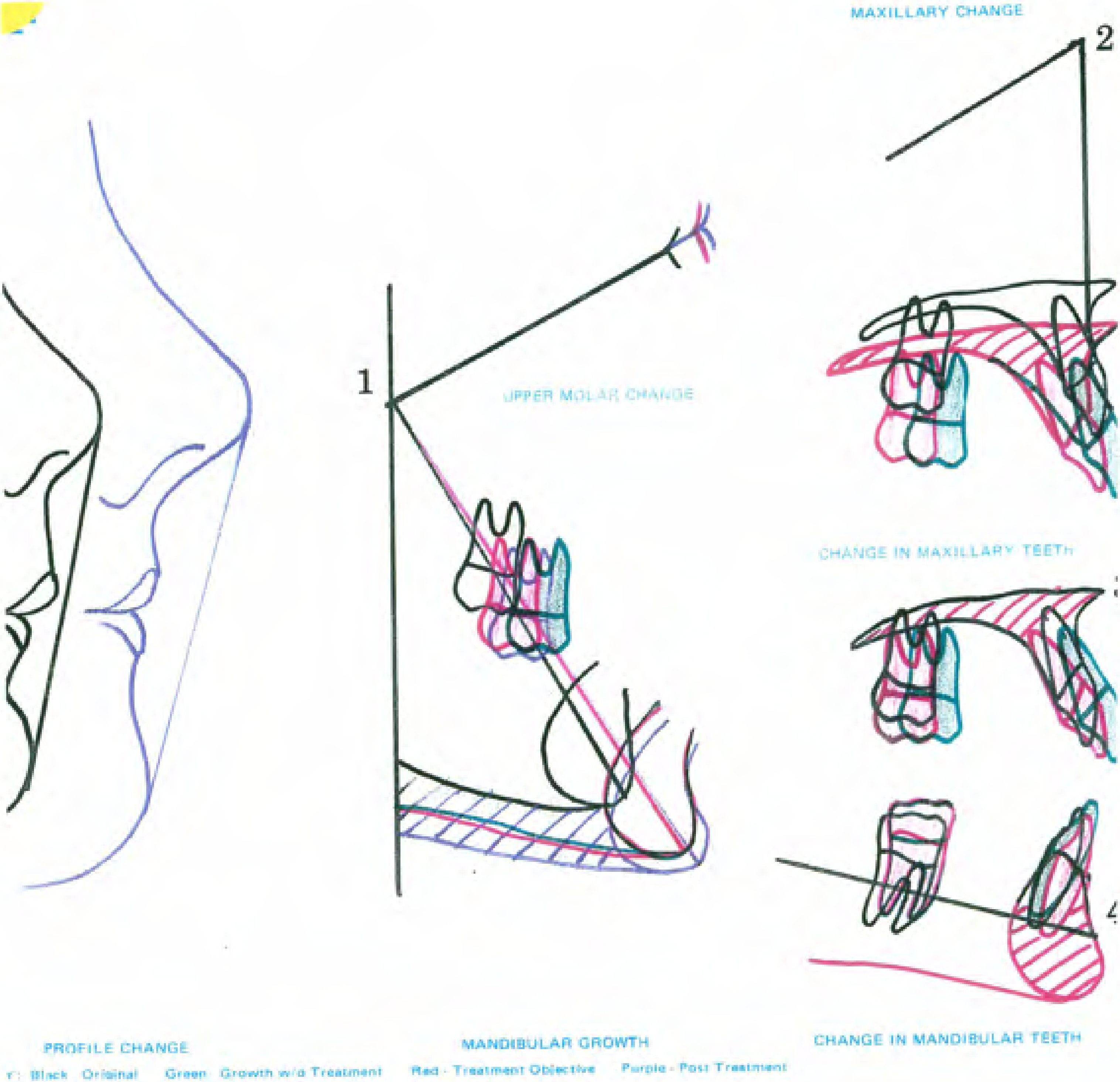


Fig. 1-4 A rendering from Rocky Mountain Information Services, a laboratory for projecting with computer processing. The four-position analysis of the forecast, shown in green, is without treatment; red is the suggested changes; and purple is long-range.

m) the profound difference offered by surgical lip release,
n) the cultural shift, in concepts of beauty, toward full lips,
o) the findings that extraction was not a guarantee against crowding.

Thus, at least fifteen factors changed the outlook in orthodontics to a "doctrine of possibility".

Extraction Rates

It is clear from surveys that by 1990 a major shift occurred regarding the frequency of extraction. From the essentially 90% extraction in the Begg school, and the 75% extraction in the Tweed school, surveys indicated that the incidence of premolar extraction was reduced to a 20% to 25% level as a mean for the adolescent population. Some practitioners claimed that less than 10% extraction typified their practice, when they started at the younger ages.

In patients diagnosed and treated in the deciduous dentition state the incidence of extraction of premolars in the Ricketts practice was only 5% to 7% in the Caucasian population. However, third molar germectomy in about one-third of the eight- to nine-year-old patients was conducted.

In the final analysis, the primary reason for extraction comes down to esthetics. Think about that! This means esthetics at maturity, and it means the smile line and the buccal "corridors" or space inside the oral vestibule. Like it or not, the fact that the face at maturity becomes a final issue brings the clinician's thinking back to a forecast. This means the profound consideration of the individual patient's future.

Borderlines

Regardless of the ideology or philosophy of the individual practitioner, there still remains a borderline for extraction even of third molars. Certainly extraction of premolars is not to be condemned when in fact it can be the most conservative approach in patients where it is strictly indicated. This is particularly true in patients treated too late to employ growth or too late to enjoy orthopedic changes to advantage.

The VTO was originally developed for a precise reason: an aid toward determining the contribution that growth could make toward the correction of a malocclusion, and helping to resolve the esthetic and functional needs of the patient.

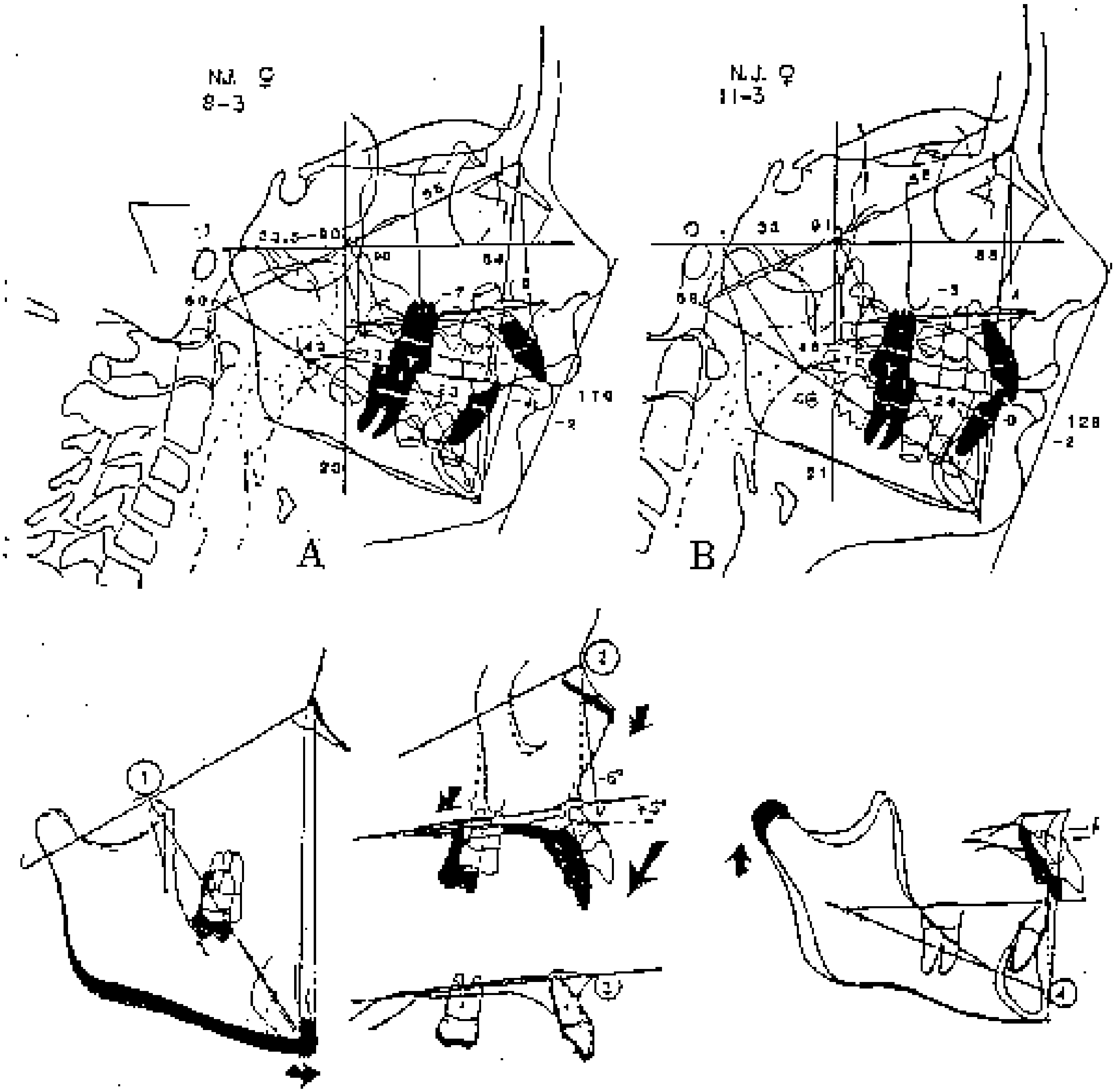


Fig. 1-5 Analysis of changes with the four-position analysis in a female 8 years, 3 months, to 11 years, 3 months, treated by cervical traction followed by "2 X 4" arches and intermaxillary elastics. Note chin came forward (1), the major movement of the palate was downward and backward (2), and with little denture change (3). The lower arch and Occlusal Plane change was nil (4).

Clinicians not schooled in the techniques or procedures implicit in the production of a VTO often concluded that its production and interpretation was all too complicated. Some found that they would treat the same way as they concluded from the studies of the models anyway. But history has proved that forecasting did change an orthodontist's opinion as previously concluded from the model alone. Long-range forecasts or visualized treatment goals did change the value judgment, often in an opposite way.

ORTHOPEDIC INTERPRETATION AND FINDINGS

Skeletal change possibilities are still argued. Orthopedics in the orthodontic specialty has been taken to mean "any alteration in skeletal maxillo-mandibular relations" that would not have occurred without treatment. But "orthopedics" in medicine includes nerve, muscle, joints, and connective tissue as well as bone. Orthopedics in orthodontics **involves also the vertical dimension.**

As described, by the mid-1950s scientific findings modified the previous conclusions regarding skeletal limitation (see Fig. 1-5). One of the findings particularly focused upon by the author was that of a radical opening **mandibular rotation** during the course of treatment. Many clinicians and professors assumed vertical changes to be only a temporary vertical growth pattern. It was learned, however, that the great majority of vertical opening **was iatrogenic**. Many assumed that such rotation was produced chiefly by **molar extrusion**. This vertical growth behavior occurs in open bite patients resulting from breathing conditions, sensitive teeth or long neck growth patterns (theoretically) (another subject for study). Findings in 1990 on larger untreated samples showed that the mean Facial Axis closed about 2° in 15 years as a mean in all types. Thus **even a maintenance of the Facial Axis with treatment is essentially an opening of the face height.**

Three-month-interval cephalometric research in 1948-49 showed rotation to occur most rapidly when the **interference of incisors** was encountered in the later stages of bite correction. This finding gave rise to the advice to "treat the overbite before the overjet". This was recommended in order to **prevent incisor interference** which was observed to stop the mandible in its closing path and, in effect, rotate it open and lengthen the face. In some patients this interference was consistent with the development of **a posterior condylar displacement** and a "click" in the joint, as discovered with routine laminagraphs before 1950.

Condyle Compression and Growth

Findings of individuals, and treated composites, have suggested inhibition of growth at the condyle to occur when **the condyle was compressed upward and forward in the fossa.** This was in contrast to the idea of pushing the condyle distally to prevent forward growth of the chin and, conversely, moving it forward to promote growth.

Maxillary Orthopedics

The second finding was that the **maxilla** was not the immutable structure previously envisioned. During cervical traction with the face bow, when employed without brackets and a straight-wire appliance or a bite-opening plate, the two halves of the maxillary complex were found to be moved downward, outward, and backward in Class II (see Fig. 1-5). Extraoral treatment induced a widened palate and a lowering of the nasal floor, and increased the nasal volume!

Later, facial anchorage (face mask) was shown to produce a movement of the whole nasal floor downward and forward for Class III correction. This is truly an orthopedic process.

The third finding was that palatal sutural alteration was possible with the .038" Eb (Elgiloy blue) soldered Quad Helix. Better nasal breathing was promoted with its use. Hence, during the 1950s efforts were made to improve mechanics in order to **control mandibular rotation.** This resulted in segmented procedures or "sectional mechanics", which started in 1954, and for which a separate manual was produced.

In addition, following the orthopedic findings in 1955 further studies led to the design of better mechanics to deliberately **induce orthopedic basalar changes in the maxilla.** Thus, for construction of the VTO the possibilities offered by the new successful techniques were added to the pre-existing objectives for treatment. Research had locked onto Sella-Nasion.

But the Basion-Nasion Plane for a reference loomed greatly, with several useful advantages.

GROWTH CONCEPTS CONCERNING CLINICAL PRACTICE

In the short range (1 to 2 years) the tooth movements required for correction (in severe malocclusions) represent a much greater change than the contribution that growth could make. This means that **the VTO (2 years) was related more to**

setting up desired tooth movements than to growth. Hence the VTO is mostly a **treatment objective.** For instance, the amount of tooth movement required to make a correction for the upper incisors in the treatment of a 12 mm. overjet, would necessitate 9 mm. of movement of teeth while growth alone could account for only 3 mm. even when utilized properly.

In the long range (5 to 15 years), as results were analysed, it was growth which dominated the whole developmental process. In long range, in the mixed dentition patient with post-treatment adjustments and with later development, natural biologic growth phenomenon could overwhelm the scene, particularly in males. The development to maturity with the desired changes was termed the Visualized Treatment Goal (or VTG), or a final treatment goal.

To recapitulate: during the short range of two years dental changes, orthopedics, and dental movement dominate the consideration in a practical VTO setup. However, in the long range, for the VTG setup, the physiologic and growth rebound and maturation are the arresting factors.

In some patients, a long range rendering will alter the treatment plan from extraction to non-extraction. Sometimes the opposite conclusion is drawn. The long-term view will influence the planned maxillary orthopedics to a more moderate goal. Some patients will be changed from an orthopedic plan to an orthodontic mechanical scheme only. Some patients will be found to need treatment **not at all**.

Understanding **of the VTO, VTG, ATO, STO**

There are **four types of treatment designs** to be applied clinically.

The VTO, or visualized treatment **objective**, is the common orthodontic idea. It is a setup for the time estimated for active treatment. It is employed for the growing patients. The VTO is formed from the individual natural growth expectancy without treatment upon which the treatment objectives of teeth, bone, and soft tissue are superimposed.

The VTG is a visualized treatment **goal** to maturity. **This** is for the long range. It applies to younger children or to patients having three years or more of growth remaining. A female at age 12 would be essentially the same VTO or VTG due to growth cessation usually by age 14.8 years. The same arcial mandibular growth procedure came to be employed for both the long (VTG) and short (VTO) range.

The ATO, or adult treatment objective, is a setup for adults or patients in whom no growth, **and no horizontal skeletal change,** is anticipated. But adults experience reposturing of the mandible in TMJ conditions. Adults also will differ in the amount of **mandibular rotation** planned for their deep bite correction, particularly with different modalities and intent. Objectives of lip alteration and esthetics are an adult consideration as well. Thus, **pre-planning in adults needs to be just as critical as it is in children.** Adults appreciate the detailed planning idea.

The STO is the surgical treatment objective. Like the VTO, it was also first developed in 1950. Originally it was designed for profile considerations and attempts to obtain balanced cephalometric values. In 1980, Divine facial proportions were discovered. The **Divine Proportions**, when planned and achieved, were in the "can't miss" category (Fig. 1-6 A & B). A separate manual was required for its application also.

Interpretation of the VTO (Analysis of the Forecast)

The first concern, in the growth and development consequence, is the behavior of the chin. This was explained as keys of the cybernetic circle. For precise evaluation some kind of central **axis of the face is needed.** Lack of a central axis was the profound weakness of the Steiner, Tweed and other analyses.

Typically, with the original "Y Axis" a mean of 3 mm. per year increase on S-Gn occurred. However, one-sixth of that was later shown to be the vertical change of Sella from the basi-cranial axis.

Directional chin changes were more difficult to predict. This was particularly true for periods longer than two years, due to two factors. The first factor was the major iatrogenic influences of orthodontic treatment on the **opening rotation** of the mandible as a consequence of (1) arch levelling, followed by (2) the extruding effects on the teeth from the pull of intraoral elastic traction without cortical **anchorage or segmented mechanics,** or by plates or techniques designed to extrude posterior teeth. Later the oblique pull extraoral traction helped somewhat to mitigate opening.

The second problem was the developmental behavior of Sella itself. It was accepted that Sella turcica was a point from which all focal growth behavior developed. This idea was gained from Brodie's demonstration of Sella as a gnomonic center for calvaria growth and the regularity of palatal behavior to SN (the nasal capsule). The use of Sella for forecasting the mandible failed, however. Also, the rotational effects of treatment were thought always to "tend to recover", which turned out not to be true. Some patients were seen to rotate open as much as 7° on the Y Axis during only 15 months of treatment. Some clinicians were so adamant in the

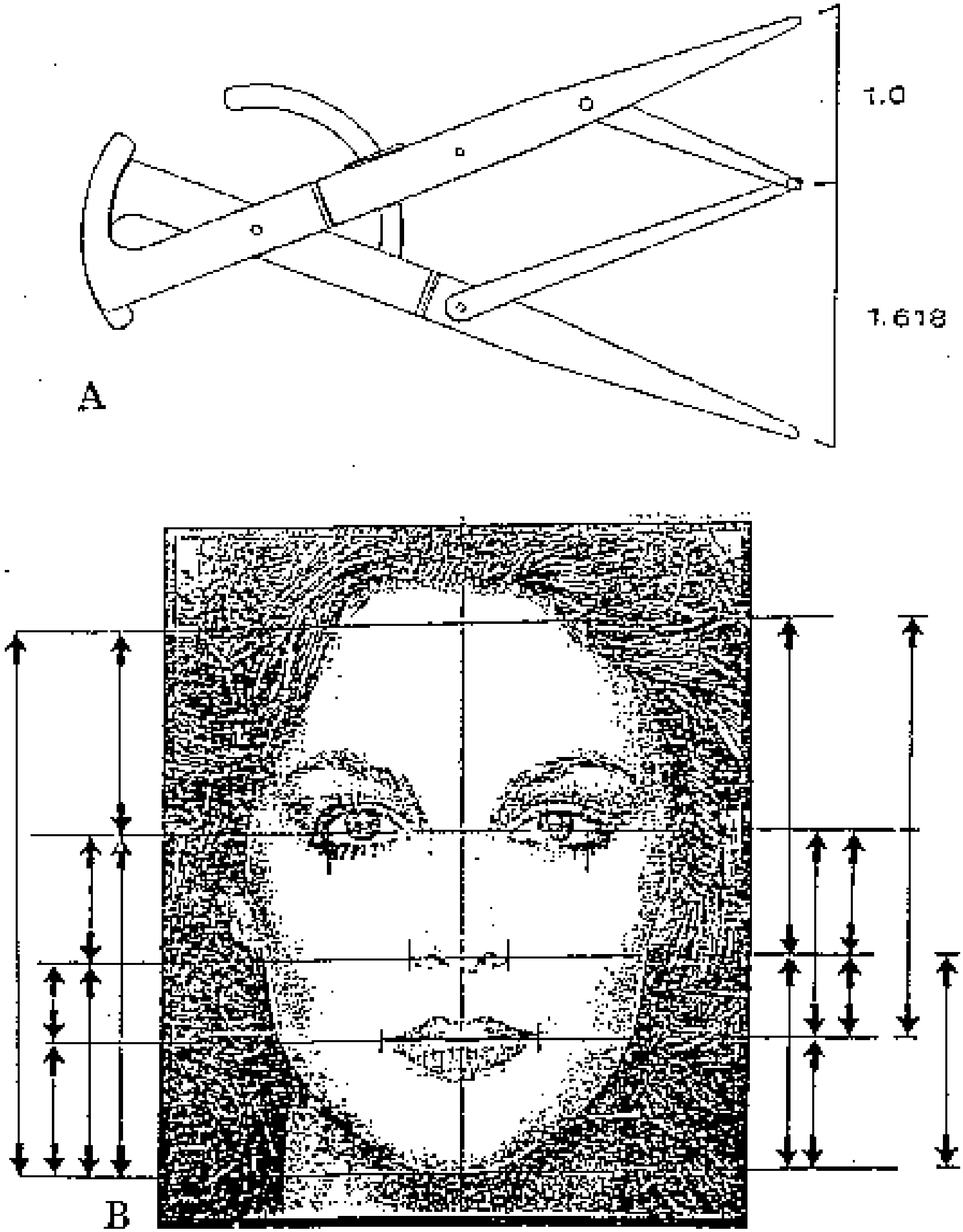


Fig. 1-6A The Ricketts Golden Divider is demonstrated (A). Findings of the facial soft tissue Divine Proportions in the vertical and horizontal are shown (B).

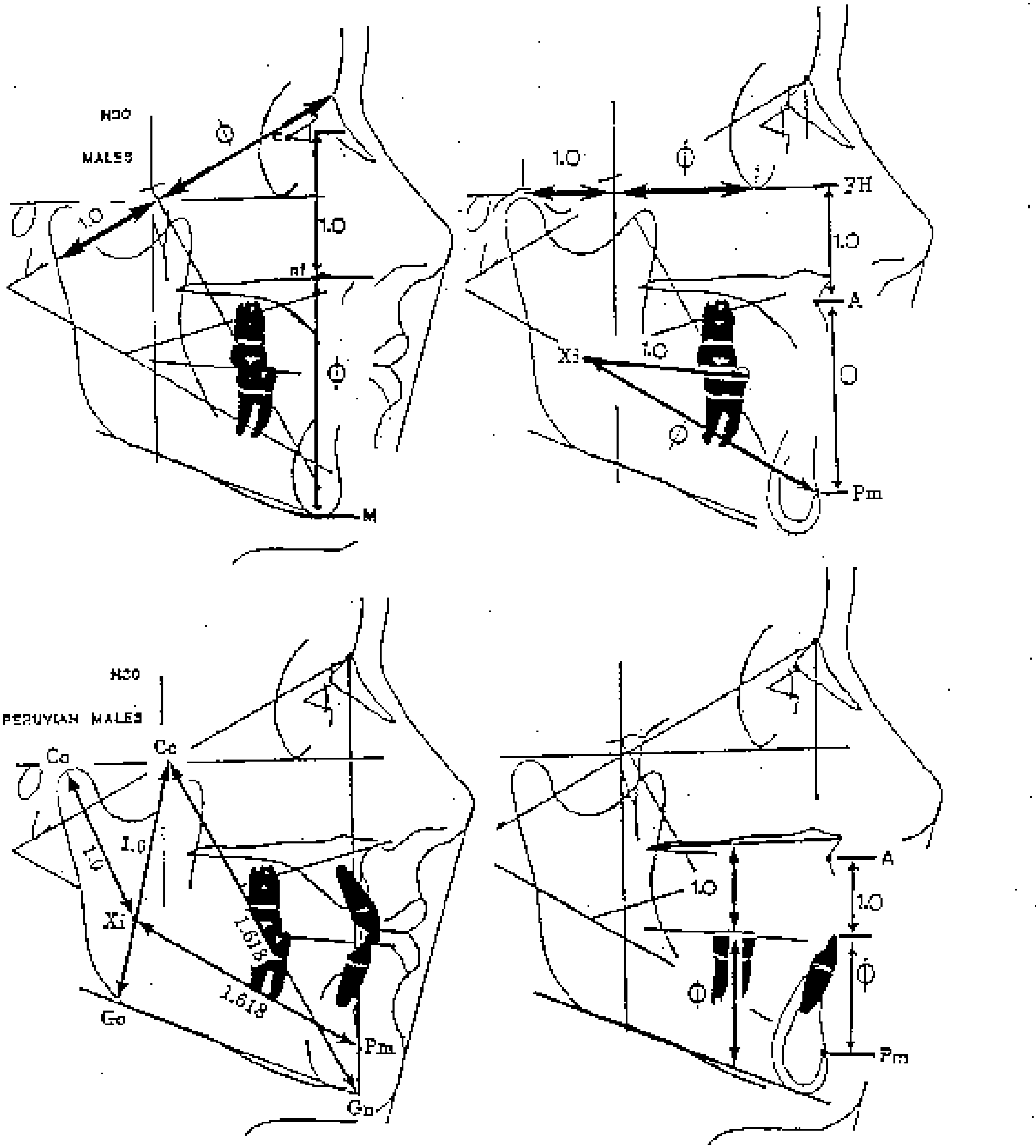


Fig. 1-6B Numerous Divine Proportions (1.0 to 1.618) are demonstrated from computer composites of normal Caucasian males (N=30), in the deep skeletal and dental components.

belief that posterior extrusion was the only recourse to treat overbite that they used vertical elastics to extrude posterior teeth. **In the latter cases some clinicians simply assumed that radical vertical behavior was a genetic abnormal growth pattern rather than iatrogenetically produced** (Figs 1-7-A, 1-7-B, 1-7-C).

Vertical behavior was a very poorly understood phenomenon, and some statements concerning it have misled the profession.

Early "Forecasts"

At the beginning of facial behavioral research, conducted with cephalometrics and laminagraphy, predictions were made on a continued pattern of development of the midface (no orthopedic change in palatal plane or Ans). Thus, in essence it was originally accepted that orthodontics was **limited** to the teeth. Changes could, however, include some induced mandibular rotation which "would recover". This was due to the unchallenged claims that the maxillary growth pattern was constant and was further immutable to treatment.

A statement often repeated after the 1938 study of Brodie, et al. was, "Growth is an advantage during the treatment process". However, in that era it was not explained how growth could work for the correction. Growth had not been reduced to unit values to calculate with anchorage during the treatment process. All growth, regardless of direction, was deemed favorable. But an argument could be made that growth via separation of the jaws actually lessens molar anchorage. The theory of "dominance of the morphologic pattern" prevailed until 1950. It was not until 1970 that -- based on computer findings -- the contribution of growth was calculated in a trustworthy manner. This will be taken up in Chapter Two.

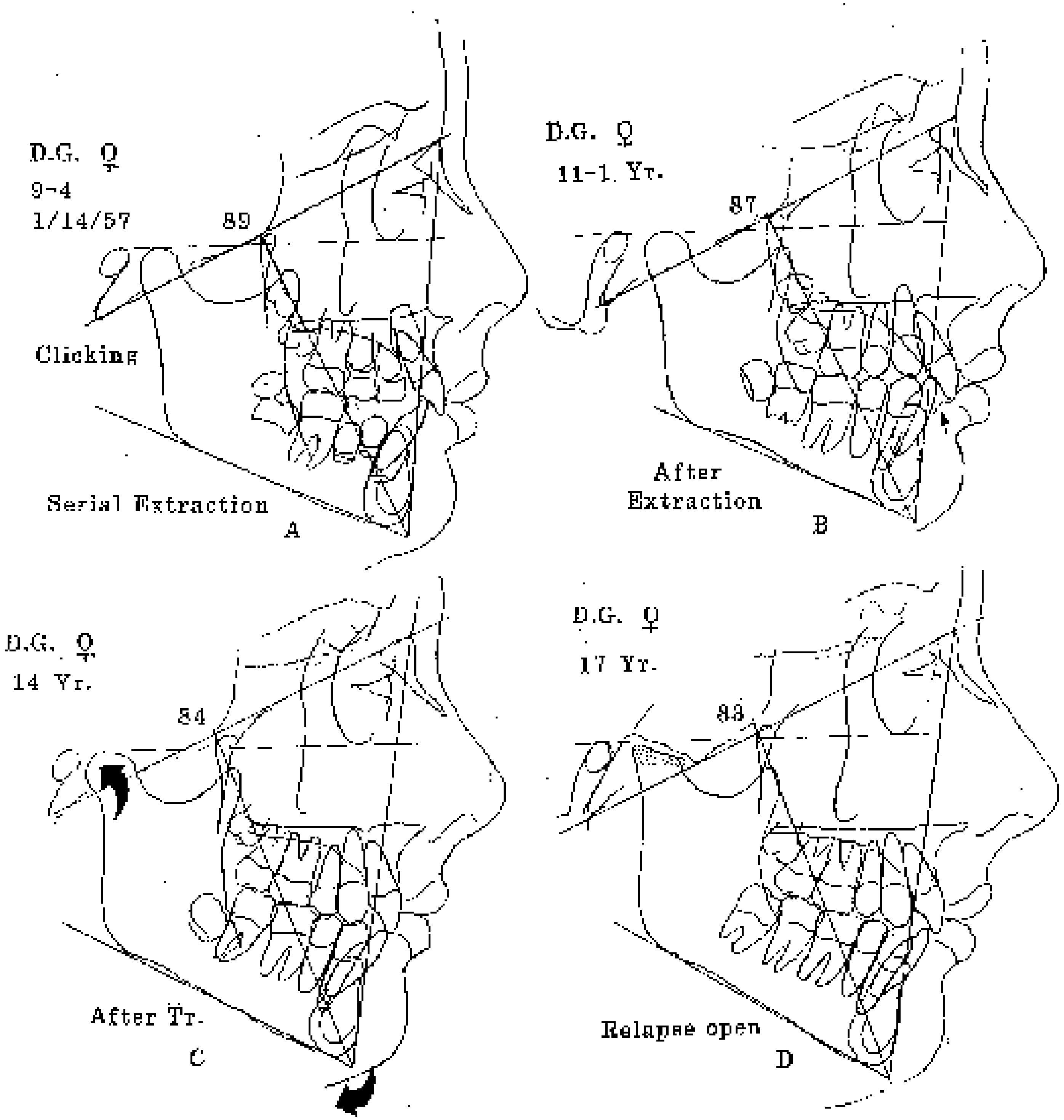


Fig. 1-7A A female patient, D.G., lost the second deciduous molar from caries at age 8.

- **A.** At age 9 four deciduous canines were removed for orthodontics.
- **B.** After serial extraction the patient was Class II and the bite deepened by age 11. Clicking of the joint was recorded.
- **C.** Ordinary extraction technique was followed and she was retained at age 13 but the Facial Axis was now 84° compared to original 89°, and the condyle showed evidence of posterior alteration.
- **D.** At age 17 note the flattened condyle and worsening Facial Axis and an open-bite condition developed.

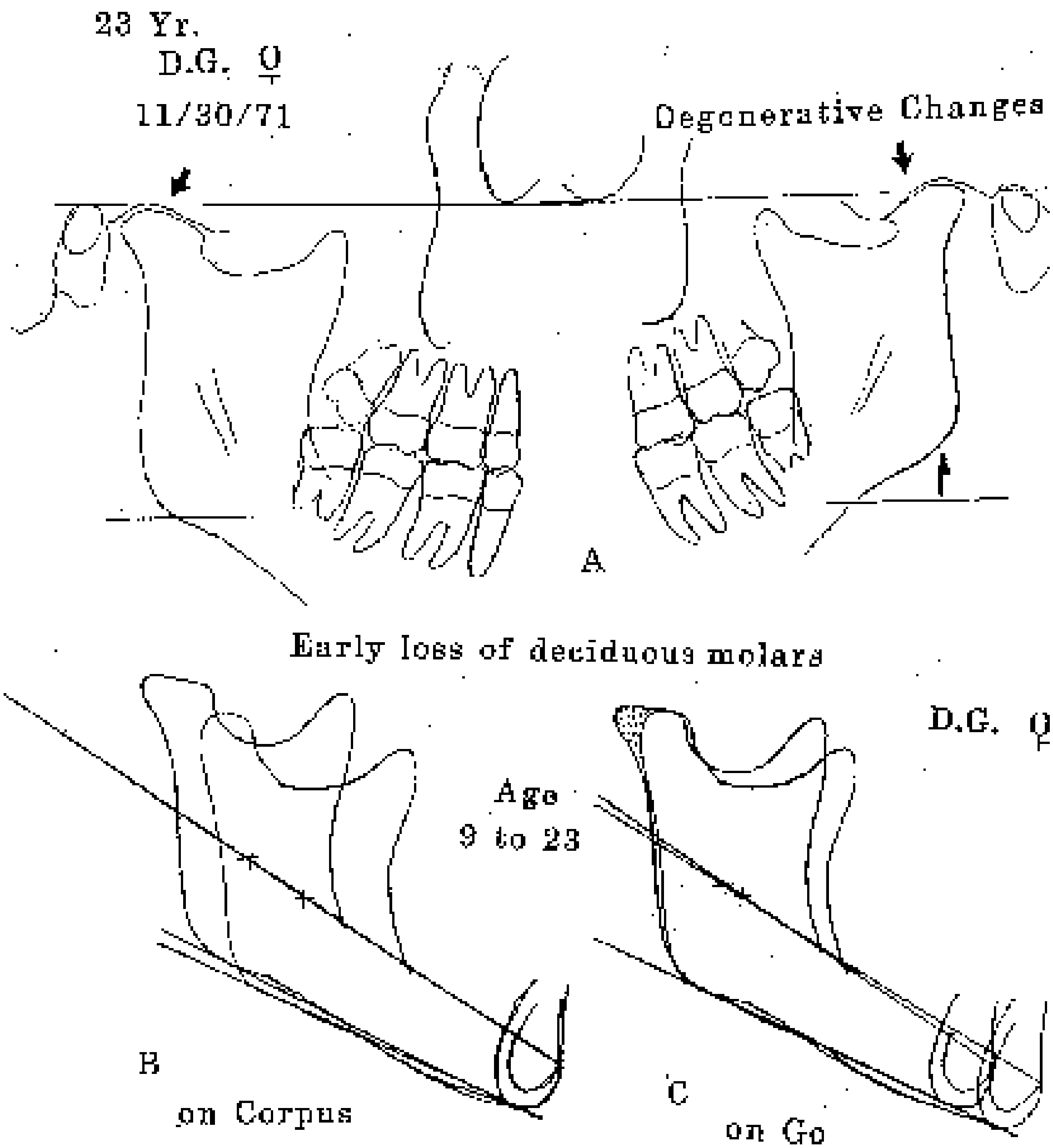


Fig. 1-7B

A. Tracings of tomograms of D.G. show advanced degenerative joint disease signs at age 23.
B. Line 1 (age 9-4) compared to age 23 on the Corpus Axis at Pm.
C. The same tracings superimposed on the mandibular plane at the gonial angle

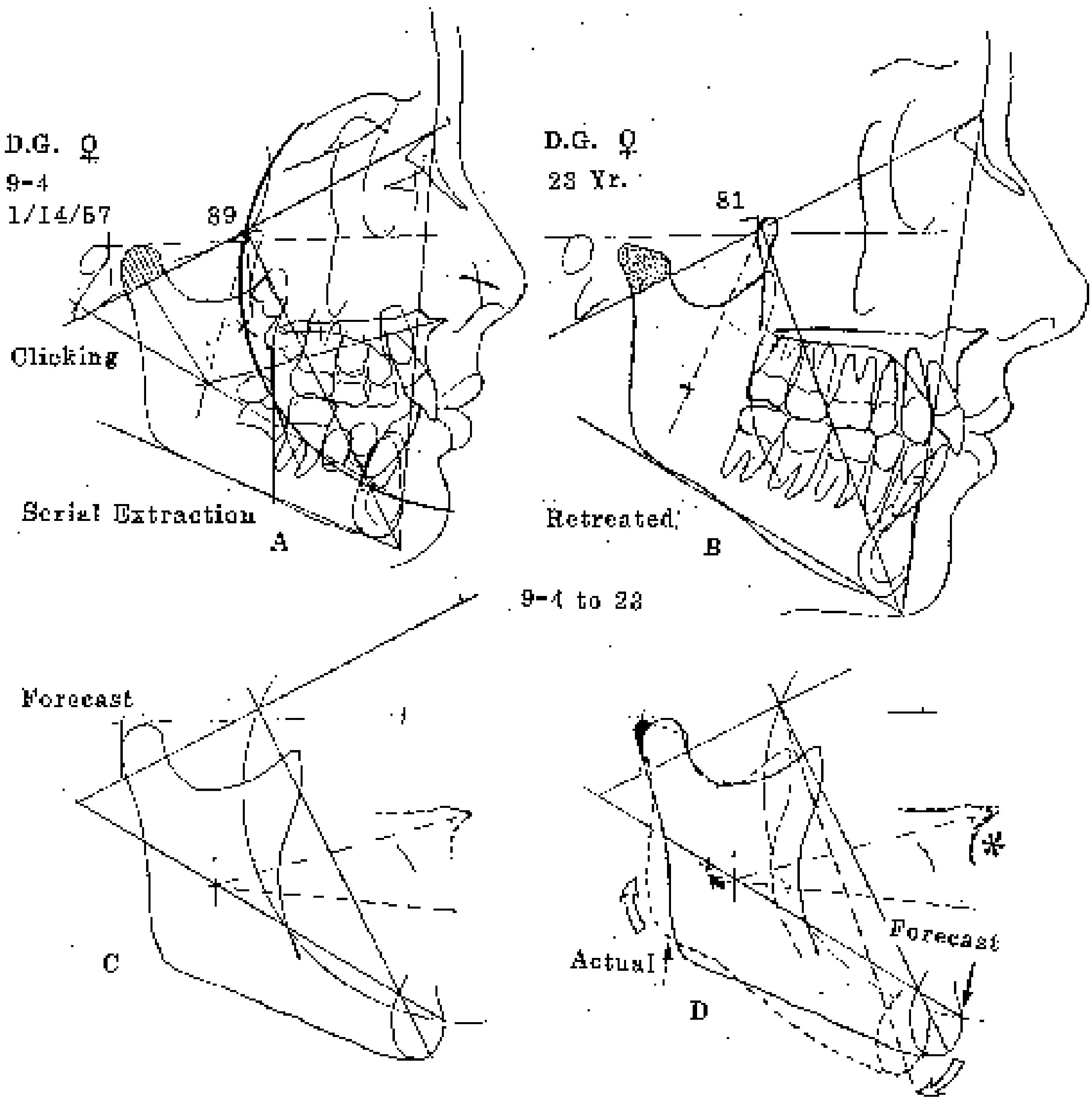


Fig. 1-7C A. Time 1 tracings showing the arc construction for forecasting.

B. The actual condition of patient D.G. at age 23 years. Note the Facial Axis at 81°. The occlusion was retreated, now for open bite due to degenerative joint changes and condylar involution. Patient was clicking by age 11 years. Note condyle flattened at age 14 to age 23 (see Fig. 1-7A).

C. Forecasted mandible and skeletal parts from age 9.

D. Comparison of the forecast to actual shows severe retrognathism to develop with opening of 9° from the forecast.

PREDICTION, PLANNING, CONSTRUCTION and MECHANICS

CHAPTER TWO

THE SECOND GENERATION OF FORECASTING: THE INFLUENCE OF COMPUTER FINDINGS

NEW SCIENTIFIC EVENTS

The movement by fixed appliance clinicians toward high pull headgear off the molars was made following a questionable assumption. It was generally accepted that mandibular rotation was entirely caused by molar extrusion or the so-called "wedge effect". Movement of molars backward on an articulator would yield this assumption. But despite a plethora of studies conducted, **the influence of the mechanics of molars alone was never proven**. In retrospect, pain was not taken into account. Also, neither breathing conditions nor muscle patterns were analysed. Together with mandibular rotation the molars did extrude. But that did not prove a cause and effect of the molar alone. This issue was addressed in 1992, when Ricketts showed numerous patients in all types of patterns in whom lower molar intrusion matched the additional extrusion of the upper molar when night use of cervical traction alone was employed. Lower intrusion occurred when the patient was not overwhelmed with excessive force and pain. Also, in many patients, but not all, more vertical growth of the condyle and ramus occurred than was anticipated.

These different characteristics resulting form specific modalities, and the manner in which they are used, will alter the VTO construction itself. Thus treatment will alter the outcome, making a retrospective study look ridiculous.

Intrusion

"**Depression**" of the incisors was described by Angle with the ribbon arch in 1916. Isolated cases treated with "Ribbon philosophy" revealed cephalometrically that incisor intrusion was possible in 1948 (Fig. 2-1). But it wasn't until the development of the utility arch and the specific experimental attempts toward intrusion in 1960 (proven cephalometrically in samples of patients) that depressive mechanics became a deliberate objective of orthodontic therapy. [See manual on "Utility Arch Therapy".]

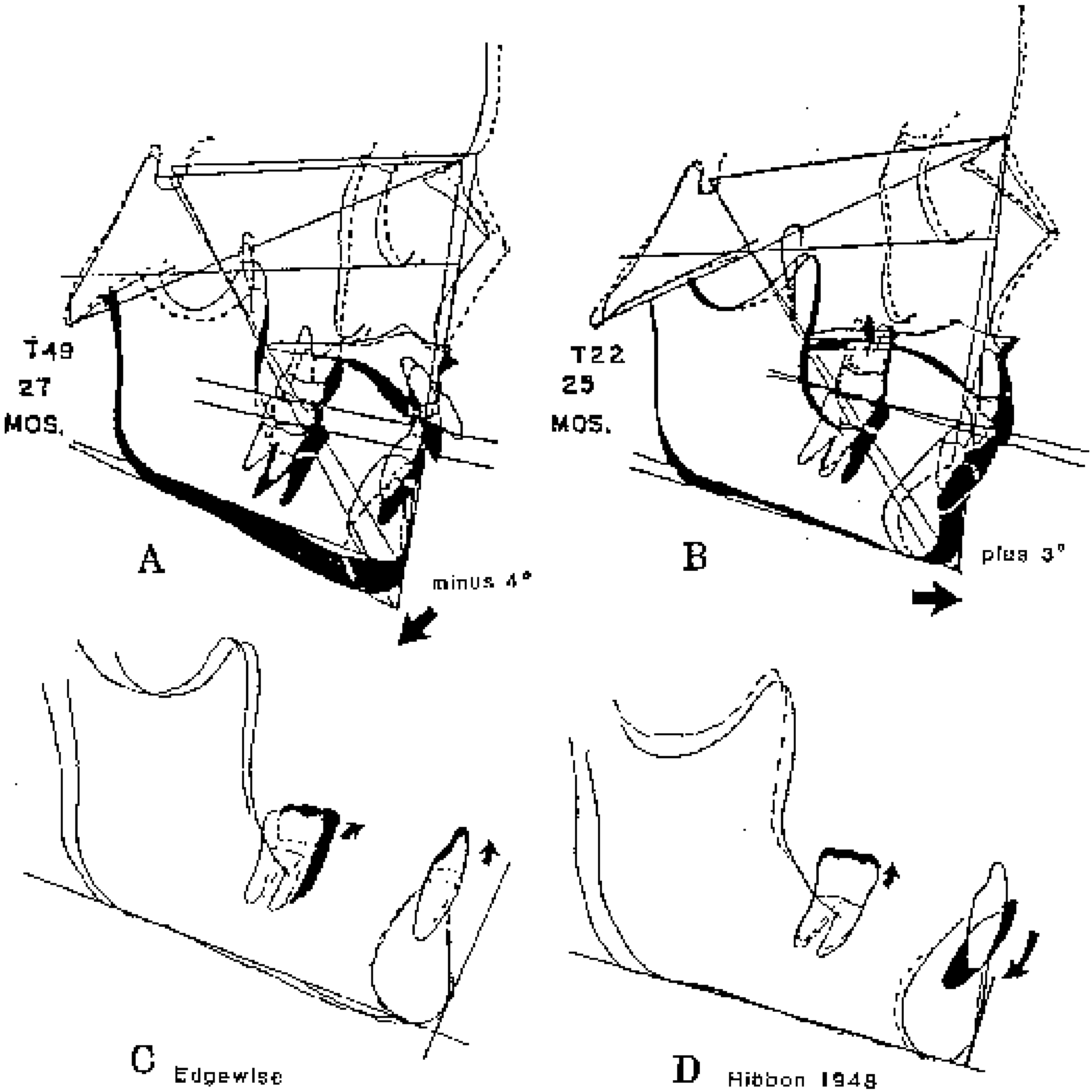


Fig. 2-1

A. Behavior of full Edgewise case (T49) typical of behavior with arch levelling and elastic traction. Note negative rotation of −4°.

B. Class II, Division 2 patient (T22) treated by Ribbon approach and intrusion of anterior teeth. Note positive rotation of +3°.

C. Molar and incisor extrusion from mandibular symphysis.

D. Note lower incisor intrusion.

Private conversations with Dr. R. Begg in 1964 revealed that an anterior tooth losing a pin attachment would remain in supra-occlusion while others would be intruded.

Following controlled studies and computer composite confirmation, intrusion became so routine that it was predicted and planned. "There is no new thing under the sun," as the writer of the Biblical book of Ecclesiastes points out (Oxford Dictionary of Quotations).

Thus, incisor tooth intrusion, both in the upper and the lower were added to the potential of "mandibular control". Over-opening of the mandible could essentially be prevented and avoidance of long face consequences resulting from mechanics could be achieved. Mandibular control, and maxillary orthopedics with treatment, was therefore added to the findings from previous studies. This further influenced nasal obstruction and mouth breathing. Objectives, or the VTO, were changed in the light of these new possibilities. Planning through the visualizing process took on even greater significance.

Emergence of the New Points

Several new scientific events were enjoyed from 1965 to 1968. Research was conducted initially with a pilot study, which was followed by an in-depth statistical analysis of records of 40 growing children for a period of 8 years. [See also the manual *Progressive Cephalometrics: Paradigm 2000.*]

Pterygoid Point (Pt) and Cranial Center (Cc)

First was the discovery that the use of Foramen Rotundum could be employed as a central reference (see Frontal). This was labeled Pterygoid Point (Pt) and was shown to have several advantages (see Chart I). The orientation to the Basion-Nasion plane was confirmed as the most cogent method.

A new central axis for the face was founded, which was called "The Facial Axis" (Fig. 2-2A). It was drawn from Pt to Gn. At the crossing of the line at the BaN plane, the point was labelled Cc (Cranial center). In some rare cases Pt is found below the BaN Plane. The Facial Axis was simple. It held a mean of 90°, showed less variation and was more critical for treatment analysis than anything experienced before. More information could be gained regarding chin relationship than for any other single parameter.

Protuberance Menti Point (Pm)

Pogonion is a point, by definition, at the most anterior curvature of the

CHART. I

FUNCTIONS OF PT -- PTERYGOID POINT

1. Biological point -- Maxillary nerve
2. Center of several stress sites:
   - -- Rostrum of sphenoid for Vomer Bone
   - -- Pterygoid plate roots
   - -- Base for flare backward and upward and forward for great wing of the sphenoid, very near coronal suture complex
3. At area near the venous plexus and sphenopalatine ganglion of the maxillary artery
4. A bilateral condition
5. Associated more with splanchnocranium than neurocranium
6. A direct point, not estimated (as sella)
7. Found at the base of the Sphenoid body when growth center of the face is located
8. Statistically as well as practically the most central area of growth
9. Forms almost perfect 90° angle with the chin to the Basi-Cranial Axis in Caucasian population
10. Divides posterior cranial base and anterior cranial base on a practical clinical basis
11. The center of Bi Polar points in growth in the frontal view

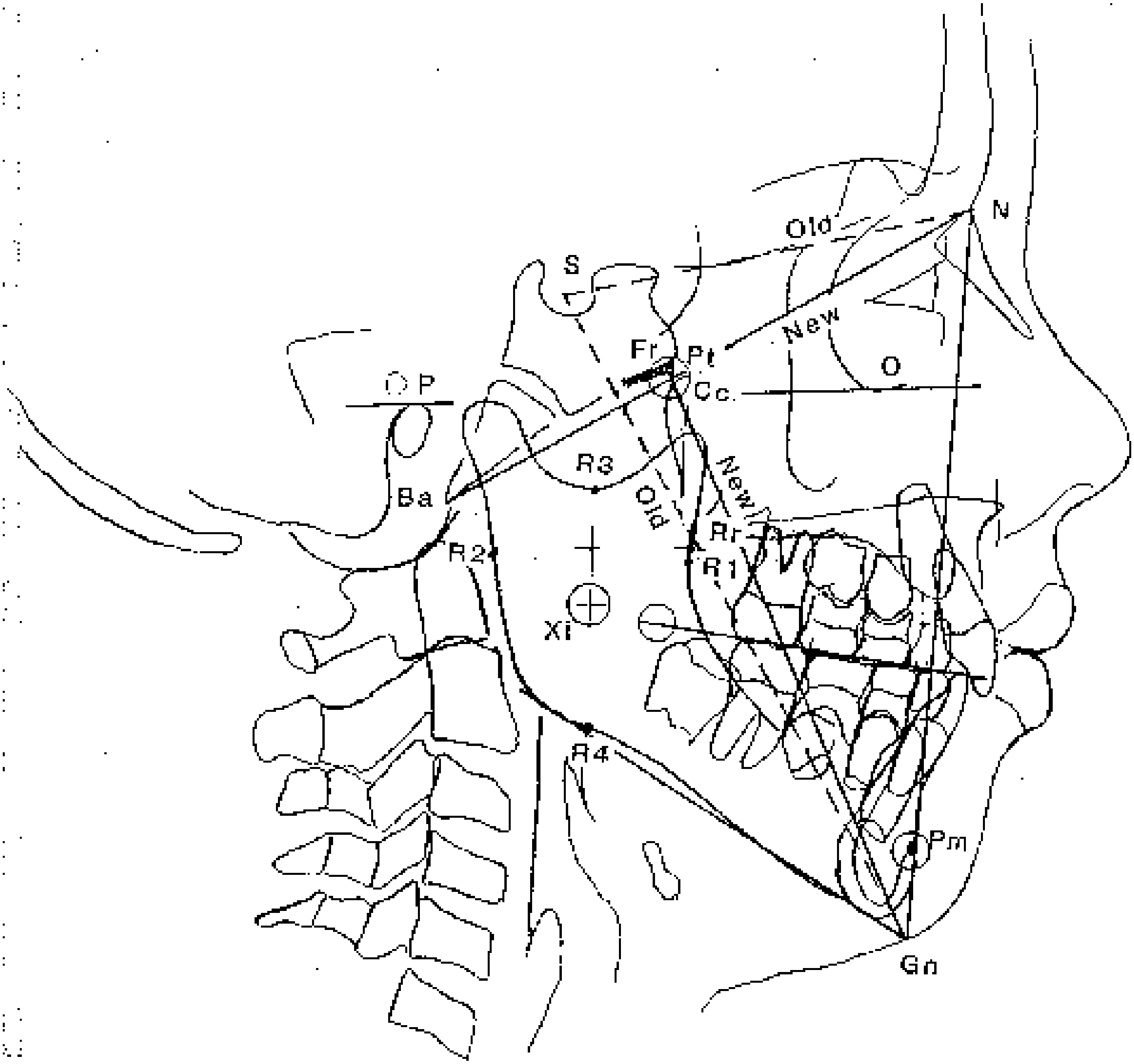


Fig. 2-2A The older Y axis (SGn) was replaced by the new Facial Axis (Pt Gn) in 1965. Pt is located at lower rim of foramen rotundum (Fr). Xi Point was a centroid selected by measurement (R1-R4) nearly always located over the mandibular foramen. Pm is the protuberance menti.

symphysis. It is horizontally determined and therefore employed for a sagittal parameter. However, a vertical point on the chin was needed other than Menton. Implant studies of Bjork had revealed a stable area at the apex of the mental trigone, the mental protuberance. This also was identified by Enlow as a "reversal line" area. Pm point was thus selected at the beginning of the recess above the pogonial area, or a discontinuing thick anterior cortex of bone (see Fig. 2-2A). The value of its use was revealed to be profound (see Chart II). It was found that in males apposition occurred around the lower border of the chin below Pm. In females, however, apposition was not seen after age six (see Chapter Three).

Xi Point (Xi)

Ironically, in 1965 the Xi Point was discovered by serendipity. Bjork had shown with implant studies, in 1963, that the mandibular plane could no longer be used for longitudinal study other than for very short periods of time (or in adults). The reason for this was that the lower border of the mandible at the angle resorbed and drifted. Bjork had also suggested superimposing on the nerve canal or the crypt of the third molar.

In an effort to find a more reliable point of reference for the depiction of occlusal plane changes, several explorations were made. Finally, an experimental point was selected, by measurement, at the center of the ramus by bisecting the height and depth of the ramal anatomy. It was labelled Xi Point (see Fig. 2-2A). This proved to be a major breakthrough but it received howling opposition (as did several of other new landmarks that had been selected). Xi Point was found to have fifteen functions (Chart III).

The True Buccal Occlusal Plane

A functional occlusal plane was sought in the original body section cuts through the condyle. This was found to be a bisection of the buccal occlusion. It was determined that anterior teeth were affected by the tongue and lower lip, while the buccal teeth were still related naturally. For the occlusal plane, for analysis and longitudinal work, the incisors were therefore ignored. The Buccal Plane became the means of diagnosis of supra-occlusion, and was a more reliable source for forecasting (see Fig. 2-2A).

Computer Findings

Because better proof was needed for the points discovered, 362 measurements were consequently included in the major computer exploratory starting in 1966 and analyzed by computer application in 1969. The new points were verified in norma lateralis.

CHART II

FUNCTIONS OF Pm -- PROTUBERANCE MENTI

1. A point at the Apex of the mental trigone which braces the symphysis (2 mental tubercles and protuberances)
2. A point of confluence at the termination of skeletal stress lines (external oblique ridges)
3. A point of convergence of stress lines from the labial alveolar process.
4. A stable point, as found with metal implant studies
5. A point at reversal line between apposition (below in males) and resorption (above)
6. A point employed for construction of the mandibular growth arc
7. A point employed with Xi (Corpus Axis) to assess lower molar drift or anchorage.
8. A point employed for vertical assessment of lower incisor in the divine proportion to Point A.
9. A point employed for assessment of lower face height with Point A and the Frankfort Plane.
10. A point to consider in surgical genioplasty.
11. A point for consideration of muscles of the lower lip.
12. An alternative to traditional B Point
13. Can be employed with A Point for a reference line for teeth (APm *versus* APo).

CHART III

FUNCTIONS OF XI

1. Divides the normal mandible into a golden section or Divine Proportion
2. Represents the Mandibular foramen – as a neurotrophic point
3. Serves for evaluation of occlusal plane
4. Serves for prediction of occlusal plane
5. Serves for description of lower face height
6. Serves for description of total face height in two ways
7. Its position relative to PTV is diagnostic for Class III or Class II
8. Serves as a basis for the Corpus Axis which is used for assessment of mandibular rotation during treatment
9. Serves for analysis of corpus-condylar bend in treatment and growth; used to locate Point Rr (Ramus reference)
10. Used to find Point Eva
11. The Xi Axis is used in forecasting
12. Holds gnomic value to Nasion in general
13. Used in planning surgical cuts in surgery
14. Used for prediction of third molar space
15. Used to assess length of condyle and length of corpus in severe dysplasias and for forecasting

Simultaneously other new points were found useful for the Frontal Analysis (Fig. 2-2B). These were: Ag point (at the trihedral eminence on the mandible), J point (at the jugal process crossing with the tuberosity), and Zf point (at the medial border of the zygofrontal suture. The top of the mental trigone could also be selected as Pm Point.

Vertex locations for allometric figures, and a usable "polar phenomenon" for growth analysis was also discovered.

* * * * *

THE CHANGE IN THE FORMAT USED FROM 1967 TO 1975

Individual Growth Forecasting

With the new computer findings, the technique of forecasting during a treatment time was reformatted from that of 1950 (Fig. 2-3A).

For forecasting on the BaN Plane, Nasion was moved upward and forward 0.8 mm. (from Cc) with one year's typical growth employed as one module (Fig. 2-3B). A standard 0.8 mm. was employed except in extreme cases where the original cranial base varied more than 2 standard deviations in either direction when adjusted for age and sex.

The "condylar plane", extended to the mandibular plane (see Fig. 2-3A), was changed to the "condyle axis" (from condylion to the Xi Point). D Point, the point of intersection of the condyle axis with the BaN plane, was moved downward and backward on the Basion-Nasion plane at a rate per year of 0.5 mm. (as one module) (see Fig. 2-3B). This simplified and yet improved both the treatment analysis and the short-range forecasting accuracy. The mandible was rotated according to previously discovered input from treatment mechanics.

With the new cranial base established, the mandible was then grown on the condylar axis 1.0 mm. per year and thence forward on the corpus axis 1.6 mm. per year (see Fig. 2-3B).*

Treatment Forecasting

For the treatment objective the untreated **mandible** was rotated according to the previous collected data. This behavior was relative to the anticipated effect of the given treatment modality as required for the individual degree of difficulty. For the

* Later shown to be Divine Proportions.

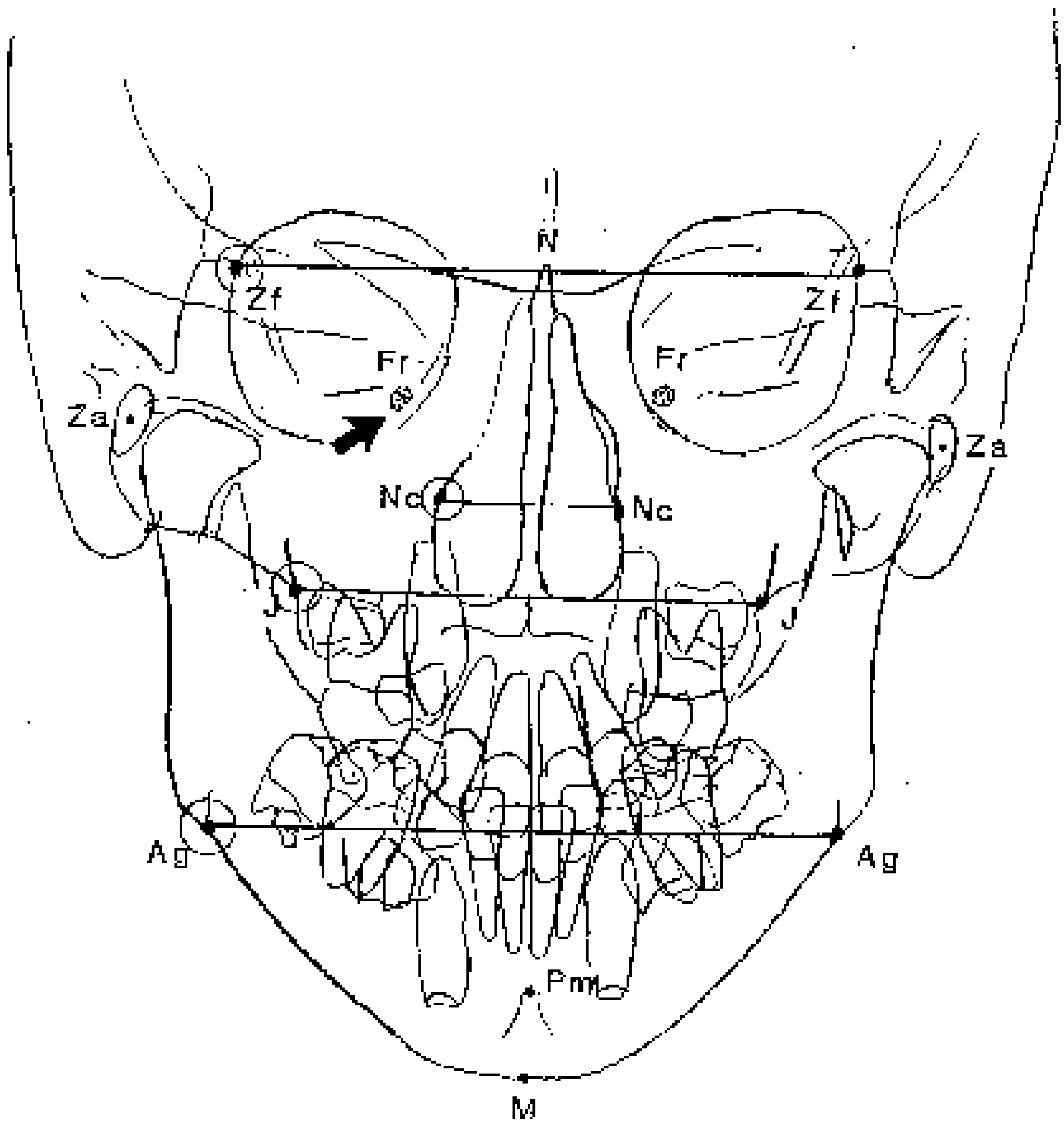


Fig. 2-2B Frontal points;

ZF- zygomatico frontal suture,
Za - zygomatic arch center,
Nc - widest point in the nasal cavity,
J - point Jugale on jugal process at crossing of outline of the tuberosity,
Ag - antegonial tubercle (trihedral eminence),
Pm - top of mental trigone,
N - Nasion,
M - Menton,

FORMAT 1950

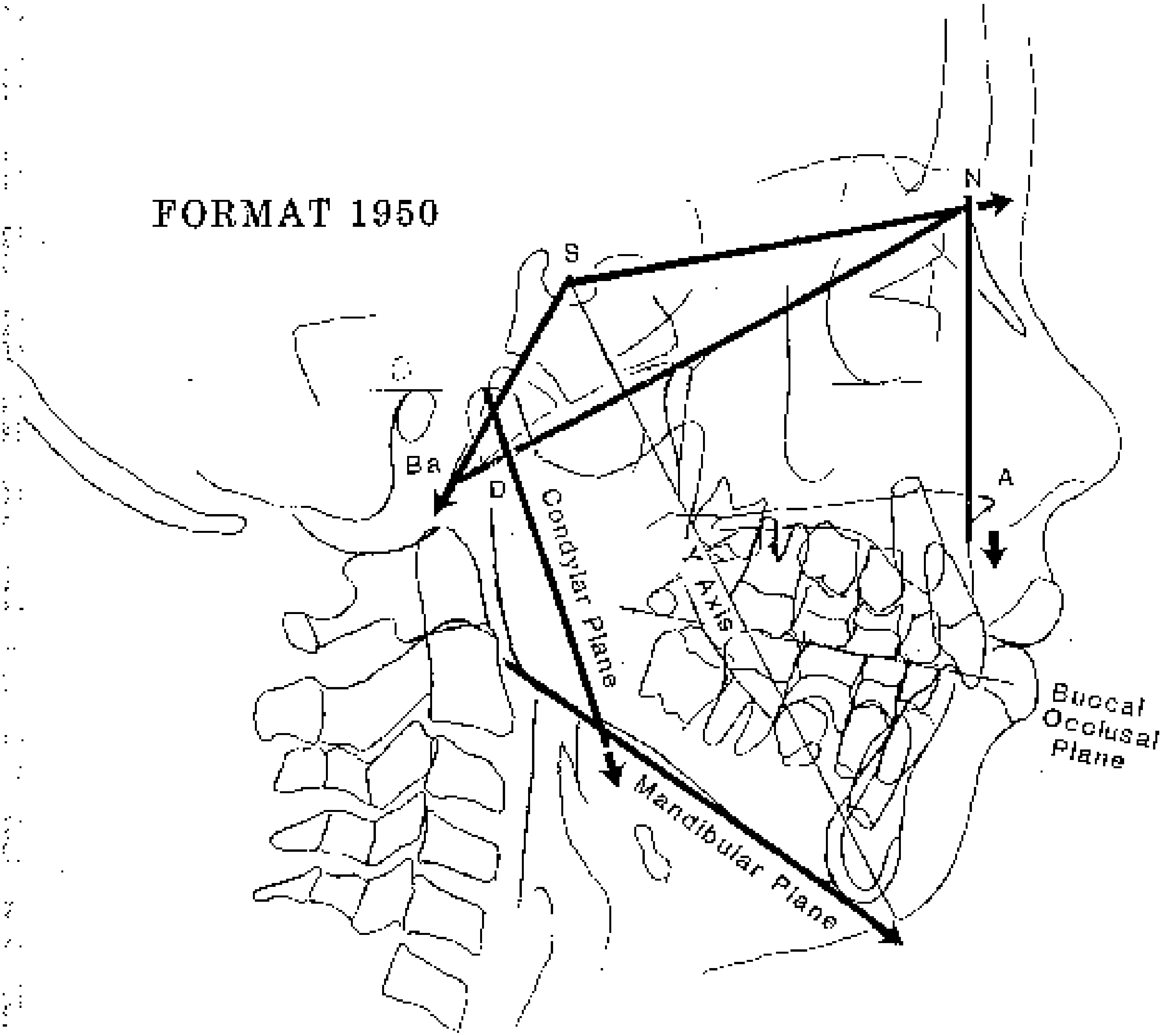


Fig. 2-3A The original format employed the triangle N-S-Ba for a new BaN Plane. A line down the long axis of the condyle from the center at Point D was used to connect the cranium to the mandibular plane. The true buccal plane ignored the incisors. Point A was related either to SN or BaN.

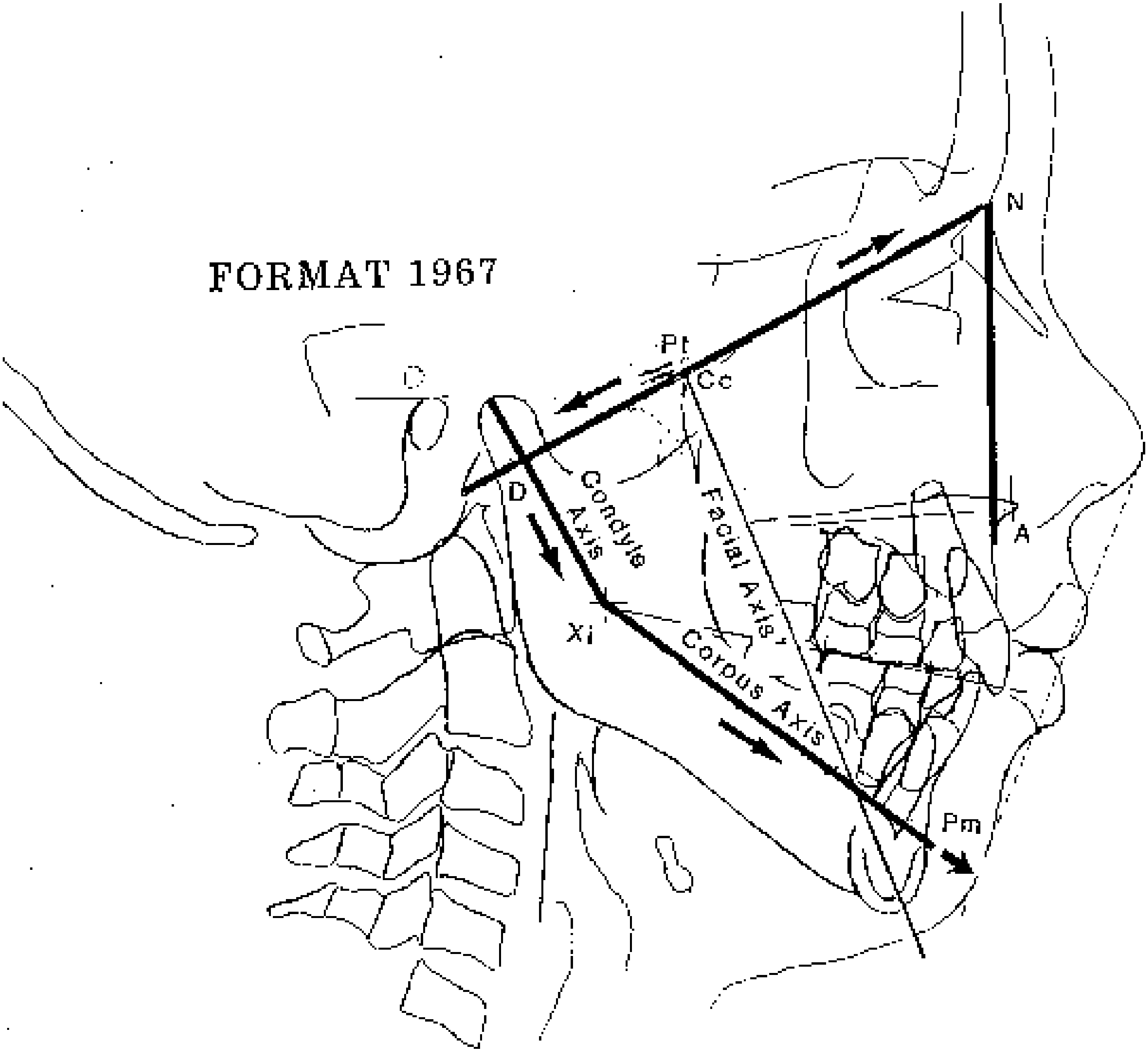


Fig. 2-3B The second format ignored point Sella and started with the Cc (Cranial center) on the BaN Plane. D Point was again used but to a new Condyle Axis which was constructed from Xi Point. Xi-Pm was the new Corpus Axis and Cc-N-Point A was employed for maxillary forecasting.

maxilla, the angle Basion-Nasion-Point A was found not to change without treatment, but for the VTO it was modified for the condition desired.

This second format, the condylar axis-corpus axis for short-range, was effective. It was, however, weaker as a long-range matrix. Consequently, when the mandibular growth arc was discovered in 1971 an arcial method for forecasting was developed which ultimately replaced all the previous methods (Figs. 2-4A and 2-4B).

* * * * *

The Essence of the VTO

Skeletal Change in the Jaws

Some clinicians were not willing to accept that maxillary orthopedics was possible and scoffed at its mere mention. They preferred to treat to the existing convexity or sought correction as influenced by mandibular behavior alone. Further, many also did not accept that the mandible could be influenced with treatment in the short term, which was found to occur. Consequently, the whole idea of a VTO for the skeletal portion of planning was rejected. It is repudiated still by believers in the limited concept of clinical possibility.

But in young patients maxillary changes were proven to be dramatically induced in 1960. In the 1970s composites of non-extracted treated groups of Class II and Class III are shown in Figures 2-5A and 2-5B. These showed unquestionable skeletal change. While individual patients are anecdotal, computer-generated composites of groups show mean expectancies for practical estimates for given modalities. Thus these results, certainly not anecdotal in perspective, should be studied for a base of reference by any clinician desiring this higher sophistication.

* * * * *

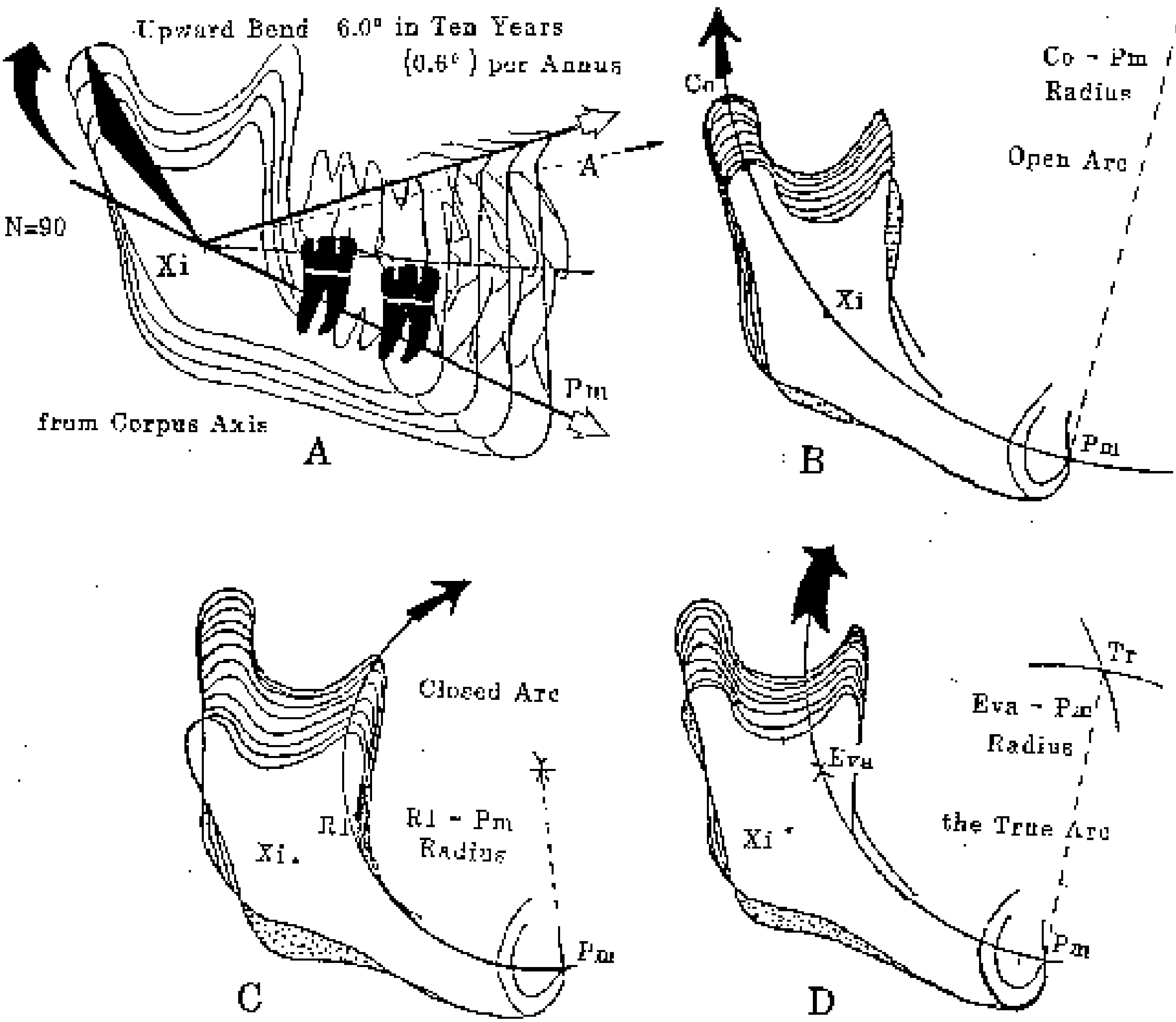


Fig. 2-4A
A. Sample of 90 untreated growing children showed an upward bending behavior.
B. An arc through the condyle and Xi from Pm opened the bend too much.
C. An arc through the coronoid and R1 from Pm closed it.
D. The true radius point (Tr) was located from Eva point centered at the base of the coronoid.

FORMAT 1975 - 1995

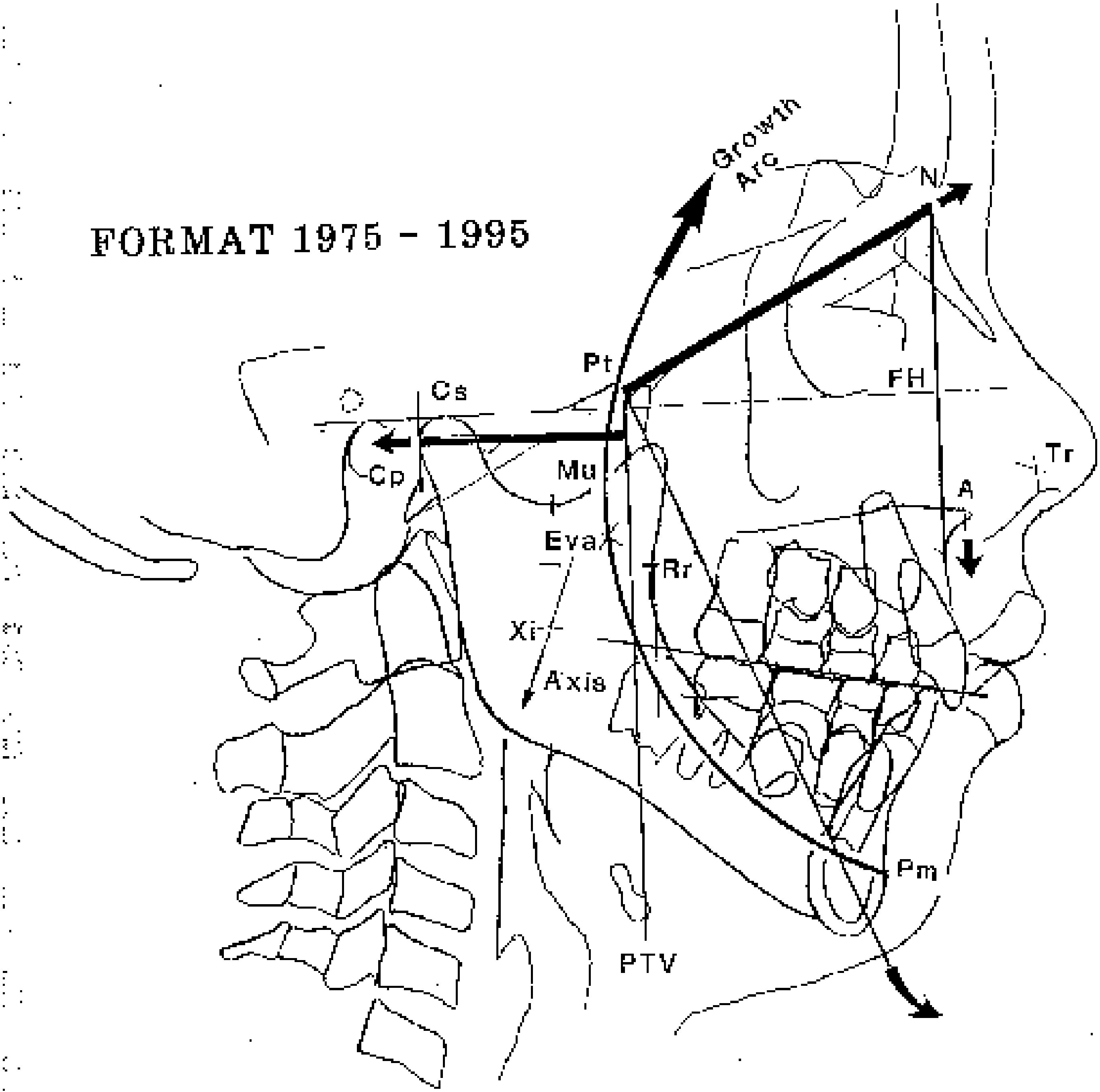


Fig. 2-4B Point Eva is located by bisecting the distance from R3 to Rr point. The crossing of the arc on the sigmoid notch was labelled point Murray (Mu).

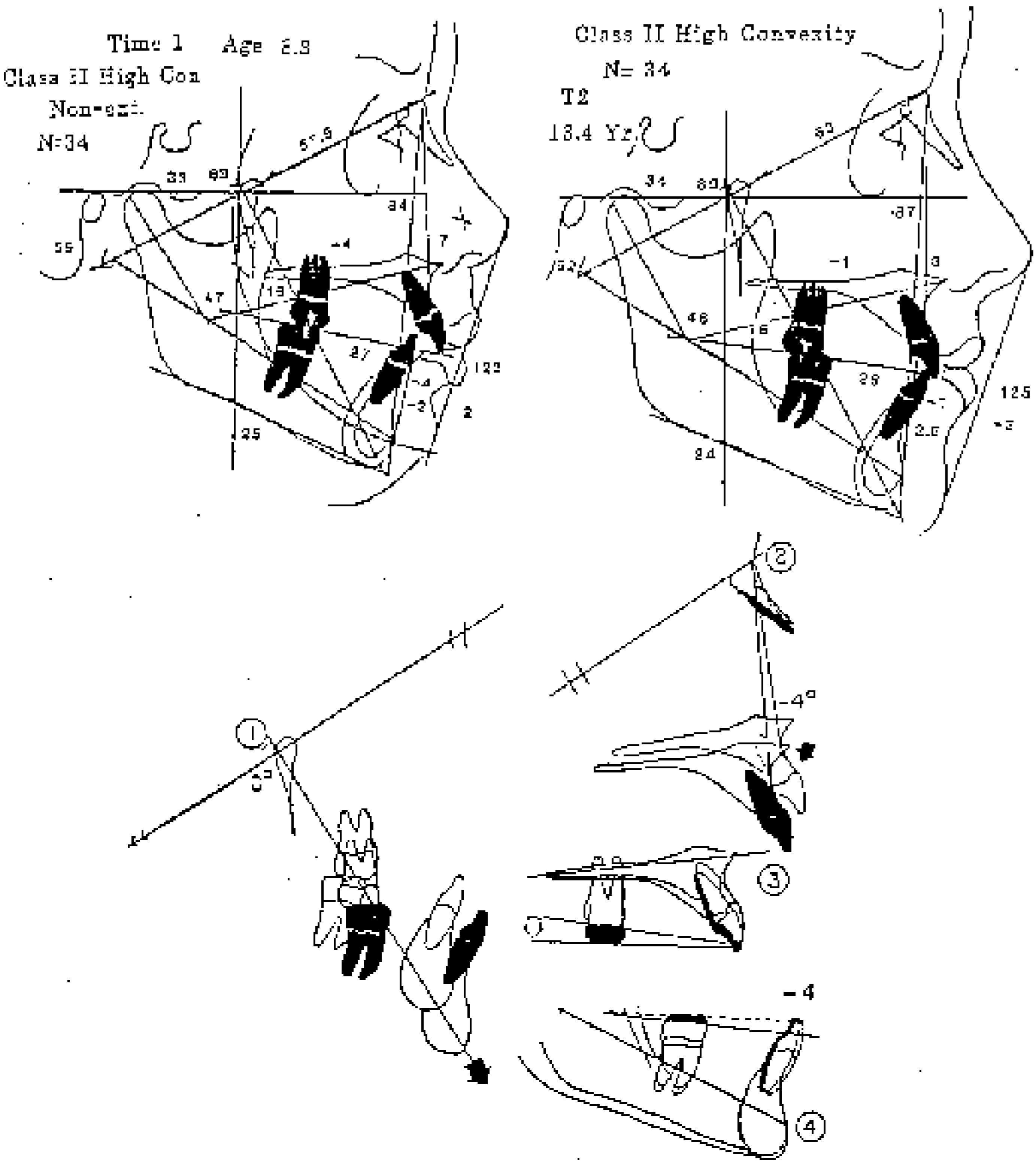


Fig. 2-5A Time 1, composite of 34 children with Class II and high convexity. T2 composite of children during retention five years later, all treated with cervical traction. Note in position ① that growth was down the Facial Axis. In ② note the maxillary orthopedics. In ③ note the influence on the maxillary teeth. Note the occlusal plane and upright lower incisors in ④.

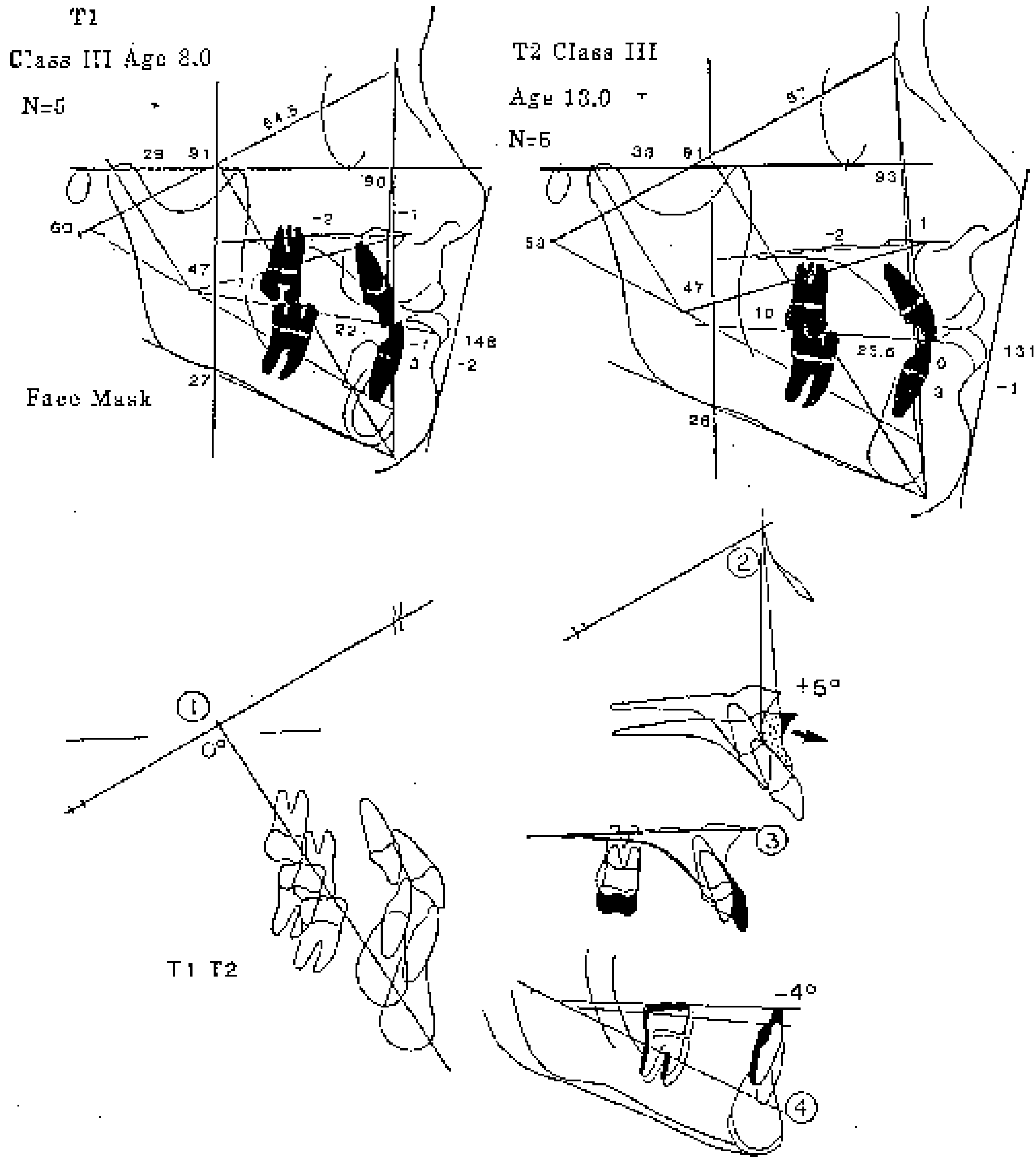


Fig. 2-5B T1, composite of small group of Class III children at similar age. T2 five years later. Compare the analysis which shows reverse behavior of the maxilla and maxillary teeth and again upright lower incisors

Emplacement of Occlusion

After the skeletal bases are established in the VTO construction, the emplacement of the teeth and soft tissue become the detailed objectives **for that individual**. The most appropriate "emplacement of occlusion" has been one of the greatest sources of controversy in orthodontics since the 1920s. **For instance**, where would the teeth be placed within the jaws if the clinician were to be given a complete choice for optional esthetics (Fig. 2-6A-1)?

On observing this situation, as if in planning the best for the patient, it is obvious that **reference points and lines are required** for anything other than a candid idea. The challenge involves the horizontal and the vertical parameters for denture emplacement.

The APo plane was employed by Downs in 1948 for horizontal reference to measure the position of the upper incisor. It was used by the author in 1949 to evaluate the lower incisor position and in 1950 for the VTO set-up. It was later called the "Reciprocal Denture Plane" by way of locating the teeth with respect to both jaws (see Fig. 2-6A-2).

If skeletal changes were planned via a horizontal position of the chin (Po) or an alteration of Point A was planned, then **a new APo plane would exist** (Fig. 2-6B). This was a difficult concept to teach to colleagues, although in the end it is very simple. The confusing problem was **growing the mandible**, locating the chin and growing the maxilla, and then moving Point A. This achievement is a key to the whole process of the VTO skeletally.

In Figure 2-6B four propositions are offered:

[1] If the maxilla is moved the APo Plane is changed.
[2] If the mandible is rotated open, the APo Plane changes as the chin moves backward.
[3] If the mandible grows forward, the chin moves forward to reduce convexity and change the APo Plane.
[4] A backward movement of A and forward position of the chin changes the APo reference planes dramatically and changes the inclination of the incisors.

Therefore, the lower incisor is placed according to the **forecasted skeletal framework**, and that placement is modified by tongue-lip equilibrium and personal choice factors of the individual.

In 1980 the height of the lower incisor at the incisal edge was found to be amazingly regular to the "golden cut" between Point A and Pm. The objective for the occlusal plane is, if possible, to keep it or place it below Xi Point. Hence, the plane from the "Golden Point" between A and Pm, for the tip of the lower incisor, became the "Divine Occlusal Plane". The True Buccal Occlusal Plane also had served a purpose for orientation before that discovery (see Fig. 2-6A-3). If the student will test individual untreated normal occlusion subjects, the results will be convincing.

For the VTO the occlusal plane and the APo plane are thus constructed. Until this stage of the construction of the VTO no teeth have been placed (as in Fig. 2-6A). Thus, a complete **free choice of dental positioning exists** for the clinician. **It now becomes the dental objective that is contemplated. Given a choice, for that patient**, the decision rests with the operator's goals esthetically, functionally, and socially. The clinician must decide on the individual objectives of incisor emplacement as modified on the basis of personality and on racial and ethnic type. The APo and the Divine occlusal point may be the framework for denture emplacement before individualization (see Fig. 2-6A-4).

In summary, to clarify once more: (See Fig. 2-6A)

(1) The chin is positioned - skeletal pattern - no teeth
(2) Point A is positioned - skeletal pattern - no teeth
(3) The APo plane is drawn - as an anterior limit reference
(4) The occlusal plane height is determined - from Xi (3)
(5) The crossing of the occlusal plane with the APo plane becomes an anterior starting point of reference for the teeth (4)

The Steps for the Teeth

The lower incisor, the first to undergo emplacement, is positioned as desired relative to the "new APo plane" (Fig. 2-7-1 [red]). This is step three in the cybernetic circle (see Fig. 1-3).

Once the lower incisor has been placed according to the individual clinician's desires (and the patient's attitude), then the lower first molar can be related accordingly (see Fig. 2-7-2 [black]). This is achieved by using the practical **arch depth dimensions**. The depth from incisor tip to mesial of the molar is influenced by tooth size, arch form, and by extractions if performed. Cephalometric arch depth is a mean of 23.5 mm. ± 1.4 mm. (18 mm. in premolar extraction conditions) (see Fig. 2-7). The lower molar on average is located 31° from Pm on the Corpus Axis Parallel. This measurement helps to determine dental protrusion.

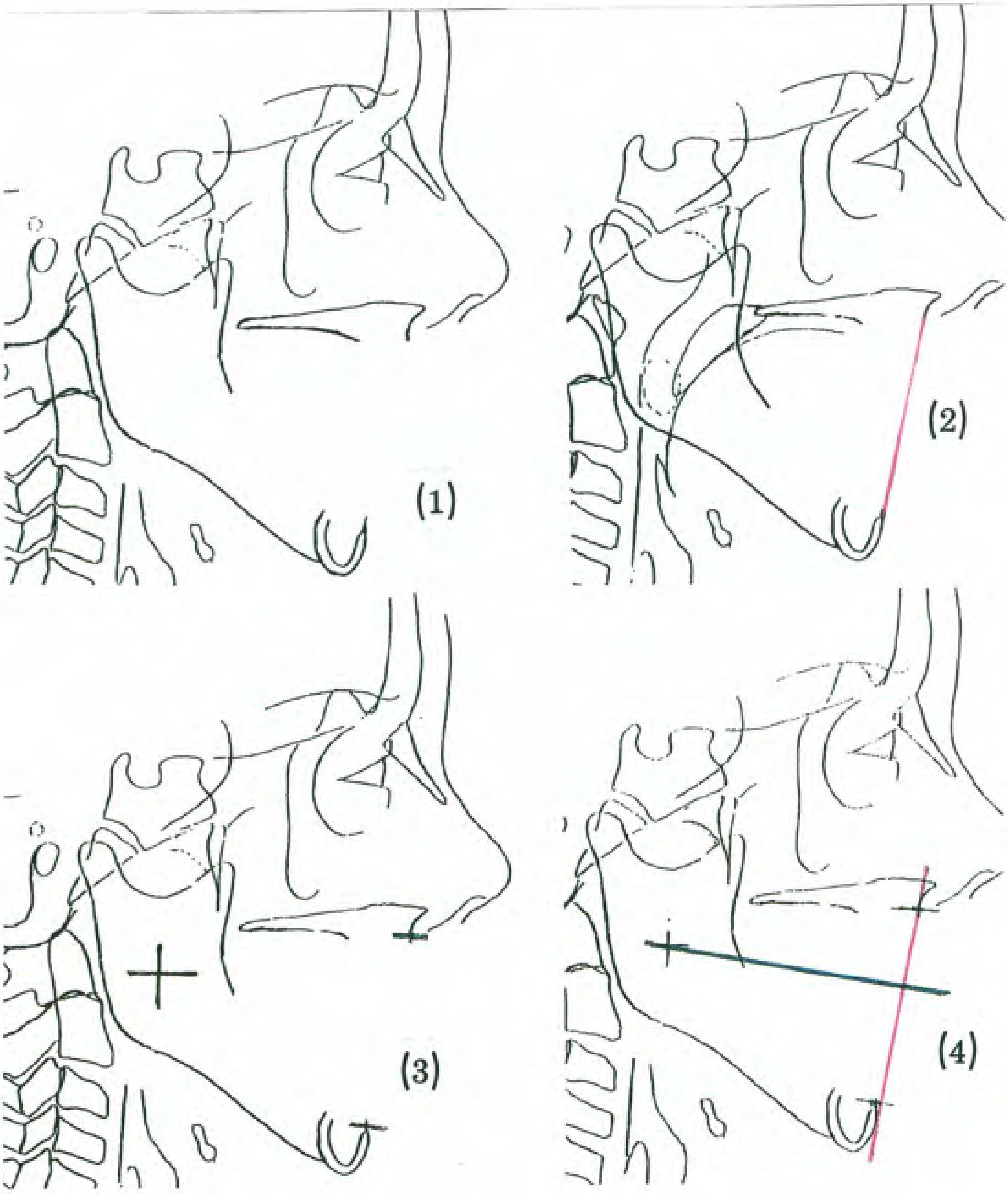


Fig. 2-6A
1. Skeletal pattern and no teeth.
2. The APo Plane as an anterior reference for the teeth.
3. Xi Point as a posterior reference for the Occlusal Plane.
4. The golden point between A and Pm as the anterior reference for the occlusal plane.

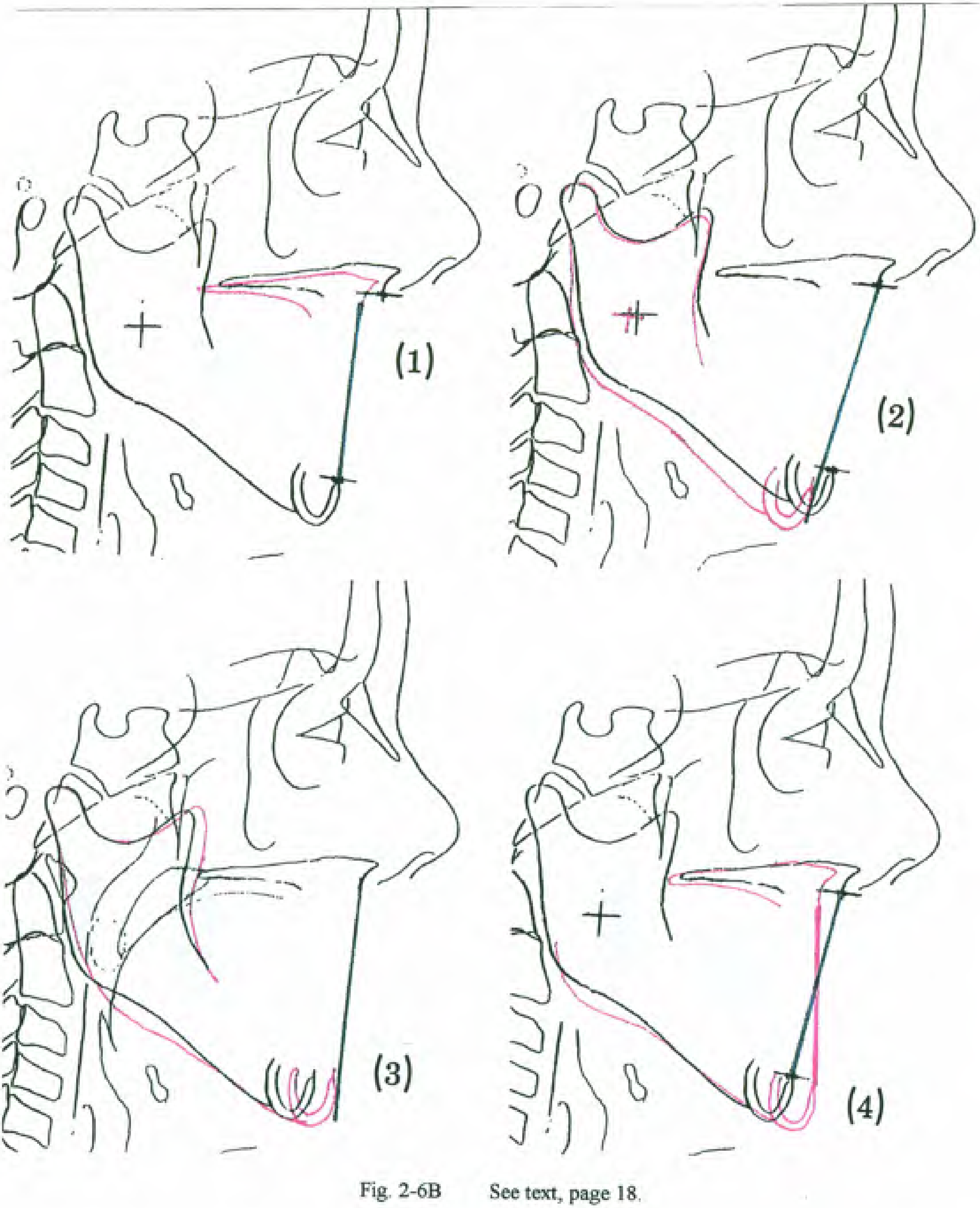


Fig. 2-6B See text, page 18.

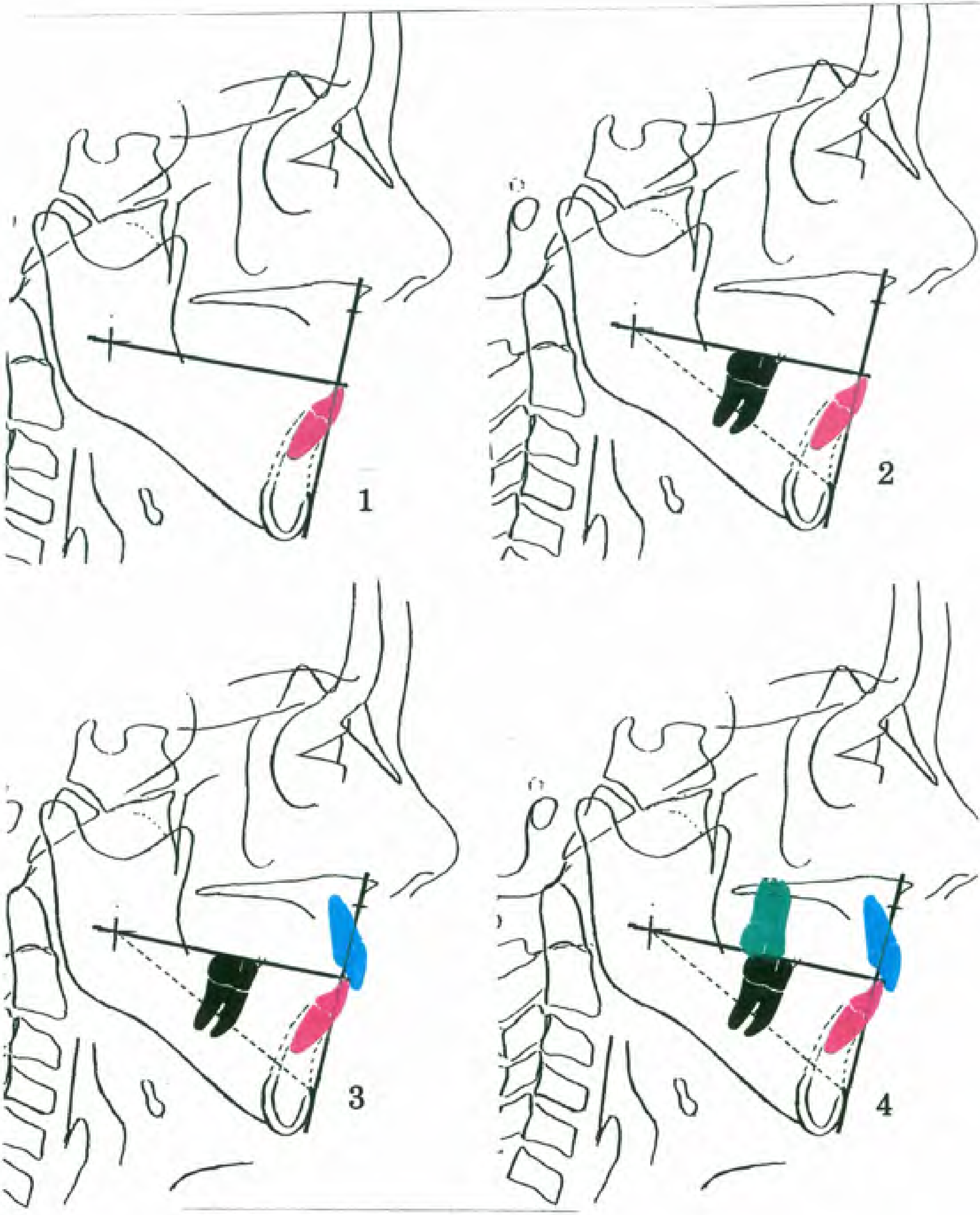


Fig. 2-7 See text, page 19.

The upper teeth are then positioned to fit the lower. The upper incisor is positioned according to type (see Fig. 2-7-3 [blue]). The upper molar is placed in Class I, or where desired (see Fig. 2-7-4 [green]).

Following the emplacement of the teeth, the soft tissue growth and the added treatment modification are constructed. A conclusion can be drawn collectively with regard to the esthetic and functional objectives. This is the total application of the Cybernetic Circle (see Fig. 1-3).

Normal samples vary in racial types (Fig. 2-8). The Caucasian generally is flatter in the profile, but a curve of lower incisor position repeatedly is 2 mm. to 3 mm. in standard deviation statistically. Normal occlusion in some individuals will have a recessed dentition and prominent nose and chin.

The issue in choosing denture emplacement (where to put the teeth) comes down to an individual **doctor decision**. When an orthodontist is chosen by a patient, the patient also must accept the kind of result the clinician will achieve, because the beliefs and the ideals form the basis for clinical decisions (Fig. 2-9). This is simply the nature of the profession! When employed, the VTO becomes a basis of communication through visualization. This practice is currently referred to as "imaging", but it has been practiced by some as a law instead of a principle.

A SUPER-SIMPLISTIC VIEW OF FORECASTING -- MEAN EXTENSION

If the clinician were to apply a simple triangle it might facilitate a better understanding of the workings of the forecasting process (N-Cc-Gn)(Fig. 2-10). It may also serve to stimulate interest in the more profound method. It might further help stimulate the advancement to greater sophistication and hopefully accuracy, when compared to practices in which no guides are provided whatsoever (Fig. 2-11A).

For the simple technique: (Fig. 2-11B)

(1) extend the Basion-Nasion line at Nasion 1.6 mm. (for two years);
(2) on the Facial Axis extend Gnathion 2.5 mm. per year
   (or 5 mm. for a two-year period);
(3) draw a new Facial Plane;
(4) copy the original N-A angle;
(5) extend N-A vertically 1.2 mm. per year (or 2.4 mm. in two years).
(6) This is a matrix over which objectives can be superimposed.

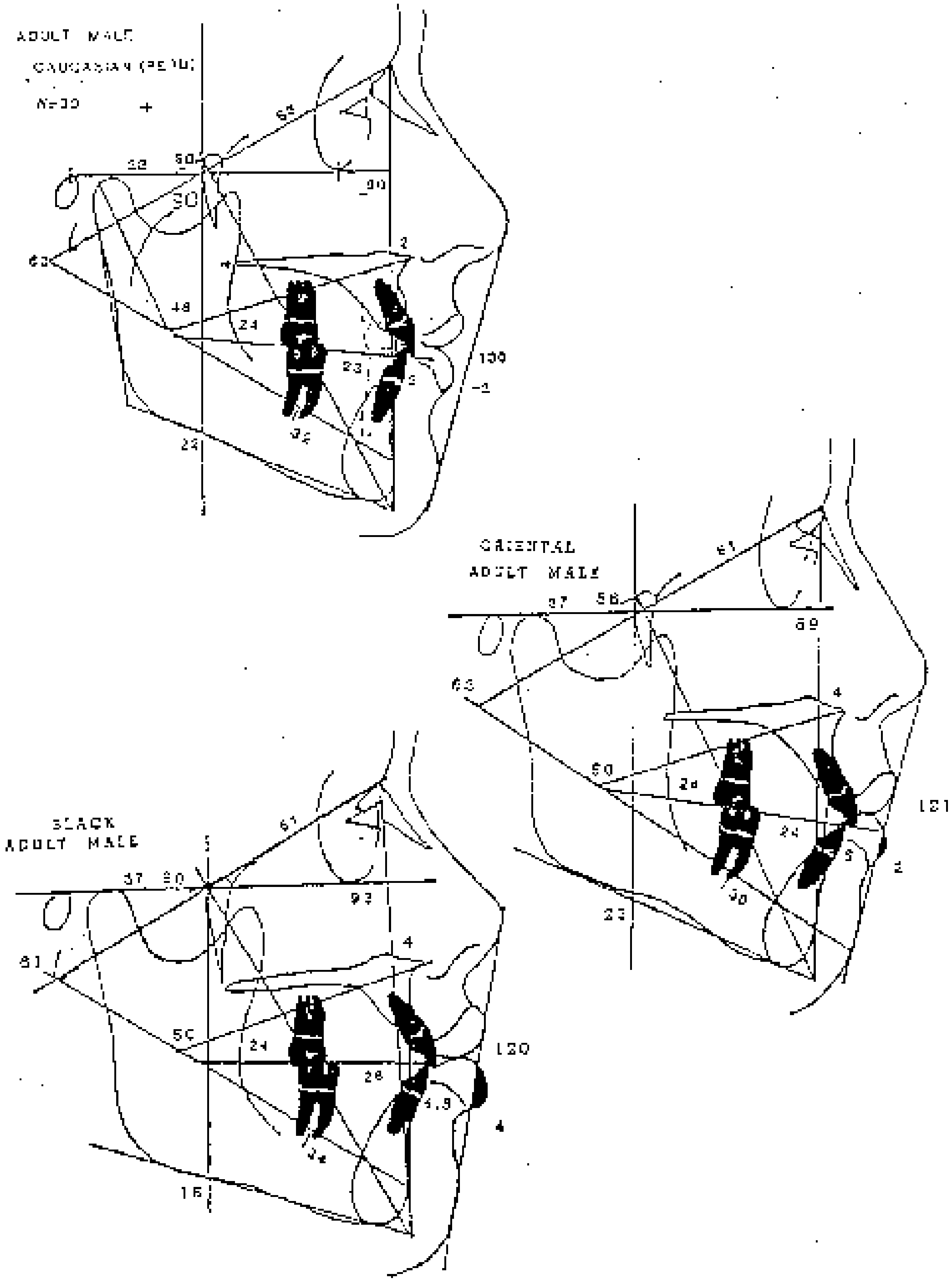


Fig. 2-8 Mean composites of adult males in facial types. Caucasian lower incisors at 2.0 mm ; Oriental at 5.0 mm.; Black at 4.5 mm. Note 86° Facial Axis in Oriental and full lips in Black.

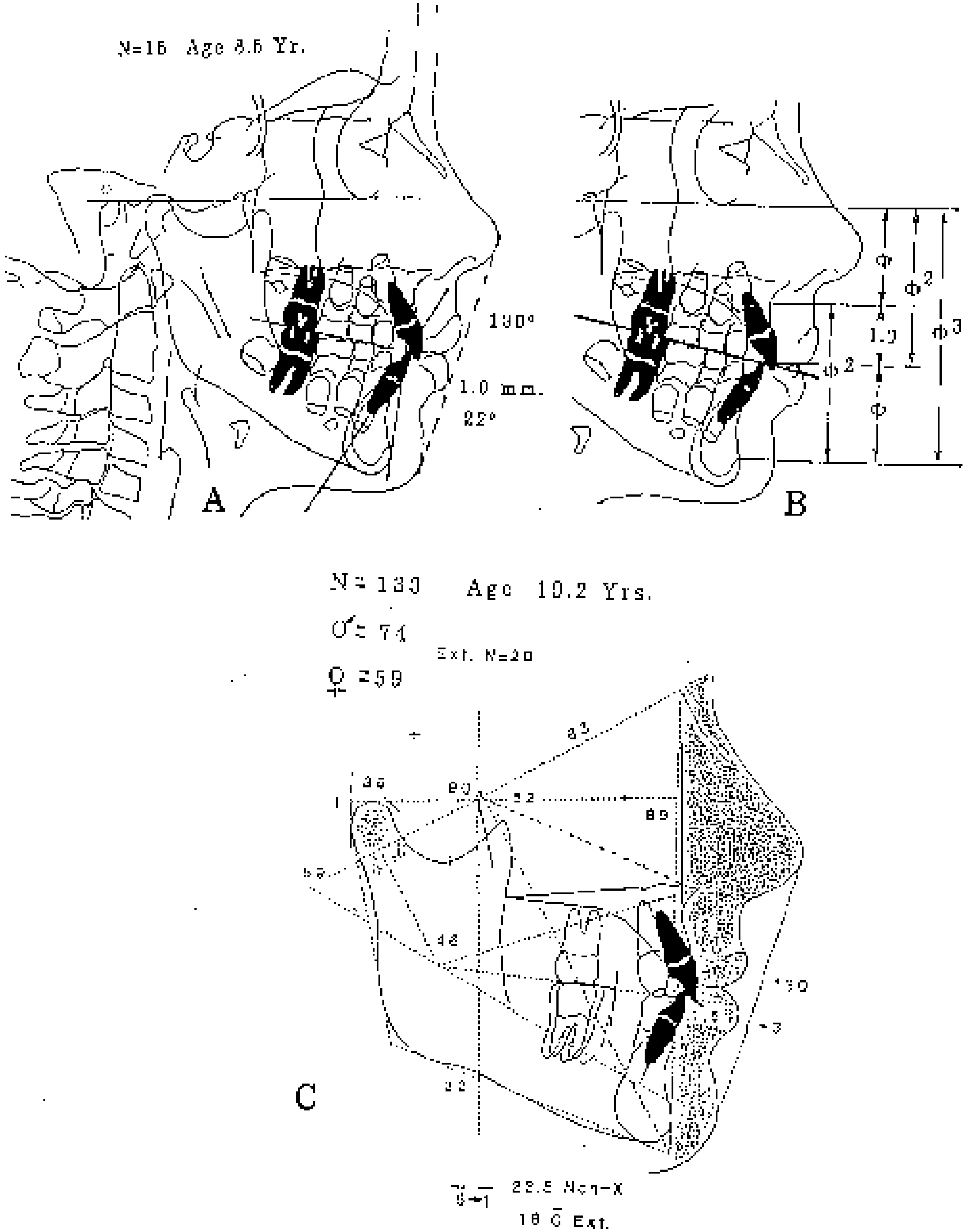


Fig. 2-9

A. Mean of sample of normal children age 8. Note +1.0 mm. at 22° to APo Plane (1950).

B. Divine Proportions in same sample (1980).

C. Mean composite of 133 subjects at age 19. Note lower incisor + 1.6 at 23° and 130° to upper incisor. Note pattern and verified measurements.

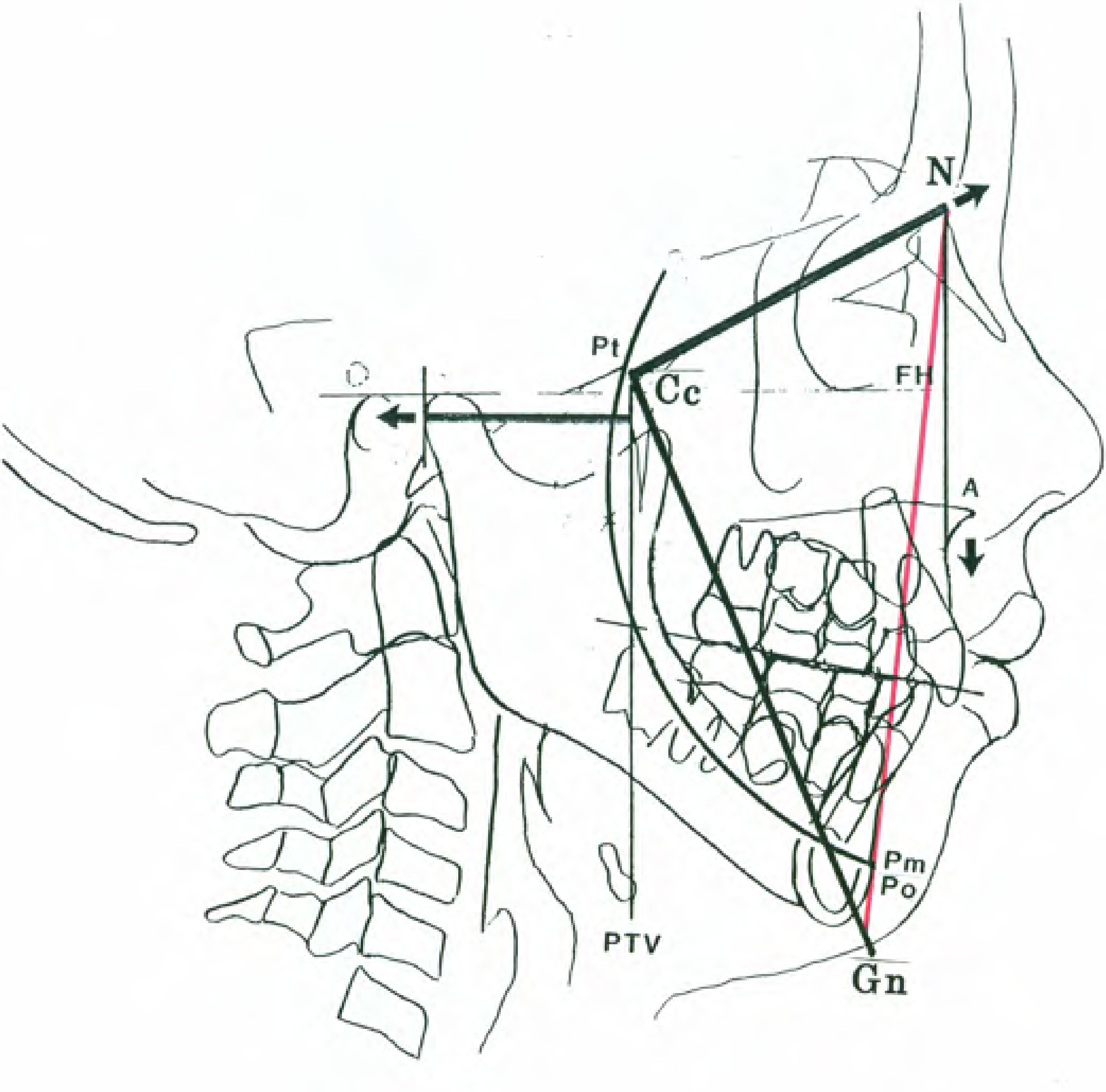


Fig. 2-10 For ultra simplicity a triangle, N-Cc-Gn, may be considered. This is the anterior cranial base Cc-N, the Facial Axis and the Facial Plane (in red). Values can be projected on the anterior base and the Facial Axis in order to produce a new Facial Plane. The anterior nasal spine and Point A are projected from the new Point Nasion.

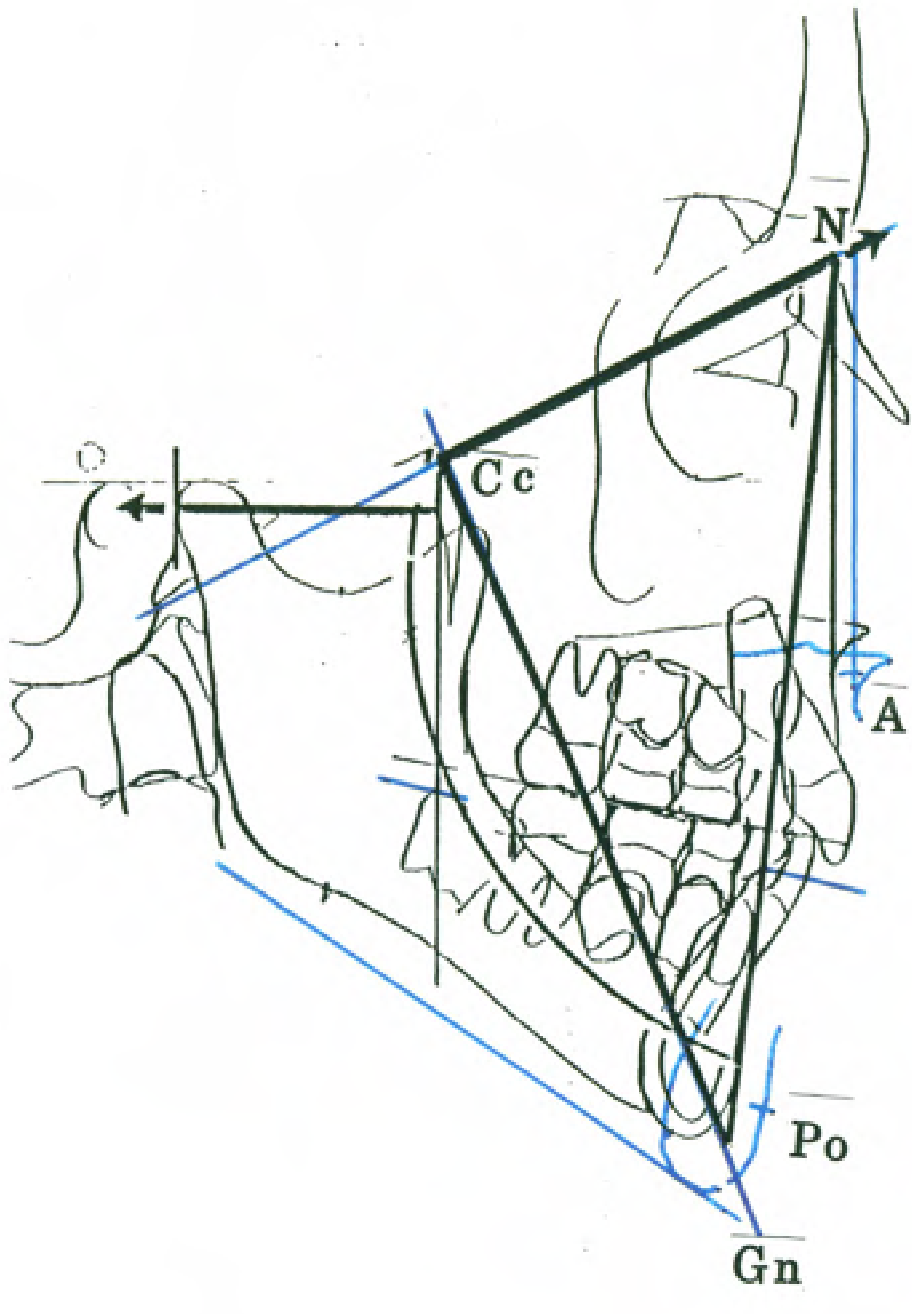


Fig. 2-11A   The points are extended as described in the text.

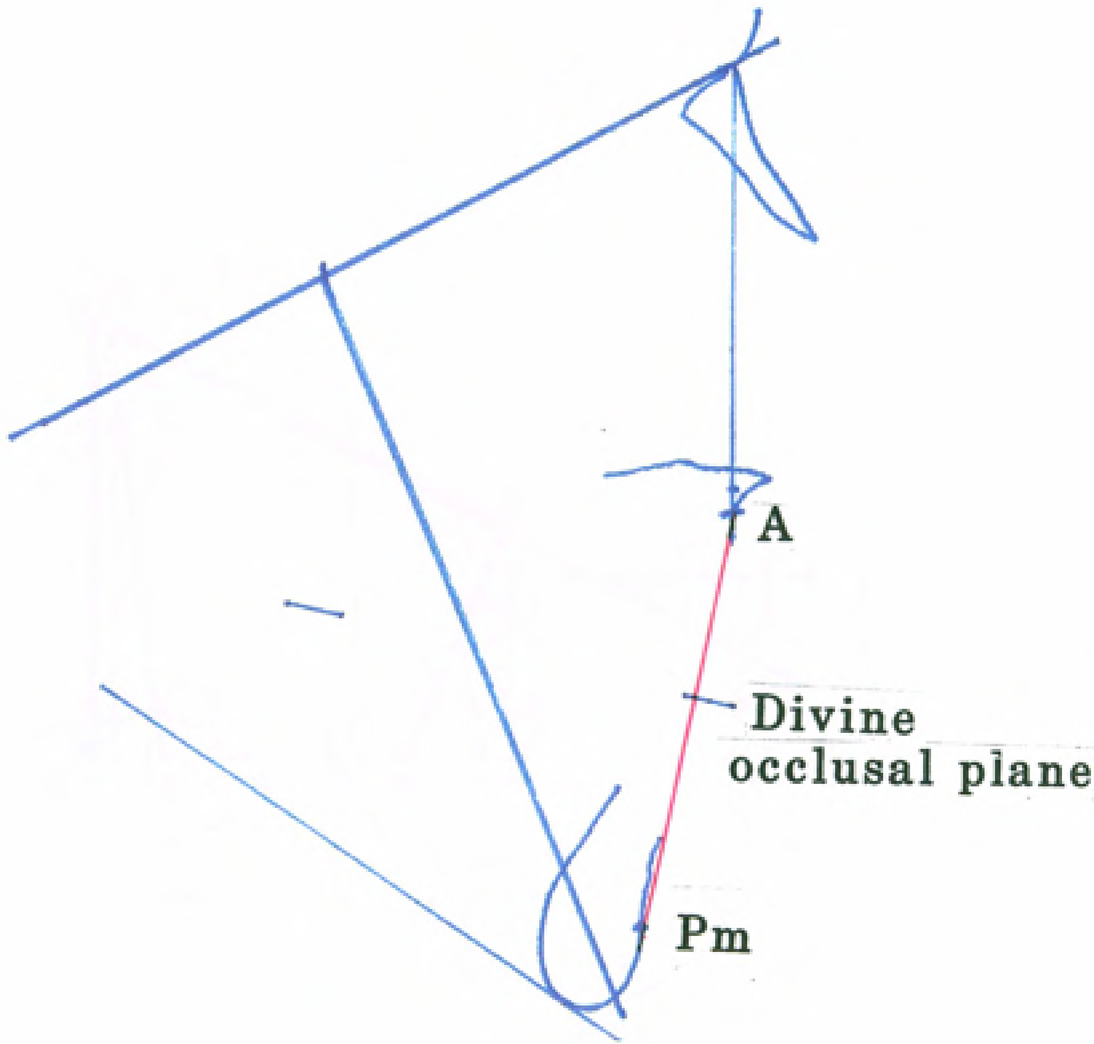


Fig. 2-11B A projection of a new matrix on which the teeth can be oriented for a planned objective. The new APo plane is in red; the occlusal plane level is for orientation of the lower incisor height.

This will give a very quick and easy-to-perform central tendency. A basic nontreated **working hypothesis** is provided for that skeletal profile in this manner. The result is nothing more than a mean extension forecast (which many have assumed forecasting to be in the first place). The mandibular plane and occlusal plane are carried over to the forecast.

With such a construction the skeletal profile may be a basis for the building of a treatment scheme. The Facial Axis can be opened or closed as anticipated to be influenced by the operator's experience with mechanics. Point A can be modified as a result of torque on the incisors and maxillary orthopedics.

(a) This is a very simplistic skeletal forecast which may appeal to the beginner.
(b) However, a much better sophistication is offered by the arcial mandibular and facial matrix technique to be described later.

DISCUSSION AND SUMMARY (FOR CHAPTERS ONE AND TWO)

When many of our leading clinical orthodontists use a visualization of an objective very successfully while educators deride it, there is something wrong with our educational process. Imaging of the outcome has become a very significant aspect of current clinical marketing in orthodontics (and surgery) to the public. The profession is hereby alerted to the state of the art in this regard.

The idea to design the intended outcome for an orthodontic patient started with Dr. William B. Downs, who tried to envision the outcome beforehand. The development of techniques to produce a visualization on paper to the best accuracy possible have been carried forward by the author since 1950. Efforts to elucidate results have gone from plaster casts to tracing paper, to computer printouts and on to TV imaging. Steady improvement in accuracy with both manual production and the computer has been made for the last five decades. This advancement should be met with respect and appreciation by the specialty rather than the continual destructive attacks which have been witnessed.

The essence of the idea is to be able to pre-evaluate and discriminate between the objectives for an individual patient. Through the VTO, growth can be applied meaningfully and orthopedic alterations can be planned as determined from scientifically proven possibilities. What do clinicians use if this is not employed -- trial and error?

The original suggestion of Downs was to reverse the Ricketts analytic procedures. A line through the long axis of the condylar process was employed to "bridge the space" between the cranial base (BaN) and the mandibular plane. This led finally to an "arc application".

For evaluation of growth of the mandible, the Basion-Nasion Plane was found to be the most cogent complete base. Growth values were added according to estimates from findings of sexual and constitutional types. The "condyle plane" was rotated as determined from behavior found in treated samples. The "prediction" was dependent upon the techniques to be employed which many objectors did not understand.

From that original schema of 1950 new points and planes emerged and were computer tested. They gave rise to a second schemata proposed in 1967. The use of Pterygoid Point, Xi Point, and Pm Point were keys to that progress and simplification.

As findings were made regarding maxillary orthopedics in 1953 and intrusion of teeth (anterior or posterior) was proven by 1960 to help control mandibular rotation, the "Cephalometric setups" were changed according to treatment possibilities and aims to be consummated.

For general professional application for the computer, a **two-degree rotational cutoff for opening of the Facial Axis was programmed. This in retrospect was a mistake. There was a lack of communication to all but a few students, teachers and clinicians. The mistake was an assumption that orthodontists in practice would monitor** progress with cephalometrics, which they did not.

The advice given to programmers was that greater than 2° rotation, when discovered by monitoring, should be recognized and the **treatment mechanics changed!** This was not grasped by clinicians, who inspected the process and the computer service only superficially. The computer programming should be clarified for a better understanding by the profession.

As ethnic types and racial variations became known, objectives were altered for setting the emplacement of the teeth for the individual patient. **Esthetics dominate the objectives**, but function and long-term stability and health also are considerations of great value.

From the beginning a range of variation in relative dental protrusion was suggested. The peak of the curve of a sample of normal mixed dentition children was accepted originally as a base. The lower incisor was found to be +1.0 ±2 mm. at 22° to the APo plane in that study of 1950. Forty years later the mean in a sample of 133 subjects followed from age 6 to maturity, of which 60 were treated, was 1.6 mm. at 23° to the APo plane (see Fig. 2-9). Currently clinicians seemed to desire the incisor to be plus 2 or 3 mm. as a central starting idea.

The real key for reference is to determine the APo relationship that **will exist at treatment's end, or by maturity**. Thus the behavior of the chin (Po) (or Pm) and its location and the alteration of the maxilla (Point A) are, in fact, the indispensable factors in determining the reference line to which the teeth in turn are set up as an objective.

However, the most significant aspects of growth and developmental forecasting are the anticipated effects of **long-term** growth and development to maturity. What will the adult face accept with grace?

With the maturity objective recognized, the arc of mandibular growth and long-range objectives led to research for the construction and application of the VTG (visualized goals). In addition, work in the frontal perspective and interests in the transverse dimension have led to developments in the frontal for analysis and forecasting.

* * * * *

These two chapters were concerned with the **philosophy of forecasting** and its progress roughly until 1972. The next chapters will deal with the discovery and application of the arcial growth of the mandible and forecasting to maturity as a paradigm for the year 2000 and beyond.

PREDICTION, PLANNING, CONSTRUCTION and MECHANICS

CHAPTER THREE

THE MANDIBULAR GROWTH ARC FOR FORECASTING TO MATURITY: INDIVIDUALITY AND THE CRANIAL BASES

INTRODUCTION

The Curve of Distribution

To the end that individual characteristics can be identified, and weighed, they are entered into a forecast as "conditional statements". When exceptions in form and size occur, like extreme variations at the tails of a curve of distribution, they are recognized. Thus a forecasting process becomes diagnostic within itself. But because any forecast is not 100%, as indeed is true of anything in clinical work, it does not make sense that the procedure be rejected for the sake of a 1.25% error at each end at the tails of distribution on the bell curve.

Current Interest in the Long Term

"When is an orthodontic treatment actually finished?" In 1890 (as reviewed in the literature) six-month retention was employed. By the 1940s a two-year retention program was usually considered to be the end of the orthodontist's responsibility. But among the problems ultimately recognized has been the care for, or the disposal of, the third molars. In addition, the maturity of the lip muscles, the final "settling" process of the occlusion, and the completion of growth together with the continuing problems in oral physiology, have all been factors which make the orthodontist mindful of the long-range implications. Retention problems are experienced even after orthognathic surgery.

The attitude of the whole profession changed in 1981 with findings by Little, et al. of long-term extraction relapse at the University of Washington. Longer time periods have become critical for the future and for the continued betterment of the specialty. Why should an orthodontist be so egotistical as to expect the perfection achieved with the "ideal" arch to be permanent? The very name "ideal" leaves a false assumption because what could be better than "ideal"? What is better, of course, is **overtreatment**. The "straight wire" is not the end. Thus, a longer term interest concerns the growth and development of children from the juvenile ages through the adolescent periods and thence on to full maturity and thereafter. It involves skeletal, muscular and psychologic maturity.

Phases Limited

Another development in the profession is that the 1980s and 1990s witnessed a new awakening, in surprising numbers, to the possibilities of early treatment **without the need for a second phase of treatment at all**. The factors to be taken into account when treating the patient at a young age (as early as three or four years) have prompted the consideration of child-to-maturity growth, its forecasting and a concern for results into middle age or beyond. The consummate orthodontist maintains interest and techniques for the child to the senile patient.

Computers

Since 1970, computers have been employed to provide forecasting information as well as aiding in treatment designing, together with administrative management functions. With more data and five decades of trial and error experience, the technology for diagnostic and prognostic aid has become progressively better and better.

The computer programs designed by the author have not been well understood and have been judged unfairly. One reason for the occasional emergence of errors in tests of computer programs was that the clinician using computer assistance was advised to **change the technique** when an opening rotation of more than 2° on the Facial Axis occurred. Retrospective comparisons were unfair because the clinician did not have a VTO to follow, and therefore no prior objectives to which to arrange the mechanics. To put it simply, a particular technique was adhered to with no monitoring conducted.

Iatrogenics

Clinicians assumed that the VTO was a failure when in fact the treatment either failed or the mechanics employed exerted iatrogenic consequences. There is good evidence that both (1) over-rotation and (2) high-pull headgear off the molars taking the molars out of occlusion can inhibit growth and lead to inaccurate forecasts. Iatrogenic condyle and mandibular influences were not fully realized, although suspected in 1960, and statistically significantly shown by Baumrind in 1981.

CEPHALOMETRICS: THE KEY TOOL FOR SOPHISTICATION

While cephalometrics itself will never be absolute, the orthodontist can look toward it as **the only method** to provide a high enough level of **clinical** information to be valid. While it is considered primarily descriptive, its greatest value may lie in the longitudinal information it provides (Figs. 3-1 and 3-2). (Refer to *Progressive Cephalometrics: Paradigm 2000* for diagnosis and prognosis.)

Without cephalometric input, what does the clinician use? A practice is conducted with simple intuition and flat-out hunches, or mental envisaging of results. Trial and error may be the method under the guise of "therapeutic diagnosis". Without "forecasts" cephalometrically the clinician may make sweeping judgments from photographs, or be dominated by original models for planning statically (without growth or physiologic change). It therefore is incomprehensible that clinicians, researchers and university professors can be so adamant against forecasting when they have absolutely nothing concrete to offer to be used instead. A drop in clinical sophistication has resulted, and mediocrity is more common.

As said previously, forecasting methods with **the computer** were criticized due to their lack of absolute certainty. But, when the alternatives are considered, and the many failures are experienced in long range (as evidenced by retreatments with surgery) the profession can be questioned about its **hesitancy to move forward with** this tool. Failures include not only relapses but also unacceptable results with straight teeth such as flat mouths or sometimes lips that are too strained and protrusive for patient acceptance. It is obvious that a plethora of extraction was practiced to avoid protrusiveness of the teeth because long-term growth was not appreciated. The profession has therefore become awakened to the fact that often the treatment decisions have been inadequate in the absence of an up-to-date long-range forecast with goals established to maturity.

More Than Mean Values Employed

Those challenging the methods assumed that only the application of averages was employed to simply enlarge the face, as suggested in the simplistic scheme in Chapter One. This is not true. In answer to those critics, the clinician or educator should be reminded of several factors that are actually taken into account in the described forecasting procedures:

(1) The pattern of the individual and the makeup of that individual matrix is not average -- that individual's morphology is used as a starting base for that patient.

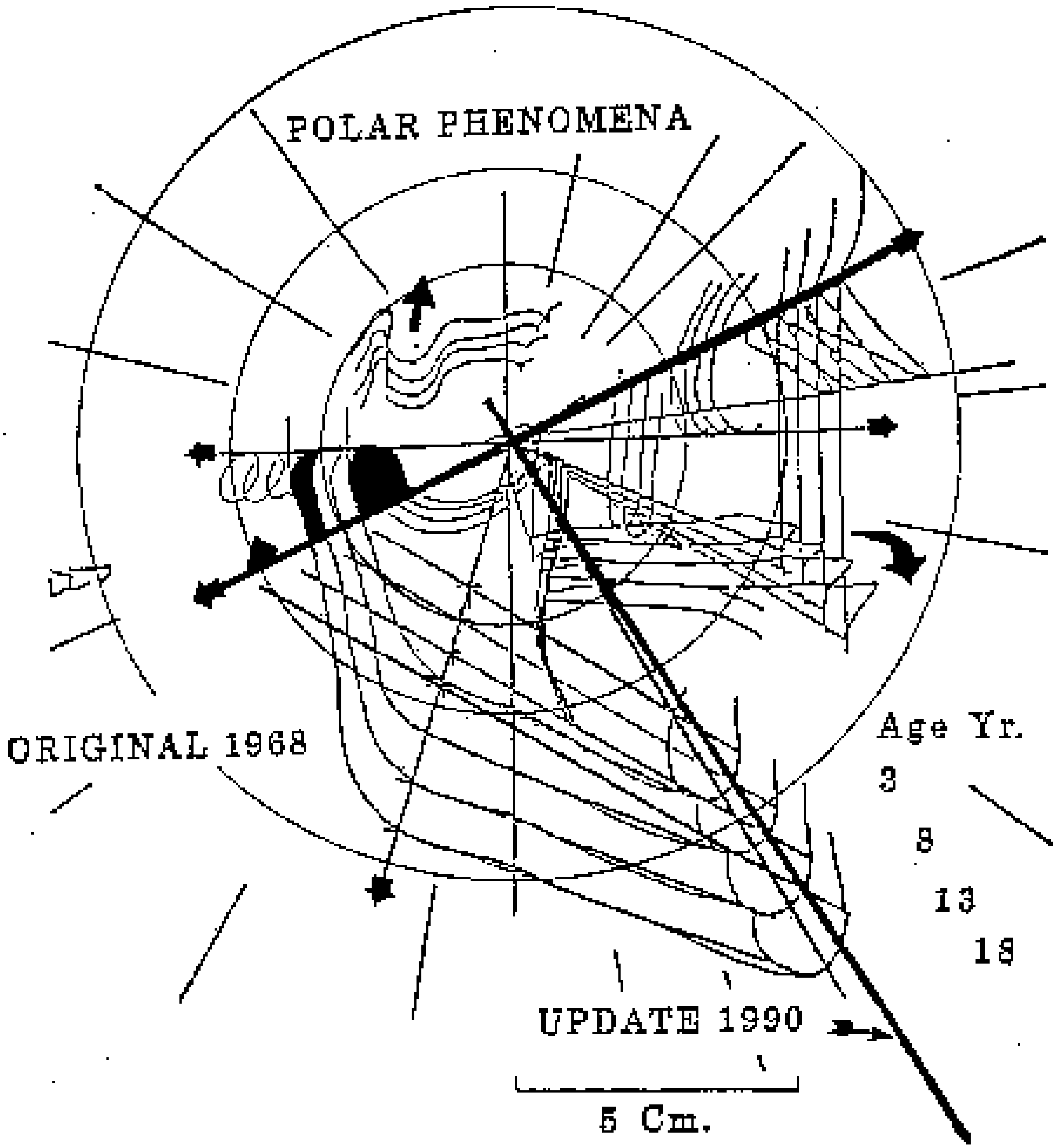
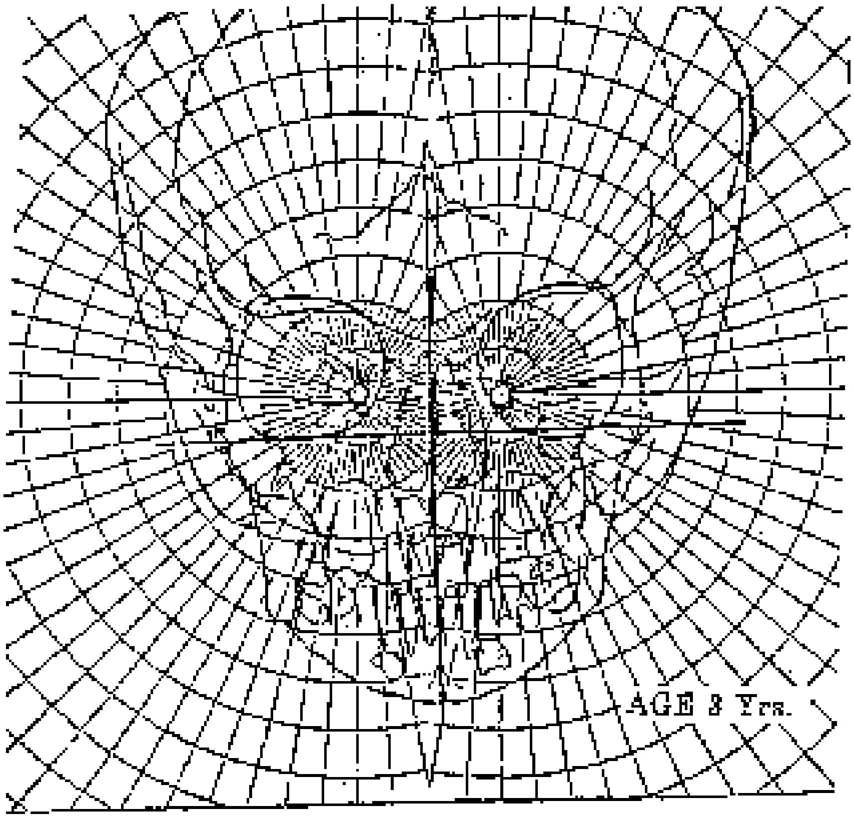


Fig. 3-1 Polar Phenomenon with update in 1990 showing chin moves forward slightly in long term. Note structure closed to center grows less and more distant structure greater in amount in order to maintain the proportions.



Frontal Growth – The Bi-Polar Phenomenon

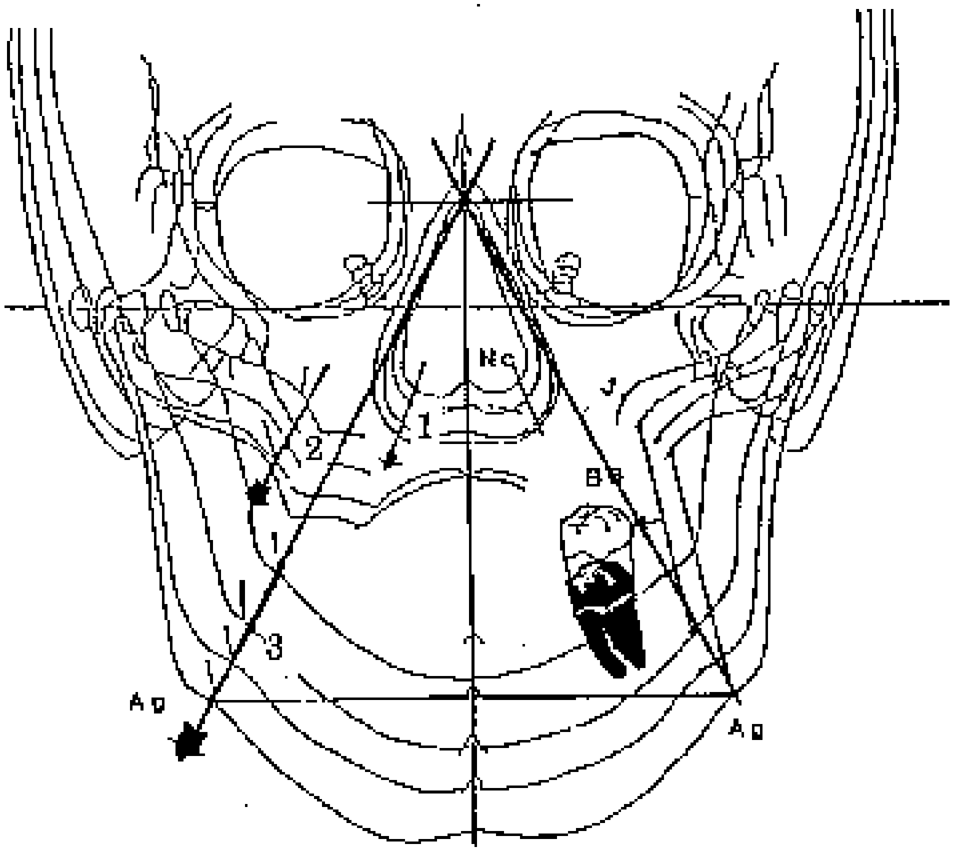


Fig. 3-2 Bi-Polar phenomenon was discovered in the frontal and was reduced to one gnomonic expression for mandibular width estimates as shown.

(2) The cutoff age for forecasting growth has been well established at 14.8 years for females and 19 years for males. While that is the peak of the curve, the variation around that age, when starting early, averages out to be more consistent than would be expected and better than most clinicians or researchers would believe. Females do not develop secondary apposition at certain sites as do males. Therefore, averages are not used alone.

(3) Conditional statements or corrective factors are calculated on the basis of specific features in the skeletal morphologic pattern.

(4) Studies are still being conducted regarding the subtle effects of treatment on the skeletal matrix. This extends even to the details of the cranial base, particularly that in the behavior of the temporal bone which supports the glenoid fossa and houses the condyle.

(5) The testing of computer forecast renderings on treated cases is grossly unfair unless the actual treatment objectives for the specific modality are **known in advance**. The VTO is an objective, and the technique employed **may not have been** directed toward a specific result. Why is this so difficult to understand? In addition, the operator may attempt to move **toward the objectives** feasibly with the realization that its full perfection could not be practically achieved!

(6) Knowledge of behavior in the different races, and ethnic types within those races, is applied. Hence, retrospective studies are useless and misleading, unless the forecast was followed in the treatment plan.

Thus, it is totally unjustifiable, unfair, and demonstrates a lack of knowledge to condemn the techniques as just using the extension of averages.

The purpose of this chapter is to explain the rationale for both short- and long-range forecasting of the cranial base, the facial skeletal structures, the teeth and profile. The aim is further to show that the contemporary forecasting procedure can contribute to the decisions made regarding various treatment regimes for a given patient.

THE GENESIS OF THE ARC

Polar Growth in the Sagittal Plane

In 1964, the first work by the author with the computer was started. The findings indicated that the Frankfort Plane had much more profound value for description of structures in the oral cavity than did the Sella-Nasion plane (which was essentially nil).

Computer research protocols for a second study, started in 1966, led to the production of trustworthy composites. Accuracy was insured by a triangulation process with the use of 362 measurements (Fig. 3-3). The material was a balanced sex sample of forty (40) children, half of which were followed from 5 to 13, all of which were followed from 8 to 13 years of age and one-half of which were Class II. This supplied morphologic and growth information through the mixed dentition period.

With the restrictions of the material available to the author for study in those years, older male samples at age 18 were collected and younger samples were used for children age 3 to fill out the growth experience. All this information was used to produce a consensus from weighting of studies found in the literature up until 1968, when the comprehensive computer analysis was formulated.

Gnomonic Expression

With the use of Pm (protuberance menti) and Xi Point (see Chapter One), the Corpus Axis was extended upward and backward to intersect the Basion-Nasion line, forming point Vertigon (Fig. 3-4). This suggested a gnomonic figure or at least an allometric behavior for the growth of the total face height (Fig. 3-5).

Even more consistent was the orderly behavior of an angle formed by points Ans-Xi-Pm which was so allometric in character that it was called, in fact, an oral gnomon, and represented lower face height. The angle was surprisingly orderly in the absence of an insult to the condyle or by a dramatic treatment disturbance. In "balanced" faces the oral height angle was 76% of the total height angle. The line from Ans to Xi was called the ORG line as an abbreviation for oral gnomon. Greater confidence was gained for the application of the Xi Point with such findings. A general growth behavior was close to the "Xi axis" downward and backward from Cc not absolute, but seemingly biologically related (Fig. 3-6).

Bi-Polar Behavior in the Frontal

Examination of the lateral composites with a polar grid revealed the center to

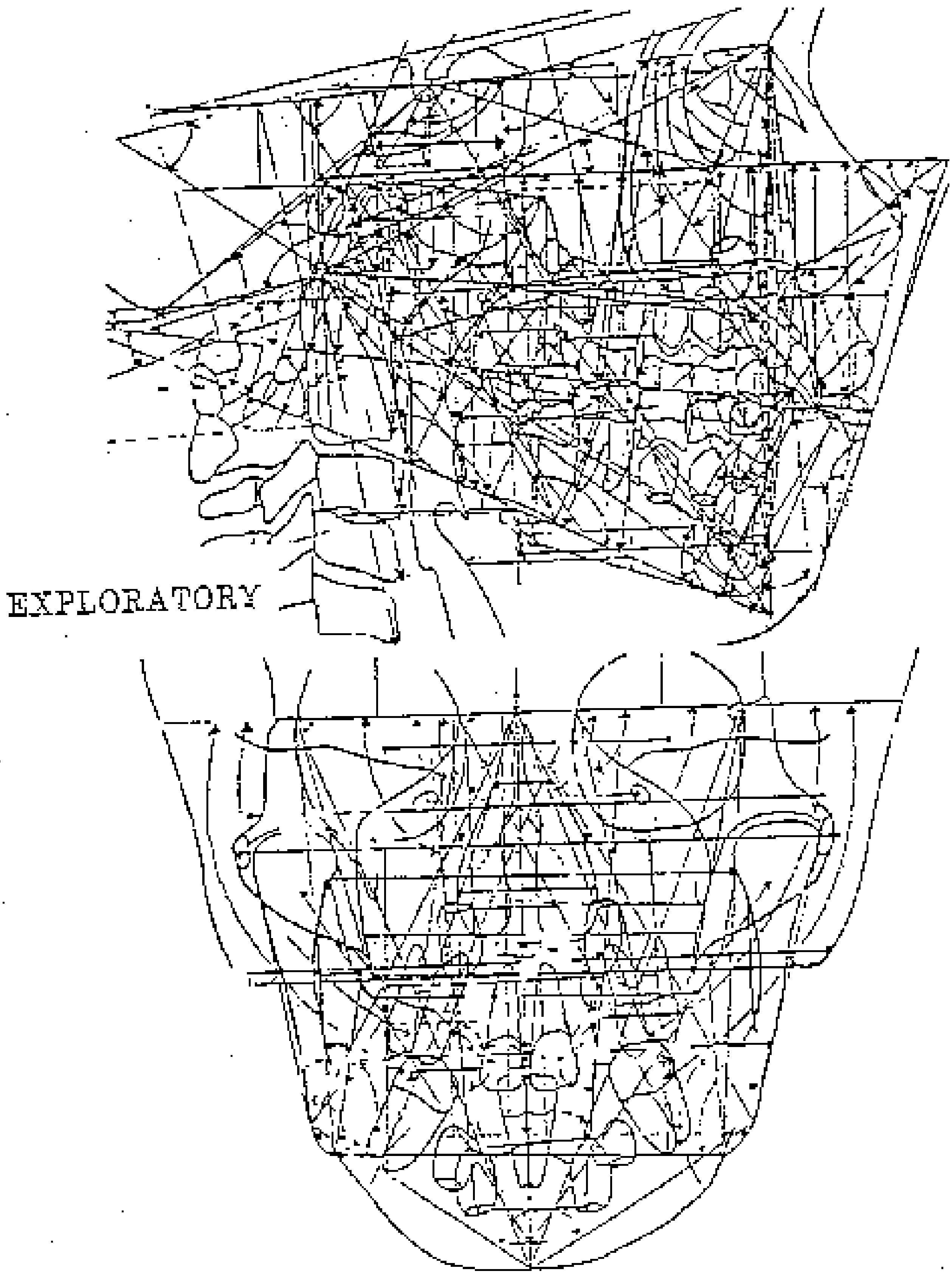


Fig. 3-3 Exploratory for the computer study (1966) with 362 measurements.

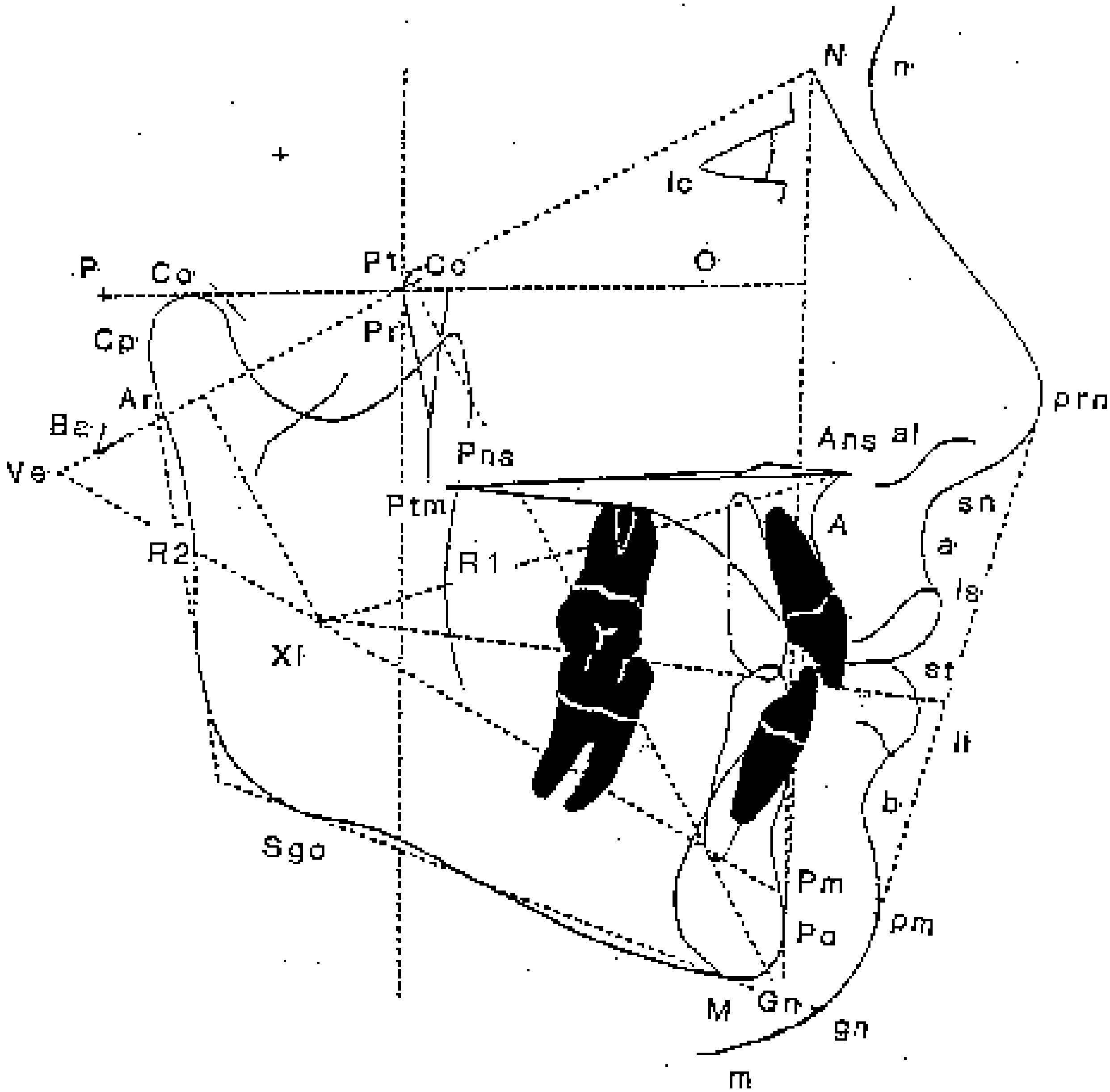


Fig. 3-4 Skeletal measurements are denoted by capital letters, soft tissue by small letters.

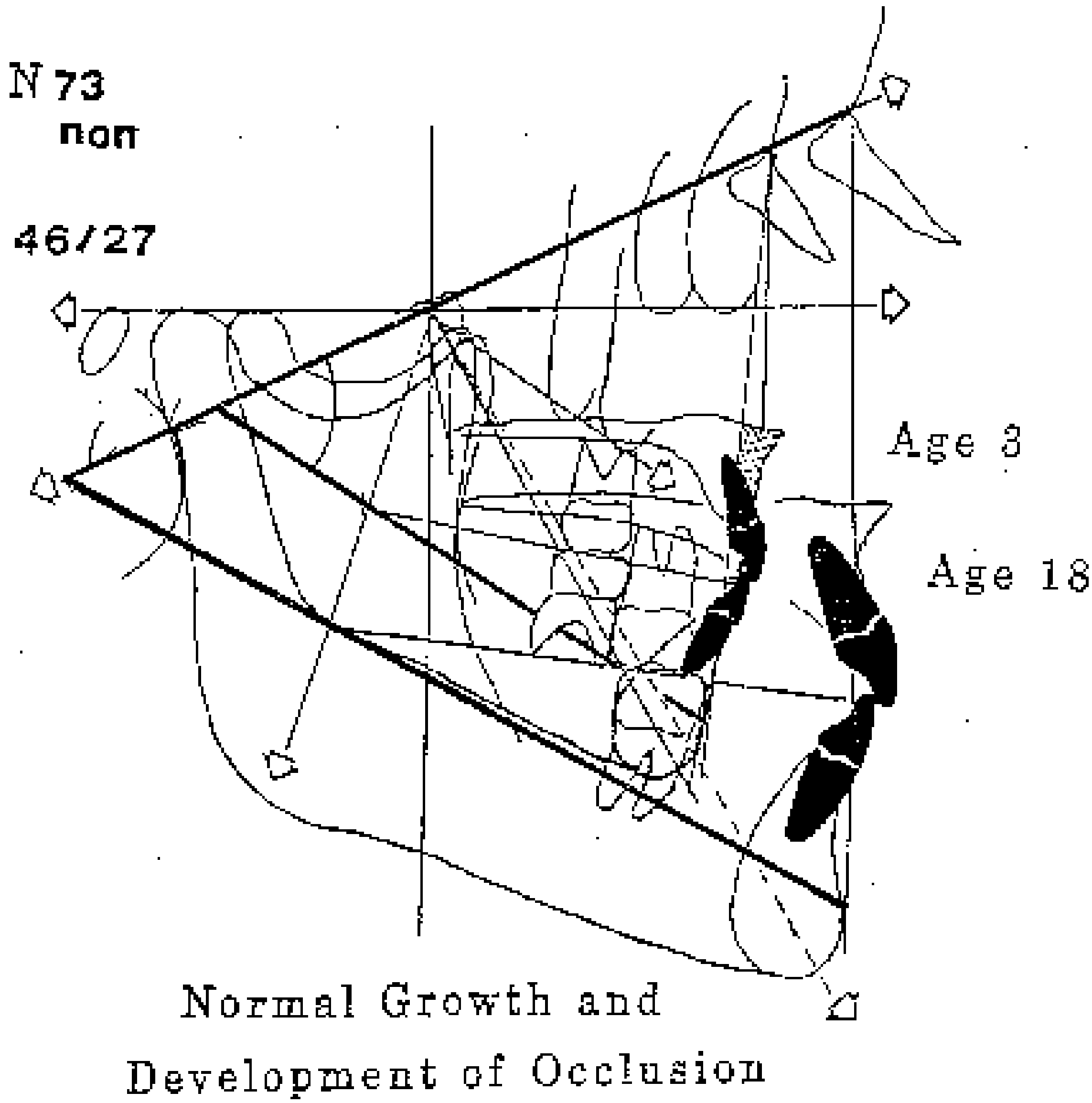


Fig. 3-5 Note near consistency of the Corpus Axis with the BaN Plane from age 3 to 18.

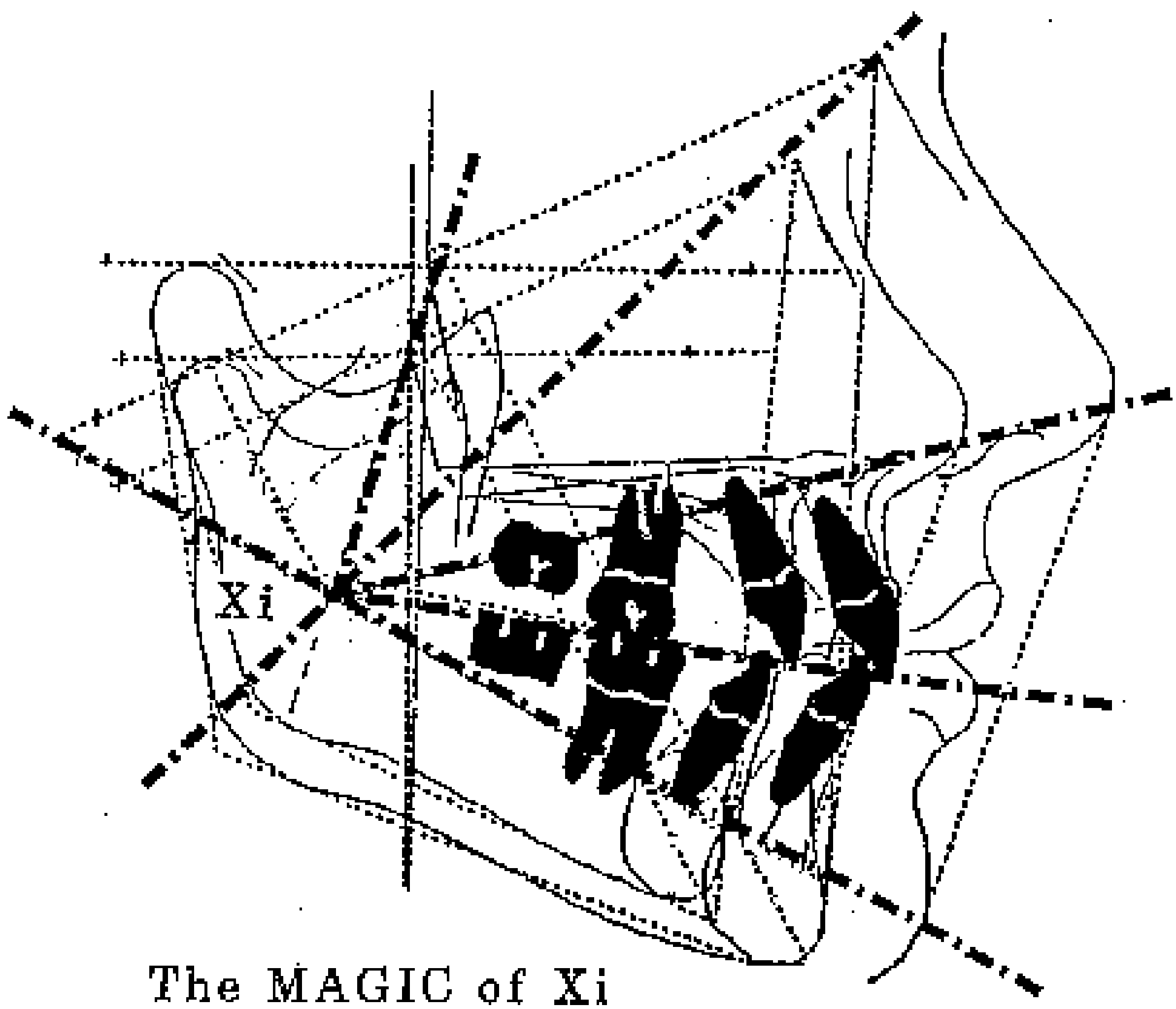


Fig 3-6 The Xi Point serves several purposes; the oral gnomon, the Xi Axis, Xi Position, Facial Height and Occlusal Plane are a few.

be near the base of the sphenoid bone (see Fig. 3-1). This was further determined to be (a) at the junction of the pterygoid plates with the great wings of the sphenoid, and (b) the rostrum of the sphenoid as a platform for the vomer, and (c) was located almost precisely at foramen rotundum.

The vertex of cavity angles suggested that a growth relationship was connected somehow with fifth nerve supply and the branches of external corotid blood supply. It led to a concept of neurotrophism. Because the point Sella did not follow the polar behavior the whole Sella Tursica area was eliminated as the reliable reference it had previously been thought to represent.

The Xi Point was located at the centroid of the ramus, and measured routinely. It was found to be located at the base of the mandibular foramen (or third branch of the fifth nerve). Although some looked upon the original proposal of Xi Point as ludicrous, comical, and a joke, it was found to be useful for 15 functions (see Chart III, Chapter One).

In the frontal view no single point could be found as a center for growth expression. A bi-polar phenomenon was discovered and was, ironically, again at each of the foramen rotunda (see Fig. 3-2). This led to an interesting conjecture regarding the development of asymmetry, as each side of the face seemed to behave on its own neurotropic impulse.* Subdivisions Class II and Class III are common and often mysterious in their etiology.

Furthermore, growth in the frontal dimension indicated a proportionality of 1-2-3-5, suggesting a relationship with Fibonacci numbers and the Golden Proportion of 1.0 to 1.618. Therefore, with the computer findings, quite extensive biologic implications were promulgated that had not been entertained before. The first clinically useful Frontal Analysis was founded in 1968.

The Three-Dimensional Context

This new three-dimensional view of growth, as revealed from computer generated information, precipitated some fresh new ideas and conjectures. Said again: Sella reference was eliminated as the sacred cow. Basion-Nasion emerged as the most revealing complete cranial base, and the Pterygoid point when connected to Gnathion led to the use of Cc point centrally and to the Facial Axis. This new orientation served admirably for typing, and in addition for sequential facial growth analysis (Figs. 3-7A & 3-7B). Comprehensive analyses were devised for use with the

*Note: Subdivisions Class II and class III are common and often mysterious in their etiology.

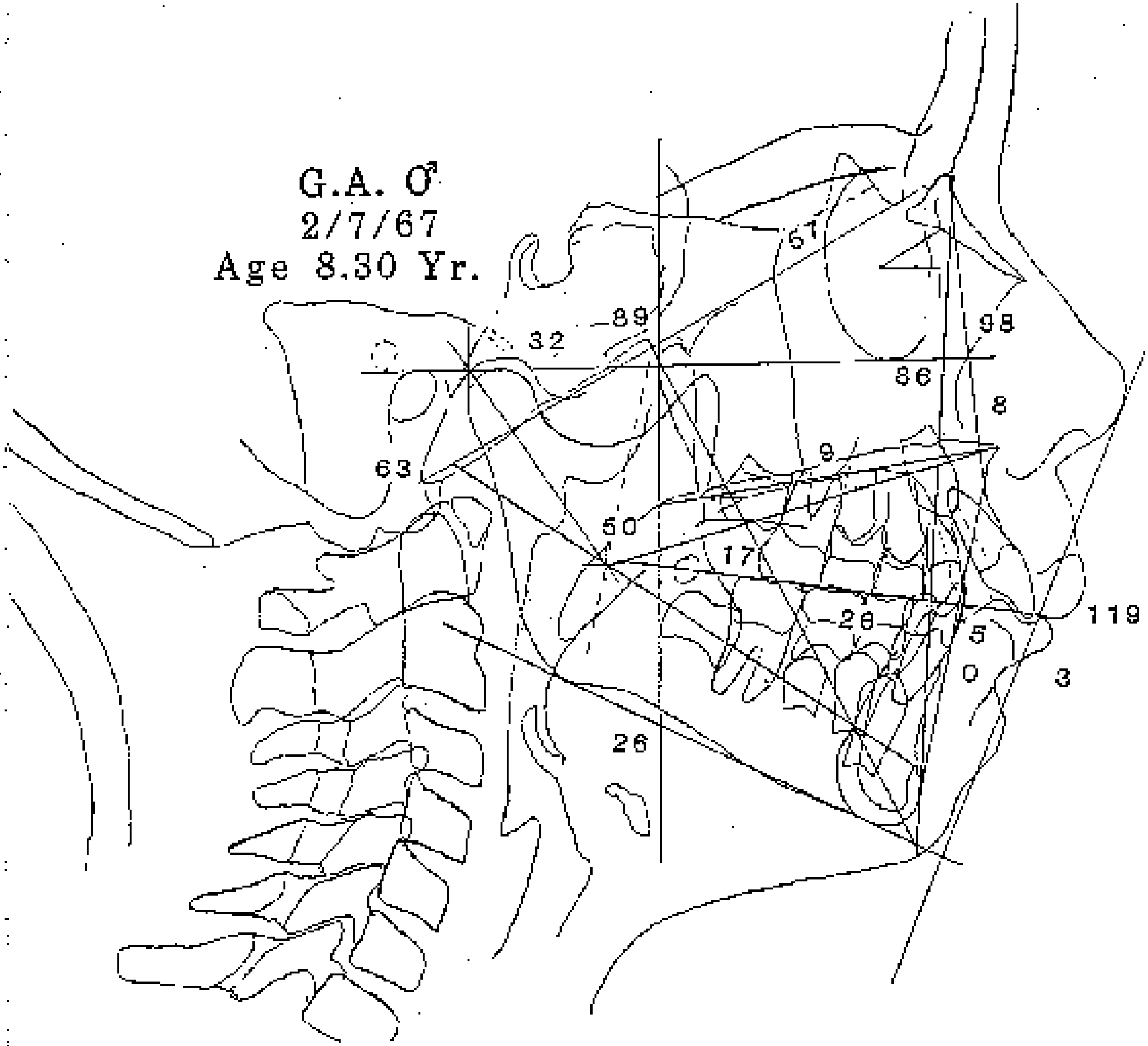


Fig. 3-7A Current Summary Analysis on male patient G.A. age 8 years.

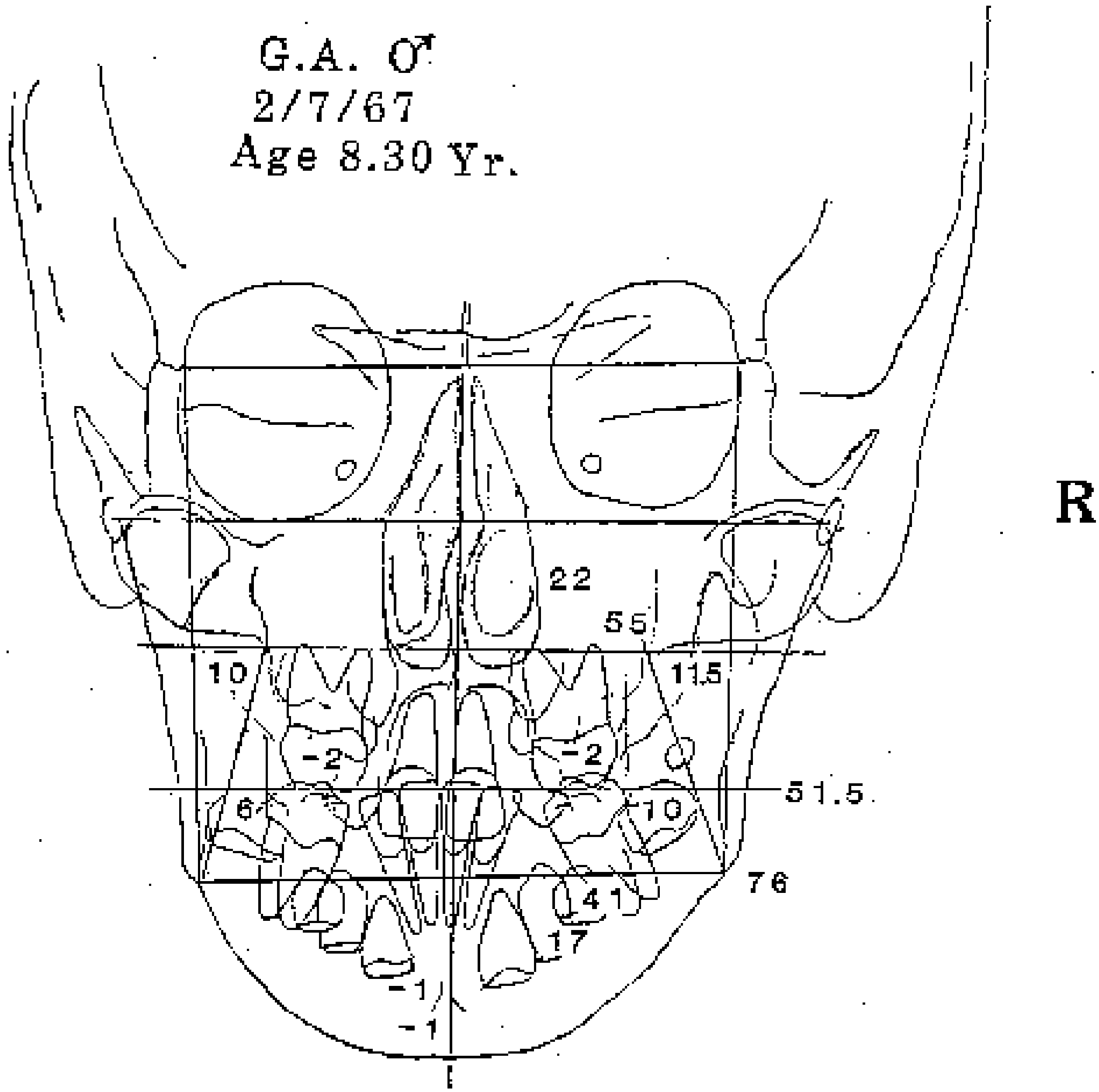


Fig. 3-7B Current Frontal Summary Analysis on patient shown in 3-7A. Most are direct width parameters and for vertical or horizontal asymmetries.

computer (Figs. 3-8A and 3-8B). Interest then became directed to the mechanism of mandibular growth in order to explain the phenomena.

The Mandibular Bend

The Xi Point performed as a point for a junction for the construction of the corpus axis and the condyle axis. A line through the center of the condyle (at the junction with the neck of the condyloid process -- Point D) when extended through the condyle, in effect, located the point Condylion (Co) at the posterior-superior aspect of the condyle (see Fig. 3-7A). It was shown that the corpus axis-condylar axis closed during natural growth. This was true for the mean behavior and also for each individual in the normal non-treated sample.

The growth bending of the mandible was not a surprise, because the bend in the gonial angle was described in the oldest texts in anatomy. The bend in the original (N=40) sample, age 8 to 13, measured in this manner, displayed a mean of 0.6° each year. In order to verify the initial data, a 10-year sample of patients (N=50) was supplied by Dr. J. McNamara at the University of Michigan. Growth in the second group of children confirmed identical values at 6.0° in ten years (Fig. 3-9). Thus, this behavior characterized 90 growing children.

In 1990 this identical bend was revealed a third time in 133 children over a growth period of ten years.

The Arc Discovery

With the discovery of the consistency of a bending behavior, it was quite clear that normal mandibular growth occurred on a curve. The objective was now to find the nature of the curve (see Fig. 3-9). It was realized, of course, that mandibular and facial growth is three-dimensional.

Another problem was to test whether or not projections on a simple curve during normal growth of an individual mandible could be employed for prediction for a 10-to-15-year period. The three-dimensional thought-form for growth was envisioned to be that which was a spiral and similar to the ram's horn, or upward and outward (see Fig. 3-9).

THE SEARCH FOR BIOLOGIC DETAILS

The first effort was a restudy of the general concepts and theories of mandibular growth as gleaned from the histologic and laboratory work in both

ROCKY MOUNTAIN DATA SYSTEMS INC.
15125 VENTURA BLVD. SHERMAN OAKS, CALIFORNIA 91403

GREG ALBRIGHT 2
AGE 8.23/ 0.0 YRS 1
X-RAY DATE 02/07/67

DR RICKETTS/BENCH
0011-74-0001
ANALYST 34 DATE 06/13/74

COMPREHENSIVE CEPHALOMETRIC DESCRIPTION
LATERAL BEFORE TREATMENT

FACTOR	MEASURED VALUE	CLINICAL NORM	CLINICAL DEVIATIONS FROM NORM	
FIELD I THE DENTURE PROBLEM (OCCLUSAL RELATION)				
01-MOLAR RELATION	3.3 MM	-3.0 MM	2.1	**
02-CANINE RELATION	4.6 MM	-2.2 MM	2.2	**
05-INCISOR OVERJET	11.2 MM	2.5 MM	3.7	***
07-INCISOR OVERBITE	3.7 MM	2.5 MM	0.5	
09-LOWER INCISOR EXTRUSION	5.2 MM	1.3 MM	2.0	*
#11-INTERINCISAL ANGLE	114.9 DEG	130.0 DEG	-1.7	*
FIELD II THE SKELETAL PROBLEM (MAXILLO-MANDIBULAR RELATION)				
#13-CONVEXITY	8.5 MM	1.0 MM	3.8	***
15-LOWER FACIAL HEIGHT	49.8 DEG	47.1 DEG	0.7	
FIELD III DENTURE TO SKELETON				
#18-UPPER MOLAR POSITION	14.7 MM	13.3 MM	1.1	*
#20-MAND INCISOR PROTRUSION	0.1 MM	1.0 MM	-0.4	
22-MAX INCISOR PROTRUSION	12.0 MM	3.5 MM	3.9	***
24-MAND INCISOR INCLINATION	17.3 DEG	22.0 DEG	-1.2	*
26-MAX INCISOR INCLINATION	42.8 DEG	26.0 DEG	4.2	***
27-OCCLUSAL PLANE-RAMUS(XI)	3.2 MM	1.2 MM	0.7	
28-OCCLUSAL PL INCLINATION	22.5 DEG	22.3 DEG	0.0	
FIELD IV ESTHETIC PROBLEM (LIP RELATION)				
29-LIP PROTRUSION	2.1 MM	-1.9 MM	2.0	**
30-UPPER LIP LENGTH	29.6 MM	23.6 MM	3.1	***
31-LIP EMBRASURE-OCC PL	-2.0 MM	-3.3 MM	0.8	
FIELD V THE DETERMINATION PROBLEM (CRANIO-FACIAL RELATION)				
#32-FACIAL DEPTH	86.1 DEG	86.4 DEG	-0.1	
#34-FACIAL AXIS	87.5 DEG	90.0 DEG	-0.7	
35-FACIAL TAPER	66.5 DEG	68.0 DEG	-0.4	
36-MAXILLARY DEPTH	95.9 DEG	90.0 DEG	2.0	*
37-MAXILLARY HEIGHT	51.4 DEG	52.9 DEG	-0.5	
38-PALATAL PLANE (FH)	8.1 DEG	1.0 DEG	2.0	**
#39-MANDIBULAR PLANE (FH)	27.4 DEG	26.2 DEG	0.3	
FIELD VI THE INTERNAL STRUCTURE PROBLEM (DEEP STRUCTURE)				
40-CRANIAL DEFLECTION	29.0 DEG	27.0 DEG	0.7	
42-CRANIAL LENGTH ANTERIOR	56.3 MM	53.9 MM	0.9	
44-POSTERIOR FACIAL HEIGHT	52.6 MM	53.6 MM	-0.3	
46-RAMUS POSITION	74.0 DEG	76.0 DEG	-0.7	
48-PORION LOCATION (TMJ)	-42.8 MM	-36.0 MM	-2.2	**
50-MANDIBULAR ARC	23.5 DEG	25.8 DEG	-0.6	
51-CORPUS LENGTH	63.1 MM	63.7 MM	-0.2	

Fig. 3-8A Lateral computer printout with asterisks to indicate clinical deviations from the norm for the given patient. Note both skeletal and dental faults. Compare to Fig. 3-7A.

ROCKY MOUNTAIN DATA SYSTEMS INC.
13155 VENTURA BLVD, SHERMAN OAKS, CALIFORNIA 91403

GREG ALBRIGHT 2
AGE 8.33/ 0.0 YRS I
X-RAY DATE 02/07/67

DR RICKETTS/BENCH
0011-74-0001
ANALYST 34 DATE 06/18/74

COMPREHENSIVE CEPHALOMETRIC DESCRIPTION
FRONTAL BEFORE TREATMENT

FACTOR	MEASURED VALUE	CLINICAL NORM	CLINICAL DEVIATIONS FROM NORM	
FIELD I THE DENTURE PROBLEM (OCCLUSAL RELATION)				
02-MOLAR RELATION LEFT	-0.8 MM	1.5 MM	-1.2	*
04-MOLAR RELATION RIGHT	-1.2 MM	1.5 MM	-1.3	*
#06-INTERMOLAR WIDTH (MAND)	51.8 MM	55.0 MM	-1.6	*
08-INTERCANINE WIDTH (MAND)	16.7 MM	23.8 MM	-2.4	**
#10-DENTURE MIDLINE	0.5 MM	0.0 MM	0.3	
FIELD II THE SKELETAL PROBLEM (MAXILLO-MANDIBULAR RELATION)				
#14-MAX-MAND WIDTH LEFT	-12.2 MM	-9.6 MM	-1.7	*
#16-MAX-MAND WIDTH RIGHT	-13.2 MM	-9.6 MM	-2.4	**
17-MAX-MAND MIDLINE	0.0 DEG	0.0 DEG	0.0	
FIELD III DENTURE TO SKELETON				
19-MOLAR TO JAW LEFT (MAND)	5.2 MM	6.1 MM	-0.6	
21-MOLAR TO JAW RIGHT(MAND)	7.8 MM	6.1 MM	1.0	
23-DENTURE-JAW MIDLINES	-1.0 MM	0.0 MM	-0.7	
25-OCCLUSAL PLANE TILT	0.7 MM	0.0 MM	0.4	
FIELD V THE DETERMINATION PROBLEM (CRANIO-FACIAL RELATION)				
33-POSTURAL SYMMETRY	-2.9 DEG	0.0 DEG	-1.4	*
FIELD VI THE INTERNAL STRUCTURE PROBLEM (DEEP STRUCTURE)				
41-NASAL WIDTH	22.5 MM	24.8 MM	-1.1	*
43-NASAL PROPORTION	57.3 DEG	58.9 DEG	-0.4	
45-MAXILLA PROPORTION	102.0 DEG	103.1 DEG	-0.2	
47-MANDIBLE PROPORTION	93.4 DEG	88.6 DEG	1.2	*
49-FACIAL PROPORTION	96.3 DEG	97.6 DEG	-0.4	

Fig. 3-8B Printout for the Frontal. Compare to Fig. 3-7B. Notice narrow dimensions.

ARCIAL GROWTH

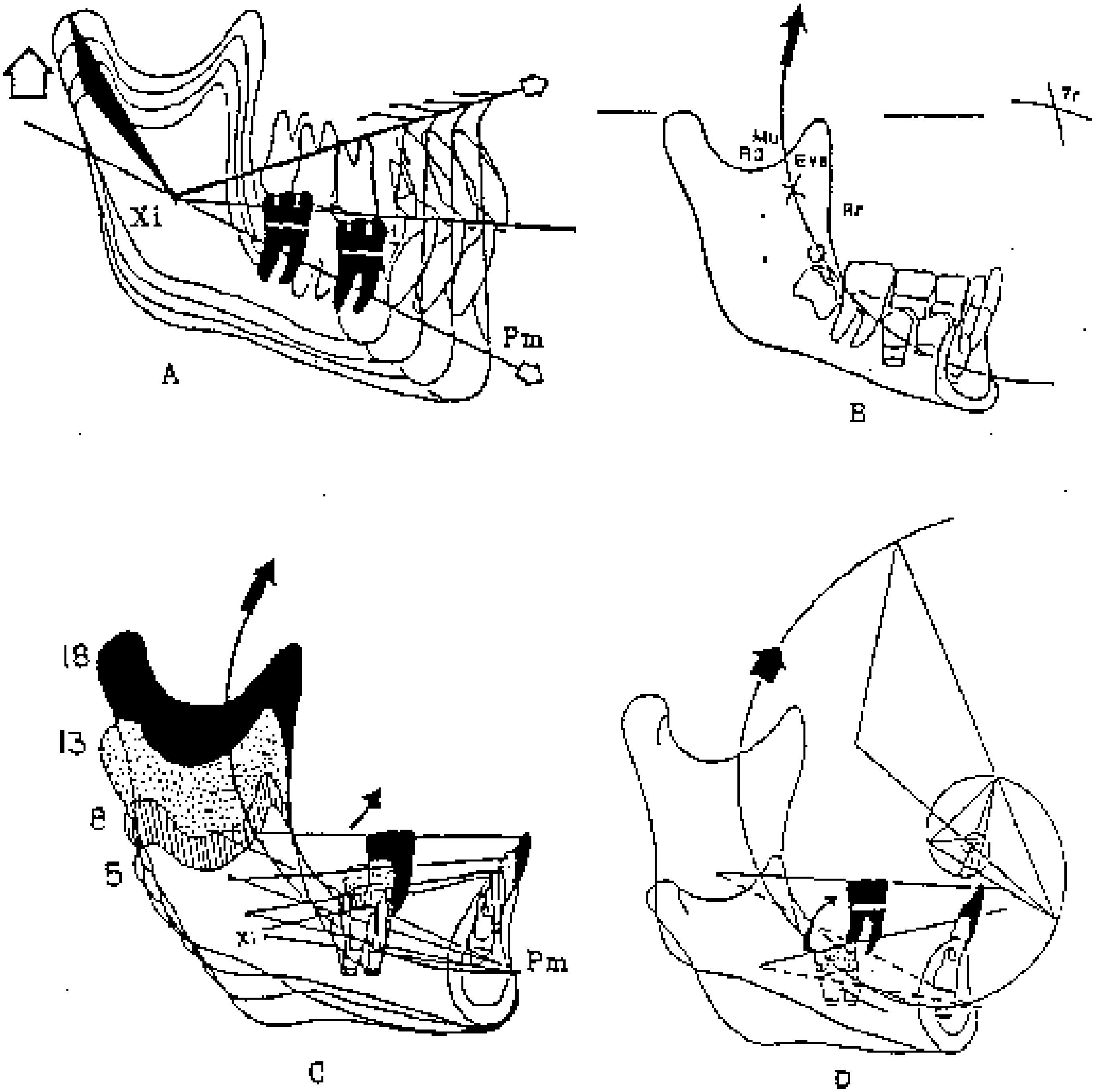


Fig. 3-9 A. Corpus-Ramus bending in normal growth.
B. Method for arc construction from Pm and Eva.
C. Longitudinal comparison of arcial growth with upward and forward development of the lower arch.
D. The arc is thought to be the long leg of a logarithmic spiral.

laboratory animals and humans. The second project was to review the bony architecture of the mandible in young specimens compared to older specimens. A third investigation was to analyze aged and weathered mandibles for the distribution of the trabeculae (or stress lines) which make up the outer compact plates of the mandible. It is known that stress lines run parallel to trabeculae which, as laid down, may tell a growth story.

Experimentally, two arcs were constructed on the composites generated from the data. One arc was drawn from Protuberance Menti through Xi and through Condylion (see Fig. 2-4). When the growth values from the data were added to this arc the gonial angle was opened too much.

The antithesis of that arc was a second trial arc. This was constructed from Pm through R1 and through the Coronoid Point (Cd). The same growth data applied to this arc closed the mandibular bend too much (see Fig. 2-4). These two arcs, therefore, enclosed a "true arc" which would be located somewhere between Xi Point and R1 and between the condyloid and coronoid processes. We were circling the field!

From examination of mandibles on the **medial aspect of the ramus**, a convergence of stress lines from the condyle was observed at the base of the coronoid process at the termination of the mylohyoid ridge. This was found where the forces of tension (from the temporalis) join the stresses of compression from the external pterygoid acting from the neck of the condyle (see Fig. 2-4). In addition, the triangular plane showed perforations for vascular channels similar to the tuberosity of the maxilla.

Experiments led to the trial selection of a point at the center of the base of the coronoid process. The point at the convergence of stress lines was later labeled Point "Eva". The Pm point had already been proven to be a non-changing point. Eva and Pm points were therefore used to construct an equilateral triangle. The third point, upward and forward, was labeled the point of true radius, or Tr (see Fig. 3-9). An arc was constructed by using a compass registered at Tr with a circle extended from Pm through Eva. With the data employed on this arc a "Eureka!" situation was experienced; this arc worked! (see Fig. 2-4). The applied data indicated that the morphology was predicted with surprisingly acceptable accuracy. It was thus made possible for everyone to find the same point scientifically rather than by inspection alone.

Where the arc crossed the Sigmoid Notch the point was labelled Murray (Mu). A second study was conducted by Dr. Ken Fischer to determine the variations in condyle and coronoid behavior from the arc. When the corrected values for condyle and coronoid expression were continued from this arc, the projections displayed amazing likenesses, to say the least.

Further Biologic Considerations

More research followed. Larger samples of growing children, which extended over longer periods of time, were collected for trials. The amounts of growth in patients having different morphology were determined. Variables included the coronoid tip, the condyle, the symphysis, the gonial angle and the occlusal plane as related to that arc. **Differences in the behavior of males and females were determined at the gonial** angle and **the lower border of the symphysis**, as will be shown in later chapters.

Discussion

The mandibular growth arc seemed to be consistent with the basic biologic phenomenon found in Nature. Averaged over years, the mean values work for forecasting so well that over-enthusiasm has to be guarded against. Morphologic extremes both in size and form were employed as "conditional factors" for use manually or for the programming of the computer. It should be remembered that by age 8 about 80% of growth starting from 0 is already completed. Starting with the size of the head at birth, about one-fourth to one-third of adult size is already attained in the calvaria.

Differences in sexual dimorphism in the skull are obvious and are generally accepted in academic circles. These are found in the symphysis, the gonial angle, the mastoid, the frontal sinus and in bulk and size. In addition to the traditional dimorphism, **the length of the condyle**, the **form of the gonial angle**, the relative **thickness of the ramus** and the **form of the symphysis are factors to consider in** future behavior (when the arc is employed).

When "misses" have occurred the errors have been more often in circumstances where growth did not reach the normal potential. Undergrowth, in nontreated subjects, is hypothesized to be related to factors of inhibition caused by muscular or functional dominance. In treated subjects iatrogenic factors in bite opening are strongly suspected, together with functional insults. Condyle compression needs more research.

Many have rejected the process as a method of employing only average values. But to say only averages are used is a disregard for truth and a cliché employed seemingly to denounce the method.

FORECASTING THE TWO CRANIAL BASES (Anterior and Posterior)

As a result of researching for four decades, two bases were found to have the greatest practical value. The first was manifested in the behavior of the temporal bone which contains the glenoid fossa. The second was an anterior base as a scaffold for the nasal capsule.

For a posterior parameter for the condyle, Porion to the Pterygoid Vertical Plane was previously used (Fig. 3-10). However, the external canal is trumpet-shaped. After years of work, two new points emerged on the condyle which were related to PTV and the Frankfort Plane. These were the most posterior point on the condyle (Condylion posterior) which was labelled Cp, and the most superior point on the condyle (Condylion superior) which was called Cs. In the absence of a clinical joint problem the Cs stays in the same relation to the Frankfort plane. The Cp moves posteriorly from the Pterygoid Vertical plane.

The anterior parameter is the N point (Nasion) as measured from the Cc point on the BaN plane. Both the posterior and anterior parameters are subject to correctional factors, depending on morphology (see Fig. 3-10). The mean values are shown in Chart I-[3].

THE FORECASTING LOGIC

The Size-Gain Argument

Since 1966, when the idea of size-gain relationship was emphatically discounted, there has been a reluctance to investigate the phenomenon of size and gain relation any further. But sophisticated statistics mean nothing if the wrong thing is measured or if a part is measured in the wrong manner. Needless to say absoluteness never is present in biologic considerations except in death. With regard to the original size and the values to be expected in the future growth, however, several factors or conditions need to be considered and recognized:

1. The polar phenomenon works because less growth (**gain**) is seen closer to the center and more growth occurs at more distant sites (**size**) (see Fig. 3-1).
2. When a vertex is discovered, and located, the gnomons or allometric shapes also bear the size-gain expression -- those points closest to the vertex increase less than those at the end of the gnomon.
3. When Divine Proportions are discovered, one shorter dimension (the

FORMAT 1975 - 1995

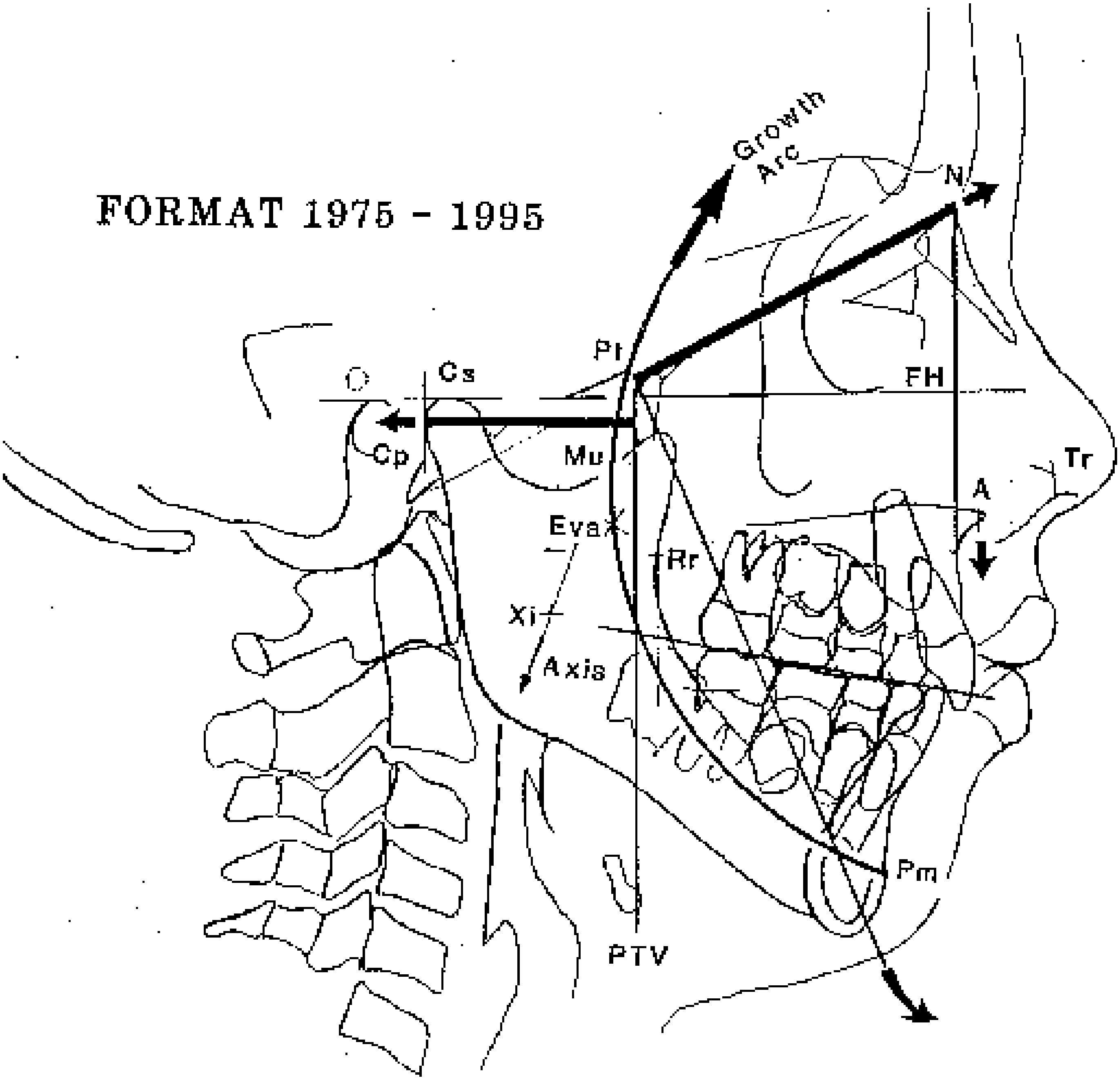


Fig. 3-10 Note line from PTV to condylion posterior is a critical factor for the posterior base. Note anterior base is from Cc to N.

CHART FOR

VALUES FOR RICKETTS CRANIAL BASE

Posterior PTV to Cc				Anterior CC-N		
Age	$\bar{X}$	♂	♀	$\bar{X}$	♂	♀
3	28.5	29.0	28.0	51.5	52.5	50.5
4	29.0	29.5	28.5	52.3	53.3	51.3
5	29.5	30.0	29.0	53.1	54.1	52.1
6	30.0	30.5	29.5	53.9	54.9	52.9
7	30.5	31.0	30.0	54.7	55.7	53.7
8	31.0	31.5	30.5	55.5	56.5	54.5
9	31.5	32.0	31.0	56.3	57.3	55.3
10	32.0	32.5	31.5	57.1	58.1	56.1
11	32.5	33.0	32.0	57.9	58.9	56.9
12	33.0	33.5	32.5	58.7	59.7	57.7
13	33.5	34.0	33.0	59.3	60.3	61.3
14	34.0	34.5	33.5	60.1	61.1	62.1
15	34.5	35.0	34.0	60.9	61.9	62.9
16		35.5			62.7	
17		36.0			63.5	
18		36.5			64.3	
19		37.0			65.1	

mean) will grow in proportion to the larger dimension (the **extreme**) so that order and proportion are maintained. The short side (**size**) has less growth (**gain**) than the longer side (Fig. 3-11) (see also Fig. 1-6B).

4. When major dysplasias are encountered they will not, as a rule, self-correct; they develop in conformity to their original proportions unless disease states are even more destructive. This is seen in synostosis. Genetic endowment is powerful.
5. The whole theory of neurotrophism supports a size and gain relationship.
6. Certain measurements **do** relate to variation in future behavior on the basis of the original size.

Thus, certain proportions of the mandible are subject to general size/gain principles. Likewise, in the cranial base certain modifications are to be considered as related to size, form and relationship. It is remembered that a three-dimensional phenomenon is expressed.

The Patterns of Dental Development

It is phenomenal how the permanent lower incisor erupts in the position occupied by its deciduous predecessor. Also, as a general principle, the upper and lower permanent first molars are **always** guided into final position by the second deciduous molars unless pathologic conditions are present. In about 7% of the population mandibular growth turgor may be so great that Class II can be overcome without treatment, especially in subjects with a level or open bite condition.

In addition, the lower incisor tends generally to continue its relation in the position relative to the APo plane (in the absence of a habit change) (Fig. 3-12). Arch depth is often consistent with typical behavior; i.e., loss of "E" space. The first molar relative to Ptv (as parallel to the Corpus Axis) does not change significantly. However, correction of oral habits involving tongue and lips, as well as finger habits, is difficult to predetermine in the absence of treatment. Forecasts can be made, therefore, both with cessation of the habit and without habit correction. Open bites without treatment tend to improve in time, but often do not completely self-correct without help (Fig. 3-13).

Soft Tissue Growth and Behavior

Forecasting of growth of the nose and lips is not as difficult as is often assumed. The prediction of the skeletal and the dental base is the first key to soft tissue behavior. The base for the support of the septal cartilage is the anterior nasal spine. Thus, if the hard palate prediction is missed there is little chance of the nose

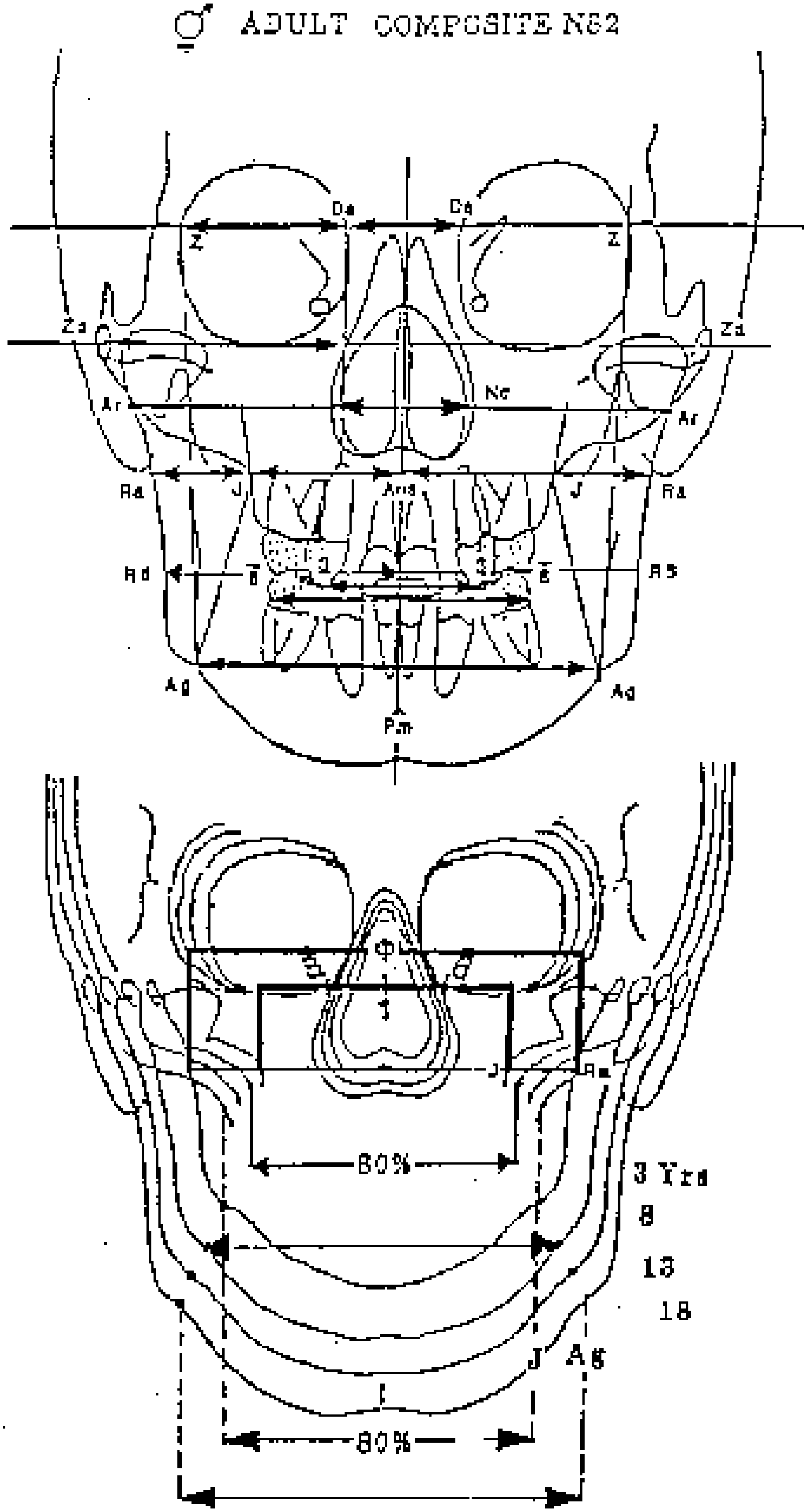


Fig. 3-11 The Divine Proportions in the frontal together with the percentages for maxillo-mandibular skeletal relationship in the frontal.

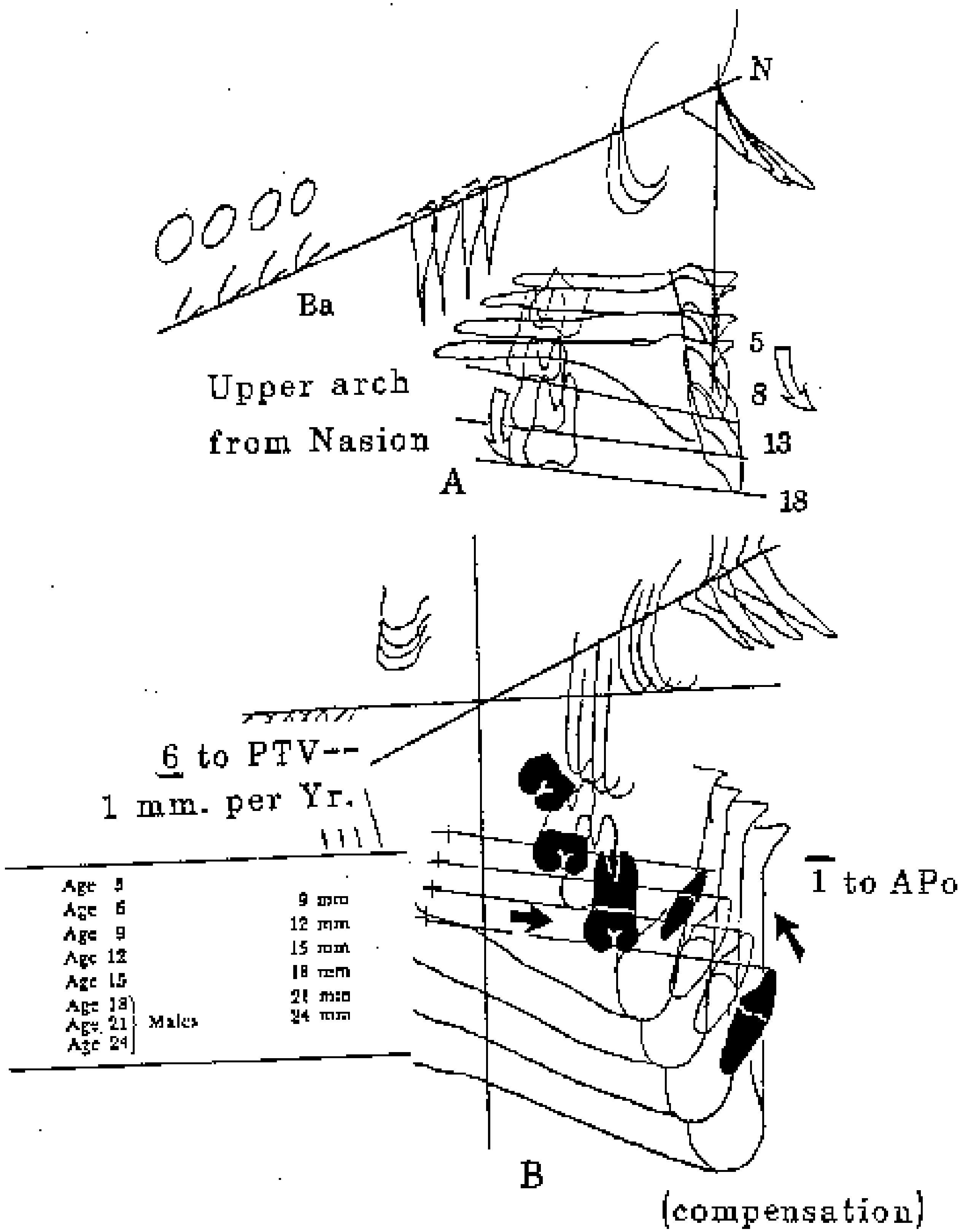


Fig. 3-12 **A.** Note the behavior of the upper incisor reflects the forward growth of the chin.
B. Note the behavior of the lower incisor tends to follow the APo Plane behavior.

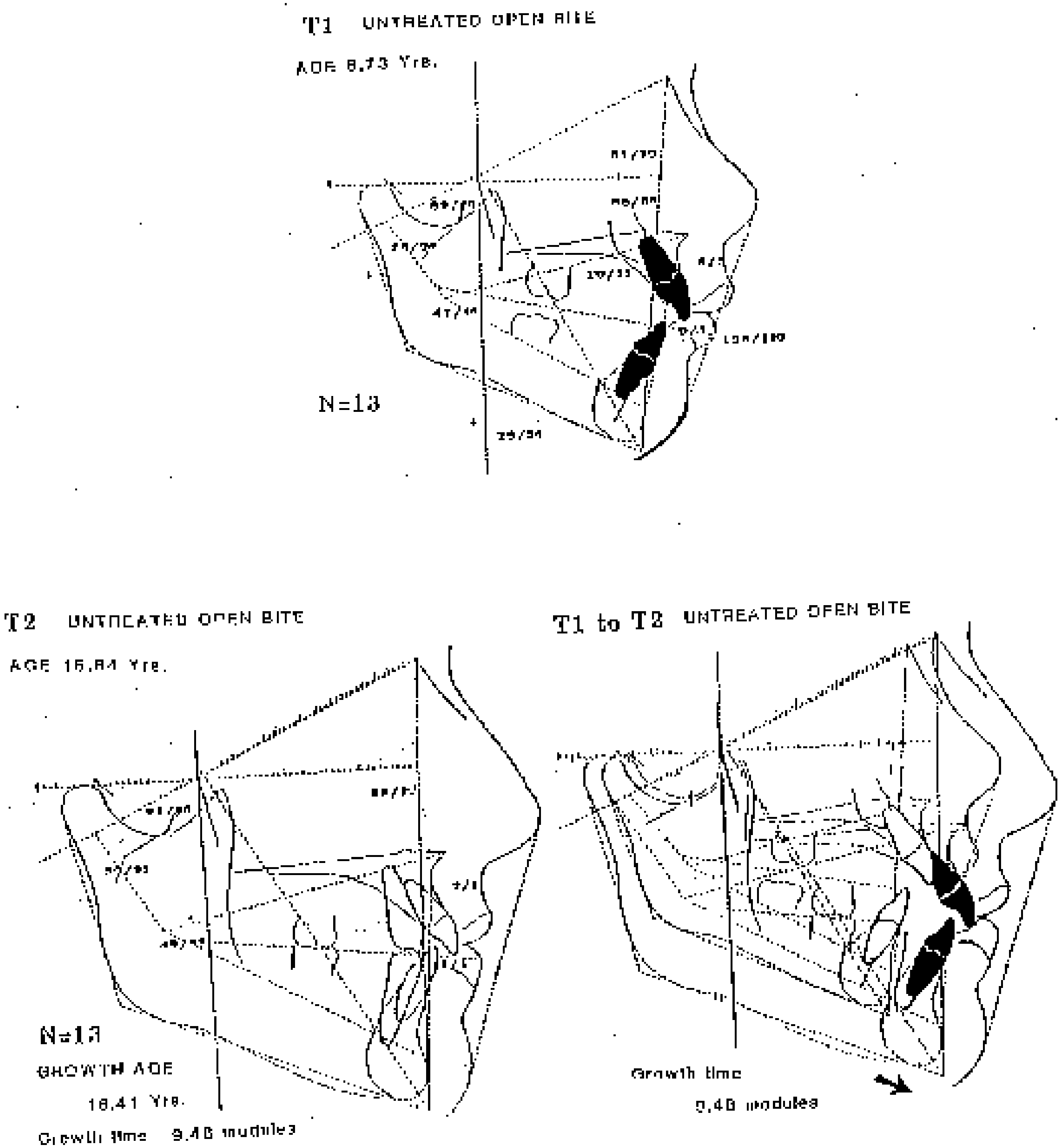


Fig. 3-13 **T1** Composite (N=13) of 6.7-year-old children with open bite. Note high convexity and Class II tendency.

T2 After 10 years (age 16.6 years) and no treatment the mean open bite space had reduced but not completely, and "end on" molar was present.

T1 to T2 Note forward "swing", convexity reduction and development of upper incisor.

being predicted accurately. In addition, the lips are based on the position of the incisor teeth.

There is also the factor of "prepubertal fat" and unrolling of the lips with vertical skeletal development. Finally, the soft tissue of the chin is influenced by lip strain which is also contingent on habits. Mean values form the Zero Base for behavior.

SUMMARY

World-scale developments in orthodontics have prompted a greater interest in younger patients. This kind of interest makes a consideration of a patient's future a more appropriate subject.

Further, with earlier intervention retention periods and retention behavior are factors in clinical management. The effects of third molars and maturation of soft tissue are factors to be taken seriously.

It is obvious after fifty years that cephalometrics is essentially the only tool for accurately monitoring treatment and forecasting future behavior. Earlier methods started with the cranial base, onto which the mandible was added. However, research led to the discovery of a mandibular growth arc which when applied was accurate to a remarkable extent (Fig. 3-14). Its evolution was described. The cranial base development and the mandible therefore needed to be associated.

Studies conducted in 1990 led to still greater accuracy and sophistication. The next need was to describe in detail the forecasting and treatment objective determination, which will be done in the following chapter.

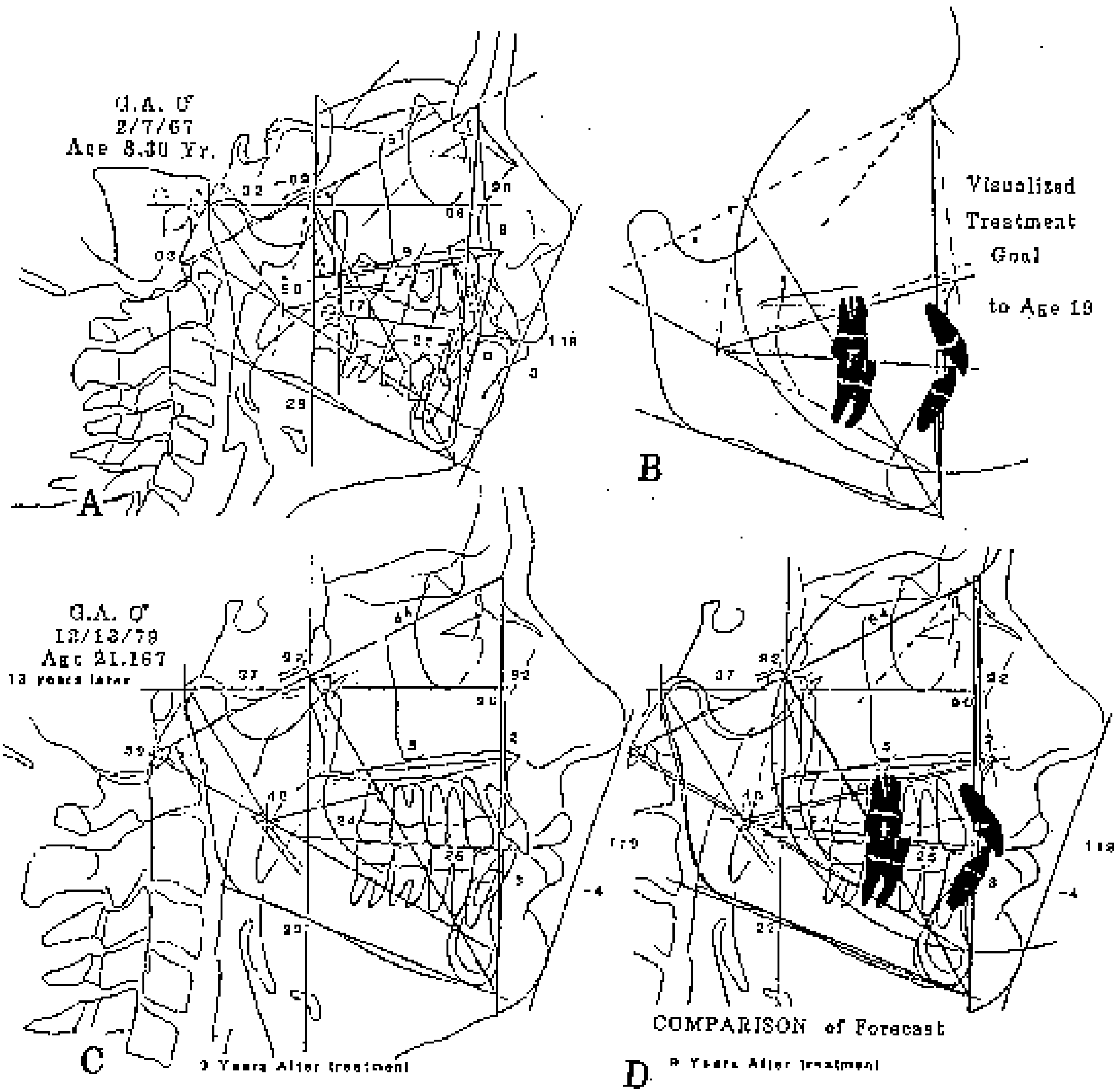


Fig. 3-14 **A.** Male patient G.A., originally shown in Fig. 3-7A and 3-7B.
B. Forecast and VTG to age 19.
C. Treated and grown at age 21.
D. Actual compared to the VTG for patient G.A.

PREDICTION, PLANNING, CONSTRUCTION and MECHANICS

CHAPTER FOUR

THE TECHNIQUE FOR FORECASTING GROWTH FROM CHILDHOOD TO MATURITY (WITHOUT TREATMENT)

INTRODUCTION

The original forecasting method (1950) and second schemata (1967) both started with the cranial base on which the mandible and maxilla were added for a two-year treatment plan (short-range). When the arcial method was discovered (in 1971) long-range forecasting to maturity was made possible. The mandible was now forecast separately and was rendered first. The cranial base was constructed and then the two were fitted together. The arcial approach was found to be greatly superior for short range as well as for the long range. Consequently, all the **previous forecasting methods were discarded** except for dental and soft tissue arrangements.

A cranial reference was still required. The representatives for the "cranial bases" employed in forecasting were the same as those measured for the Summary Analysis (see Chapter Two). For the posterior cranial reference the distance was taken from Posterior Condylion (Cp) to the PTV (parallel to the Frankfort Plane). It is essentially a "joint" reference. Anteriorly the base employed was from Cc to Nasion (on the BaN Plane). This is primarily a maxillary reference (Fig. 4-1).

On a gross basis, the posterior and anterior parameters employed tend to behave (without treatment) on a size-gain expression, at least enough so that predictions are expected to be sufficiently accurate for clinical work. Only 0.1 mm. per year difference in prediction in ten years will mean a 1.0 mm. mistake, but in 15 years will add up to 1.5 mm. The cranial bases are important because they serve to forecast condyle position, and particularly Point A is forecasted from Nasion. **The goal is** to be as trustworthy as possible, and **to be within a 1.0 mm. accuracy at maturity.**

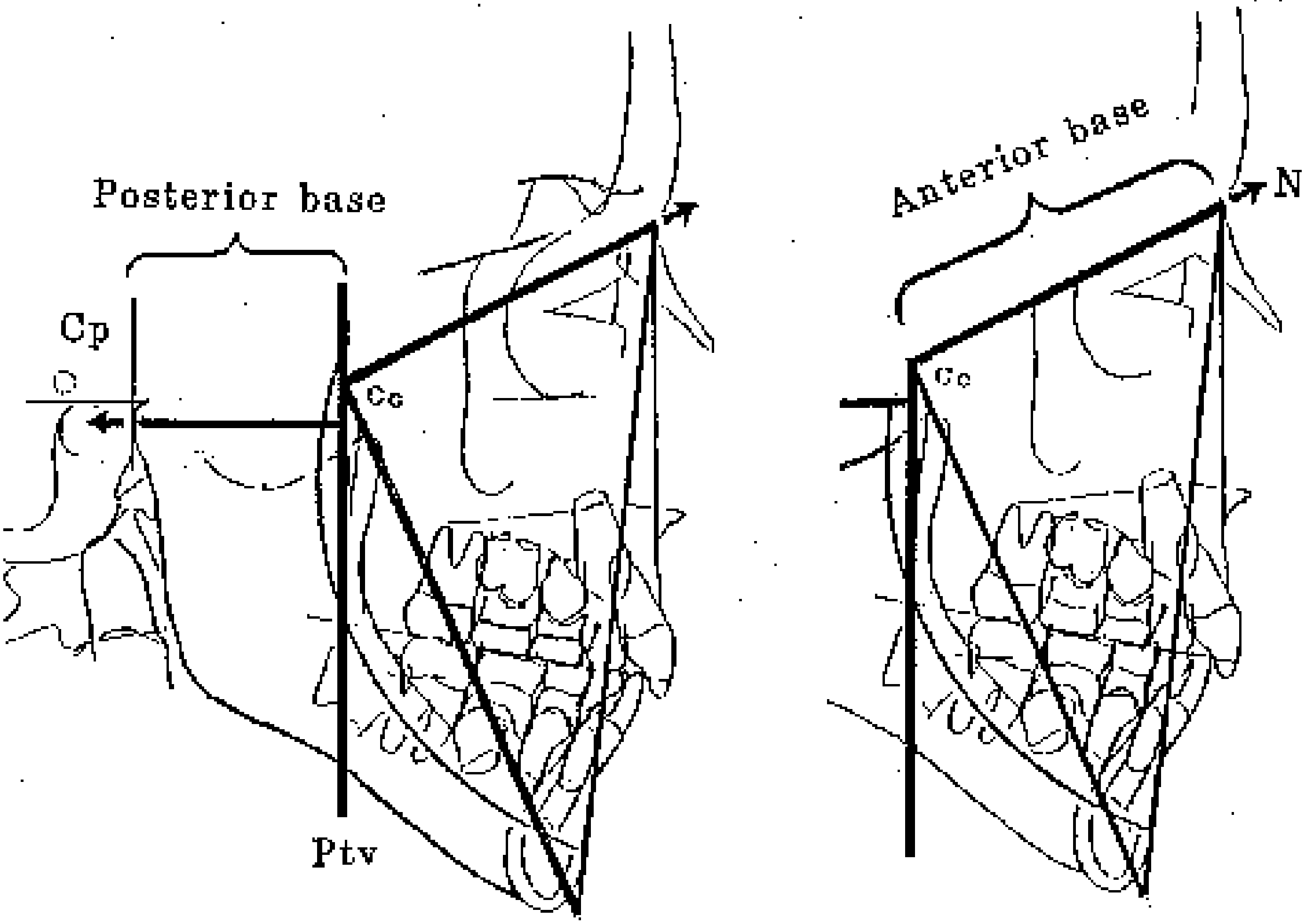


Fig. 4-1 The two cranial bases that emerged with continued research.
Posterior: PTV to Condylion posterior CP;
Anterior: Cc to N.
Illustration also shows the mandibular growth arc.

Discussion of Posits

Some observations, facts and explanations for growth and physiologic behavior are indicated because the last part -- the fitting of the mandible to the basalar skeletal parts -- is the most taxing part of the entire exercise.

Mandibular Support

The mandible is recognized to be cradled in muscles, fascia, ligaments and the epithelial layers of the face. Further, it is influenced by behavior of the circumferential kinetic chain of muscles which is affected, in turn, by cervical vertebral growth and altered by breathing phenomena. Behavior in the sagittal plane is the most important clinical aspect for the forecast of the maxillo-mandibular relationship, both in height and depth.

A most surprising finding, in five different normal non-treated samples, was the regularity discovered for the vertical maxillo-mandibular relationship as displayed by the oral gnomon (Ans-Xi-Pm) registered at Xi Point. The consistency of this finding, by deduction, would infer that there was a relative constancy with the development of muscle. It is another intriguing factor in biology, and the question arises regarding earth gravity (Fig. 4-2).

Polar Behavior and Nature's Articulator: The Glenoid Fossa

For a basic reference, a forecast of the glenoid fossa (for temporal bone movement posteriorly) was developed.

Computer findings revealed (in the sagittal plane) that Point Porion (at the most superior border of external auditory meatus) moved posteriorly from the PTV at a mean rate of 0.5 mm. per year. Also, the amount of growth estimated to be expressed **was a function of its original distance from the pole** (size). As each radius of a circle enlarges, as in a polar phenomenon, the growth within that radius is somehow respondent to the original size of the radius itself.

It is recognized, however, that the facial growth phenomenon is three-dimensional, not sagittal alone. As each radius from the polar center increases it would mean progressively greater growth, and such is not the case. For instance, growth on the Facial Axis stays surprisingly even at 2.5 mm. per year. D'Arcy Thompson described growth behavior as the application of the formula for the volume of a sphere $4/3\pi r^3$ [solid geometry]. The interesting feature, to bring that volume concept into a better understanding, is that a one-mm. increase at a radius of 10 mm. results in a 33% increase in volume, while a one-mm. increase at a 50 mm. radius increases the volume at only 6%, and at a 100 mm. radius one mm. adds 5%

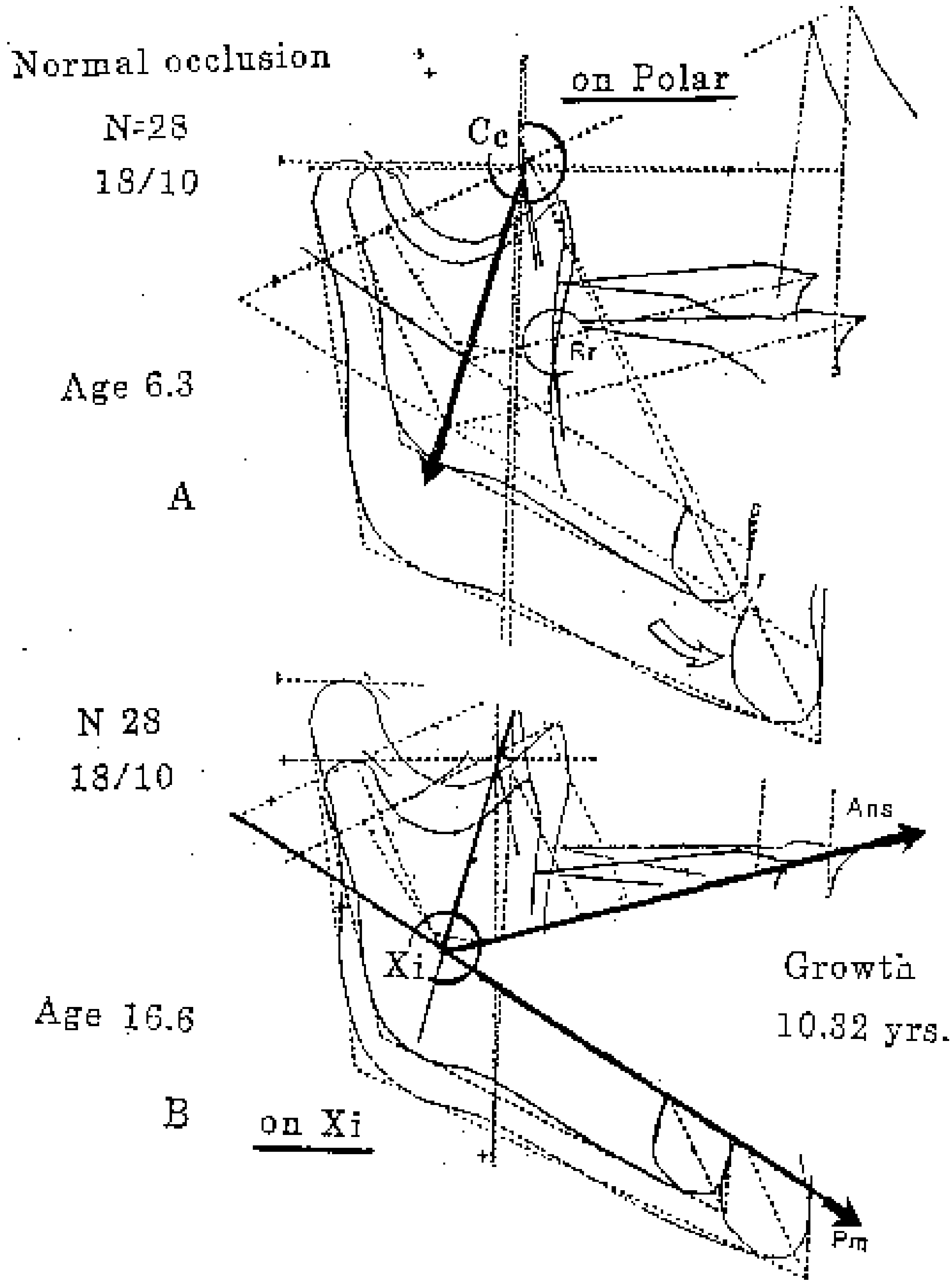


Fig. 4-2 Growth behavior in children with normal occlusion from age 6 to 16 years (N=28:18 males, 10 females).

A. The Facial Axis was found to move forward (closed) in the polar phenomenon from BaN orientation with Cc registered. Note the point of orientation of the mandible at Rr Point (in circle).

B. A surprising regularity was discovered in the Oral Gnomon (Ans-Xi-Pm).

to the volume. Smaller radii are required for proportions to be stable.

The total concept is further confused by the fact that the two halves of the face, with two centers, meld at the midline and oppose each other at the sagittal and mid-palatal sutures. In effect, two volumes develop in the face.

Without treatment, the general phenomenon of **proportional increase** seems to be relevant until factored differently by the qualification by certain variations that can be identified.

Three Factors for the Fit of the Mandible and Cranium

The Cp Point (Condylion posterior) and Cs (Condylion superior)

Because the right and left side are superimposed in the lateral headplate, and because the outline of the external meatus is a funnel shape (or trumpet shape), the exact location of a point for Porion in a definitive manner was difficult. That being the case, the **outline** of each **condyle was traced and the points were bisected** (see Fig. 4-1). A measurement was made from the **posterior outline of the bisected condyle (Cp)** directly to the Pterygoid Vertical plane. This, in effect, was taken to represent the functional **depth of** the **posterior cranial** base for a clinical application. Inspection was first made of the joint in an effort to determine a mesial condyle position or "false bite" at the time of recording, or that a displacement was present.

The superiormost point on the condyle was selected and labelled Condylion superior (Cs). It was oriented to the Frankfort plane. Brachyfacial faces proportionately in theory (the transverse aspect) do not express as much posterior movement of the glenoid fossa in the sagittal plane as do long, narrow faces. The Facial-mandibular Index is about 75 (Nasion-Menton related to width at Ag Point). Dolichofacial types develop more than average proportional facial height than facial width. Research is still under way to determine whether or not larger posterior base dimensions must be given greater weight than smaller dimensions, but until proven differently marked extremes are factored for the forecast -- i.e., the larger given more and the smaller given less in this particular small but critical dimension (without treatment).

Samples of eight-year-old Class II and Class III children revealed differences in this dimension (see Chapter Two, Figs. 2-5A and 2-5B). The Class II was more posterior and the Class III was more anterior when compared to the controls. Even more ironic was the fact that after treatment of the Class II and the Class III, compared at the thirteen-year-old age, both the Class II and Class III were more normalized. If this be true, there is a suggestion that treatment influences more than the maxilla or the mandible, and indeed may have some minor impact on the temporal bone itself. This has been shown to be true in animal research and in human dysplasias. It is all the more interesting in that none of the 60 patients in the studies for long-range behavior were treated with mandibular posturing techniques (see Fig. 4-1).

It was of further interest that in the deep bite untreated group the PTV-Condylar (Cp) dimension showed the greatest posterior increase. If this could be verified in larger samples, it would give to those who claim there is no joint relationship to occlusion a cause to reorganize their thinking (Fig. 4-3).

* * * * *

The Anterior Border of the Ramus (Rr)

After positioning of the condyle relative to PTV, the next procedure regards the **fitting** of the mandible. Most clinicians want to know where the chin will be related to Nasion, but many prefer a Frankfort Plane reference for clinical application.

The first study was to try to find the part, or area, of the mandible at age 3 that was consistently related at age 18.

A review of seventeen (17) composites generated by the computer in 1990 showed that the **only** area of superpositioning with the polar orientation was at the **anterior border of the ramus** near the base of the coronoid process. This was labelled Rr Point (for Ramus reference). In the composites the anterior border or base of the coronoid generally stayed consistent to the Pterygoid Vertical plane (see Fig. 4-2).

Several investigators (Broadbent, Brodie, Bimler, Enlow, and others) have proposed a vertical line or plane to separate the anterior and posterior parts of the cranium. All of these lines are, in general, thought to be essentially representative of the **coronal suture complex.** That suture divides the parietal and frontal bones and runs downward through the area of the great wing of the sphenoid (which is buttressed behind by the temporal bone and anteriorly by the zygoma). The sutural division then passes through the pterygomaxillary fissure and through the zygomaticotemporal suture. Therefore, in theory, growth occurs both anterior and posterior to that sutural plane.

In essence, this sutural complex is represented by the Pterygoid Vertical Plane

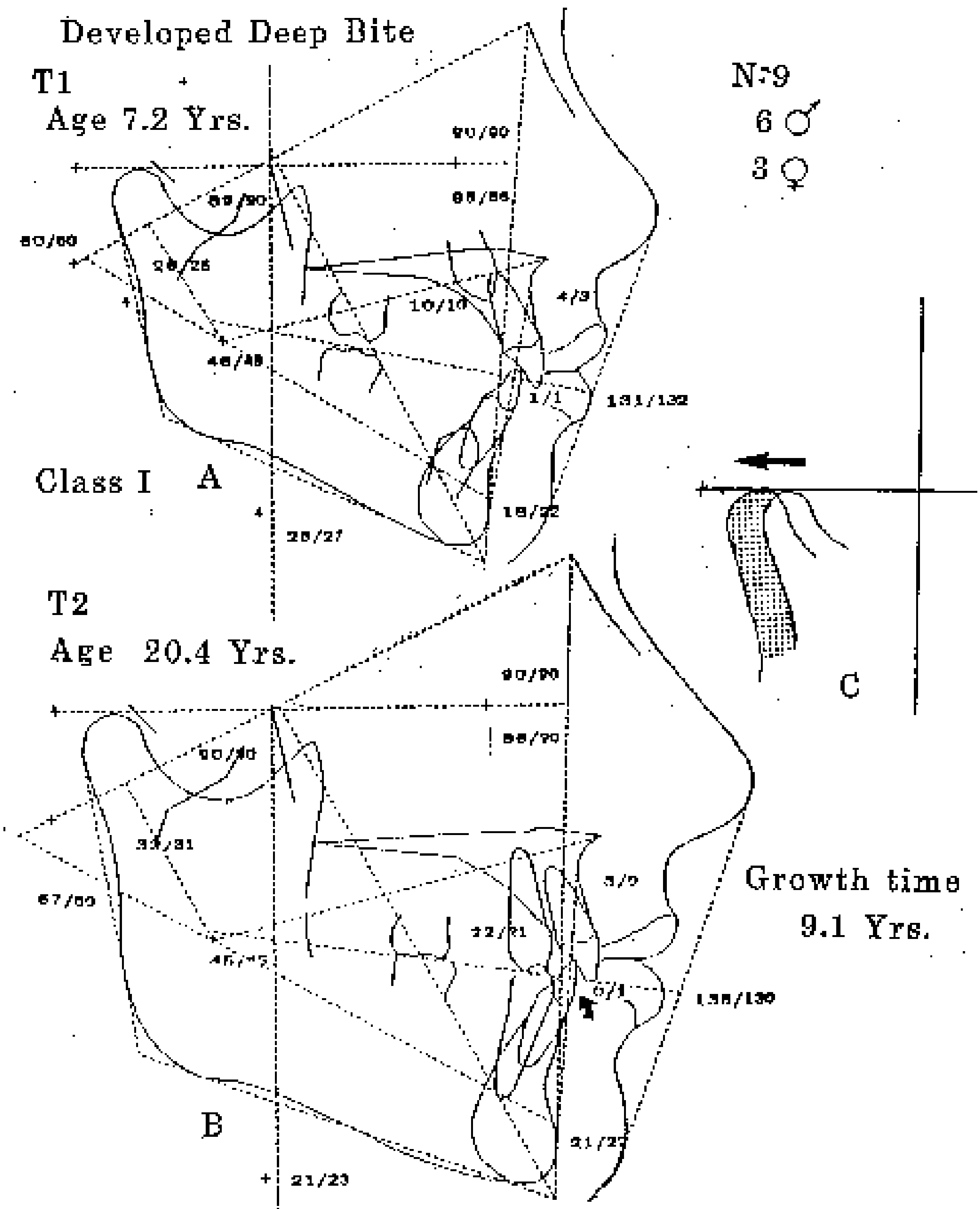


Fig. 4-3 Composite of N=9 untreated children (6 males, 3 females) with deep bite. A. T1, age 7.22. B. T2, age 20.37. (Growth time to 16.3 years, to 9.03 modules). C. Comparison on PTV showing highest backward movement of the condyle of all the groups studied.

which is constructed from the base of the pterygoid plates. These plates, at the palatine wedge, serve as the buttress for the maxilla. Ironically, the lateral pterygoid wing also serves for attachment of both the medial and lateral pterygoid muscles. These muscles support the mandible. **The Pterygoid Vertical Plane is a key intermediate zone. It is nearly halfway in the skull base anteroposteriorly, and is a** site for support of **both** jaws -- in the maxilla by a buttress and in the mandible as the origin of supporting muscles.

As a general statement, the great temporal crest, which extends from the zygomatico-frontal junction through the parietal bone and thence through the temporal bone, terminating from behind at the supermeatal crest, is like a great bridge suspension. It supports the temporal fossa which houses the large fan-shaped muscle. This suggests the **temporalis** *muscle* **to be the great mandibular suspender.** It ties the mandible to the basal skull via the coronoid process. Thus the base of the coronoid at the origin of the heavy external oblique ridge stays generally in a functional relation with the suture and is represented by the Rr (Ramus reference) point, and a line dropped from it serves as one reference for the future condition (see Fig. 4-2).

The Xi Axis

Starting with discovery of the arc in 1971, research in long-range behavior continued through 1995. The original untreated sample was N=40. A second group of N=73 untreated children age 6 was followed for 12 years. The accuracy of prediction, or forecasting, techniques was consequently restudied.

One of the surprises with the T1-T2 composites compared was to discover that Xi Point served so many purposes (see Fig. 4-2). The original computer study reported first in 1969, represented an aggragate data from the literature. It seemed to suggest that the average mandible grew without a change in the Xi axis. The 1990 findings suggested that Xi moved forward but only 1° each 10 years, on average, from its original relationship. Therefore, a "conditioning factor" for the forecasting procedure was employed so that the Xi axis could be changed contingent upon: (1) mandibular type, (2) facial type, and (3) conditions of the joint.

Composites of the forecast of males and females were compared to the actual in order to test the method. The females are shown in Figure 4-4.

The growth cut-off for females is well established at 14.8 years. For males essential growth is finished by 19.0 years. These terminal times are employed unless skeletal development is advanced or delayed, as evidence in wrist plates.

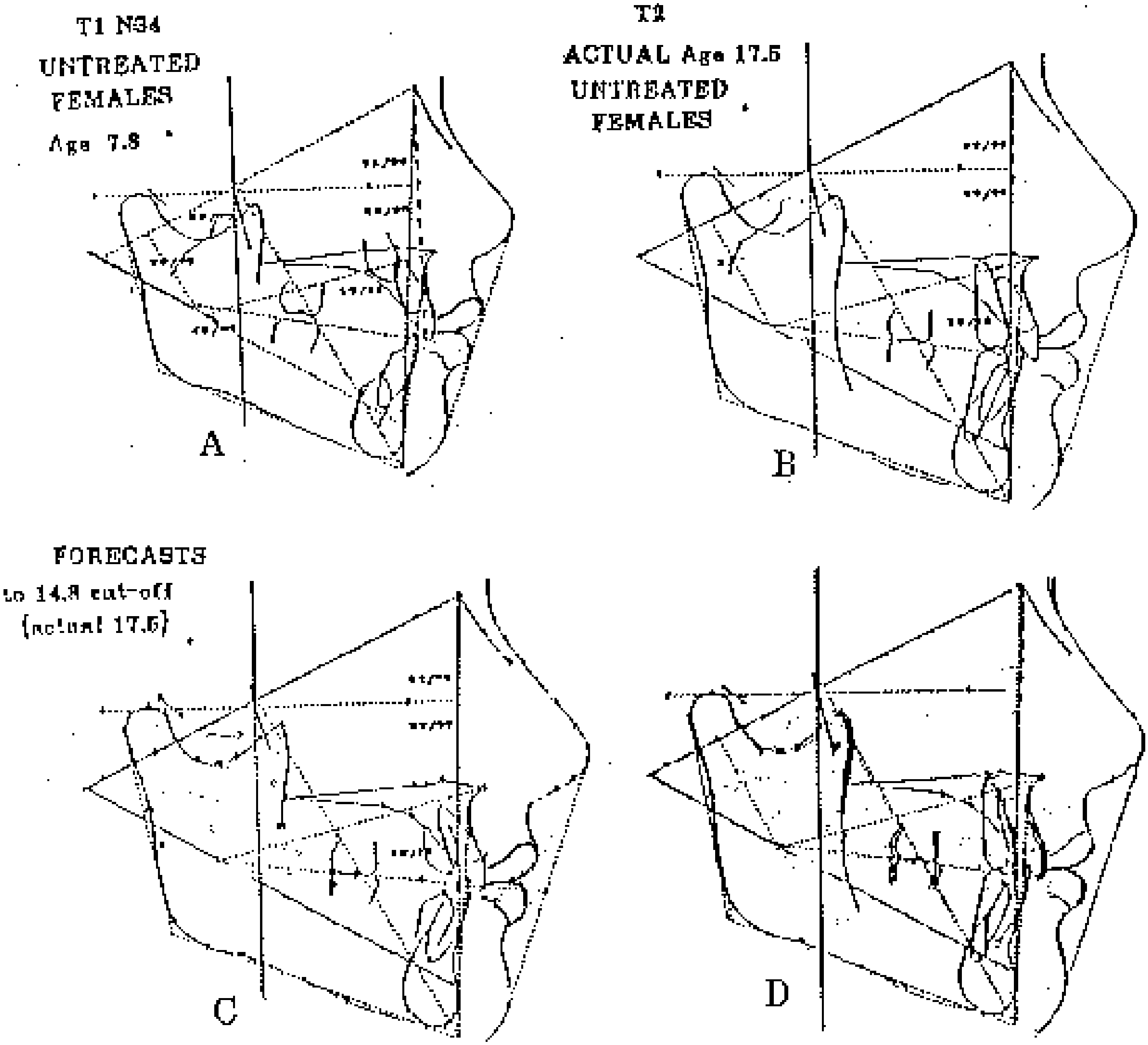


Fig. 4-4 **A.** Composite for growth in females (N=34), age 7.8 years. **B.** Composite of same group, actual growth to age 17.5 years. **C.** Individual forecasts composited for the same subjects. **D.** Comparison of forecasts to actual shows almost identical fit. Note soft tissue prediction.

PART ONE: Technique for Cranial Base

The original tracing is referred to as Time One (T1); the final tracing is Time Two (T2). The symbol Tf is used for Time forecasted. The female (L.A.) Is represented in Figure 4-6A and the male (N.N.) Is displayed in Figure 4-6B.

Eight Steps

Use a new sheet of tracing paper and proceed as follows:

Step 1: Near the center of the sheet draw a straight line as a new Frankfort Horizontal and draw a 90° angle for the Pterygoid Vertical plane as the Tf cranial element (Fig. 4-6A-A). (Also see N.N. in Fig. 4-6B, A).

Step 2: Superimpose the new paper on the (T1) Frankfort Plane at PTV for the behavior of Posterior Cranial Base (Joint Factor). Mark a short vertical line a mean of 0.5 mm. per year posteriorly for the new condyle position (Cp) (for later reference) (see Fig. 4-6A-B).

Comment: The mean starting posterior (Cp to PTV) dimension for boys is 31.5 at age 8, while for girls it is 30.5 mm. at age 8. A conditional factor is employed if the original size is 2 mm. or more different in either direction (as corrected for age). If a longer length (say, 33.5 mm.) is present, a module of 0.6 mm. per year is used; if shorter -- say, 28.0 mm. at age 8 -- only 0.4 mm. is added to forecast, in essence, the future condyle position. Refer to Chart I for mean values (for Cp and Cc-N) at various ages.

Step 3: With the PTV registered, draw a new BaN Plane below and parallel to original BaN plane at 0.14 mm. per year or 1 mm. in 7 years.

Comment: While on average in a 15-year longitudinal study the angle between BaN and FH was not found to change, the planes did shift relative to each other. The Frankfort plane moved superiorly, or the BaN plane moved downward, depending upon which is considered to be fixed. The angle between the two may change, as a phenomenon of the third dimension, but to date this variance has not been investigated (research project for a student!). It has been found useful simply to keep the angle the same (see Fig. 4-6).

THE LOGIC OF THE SEQUENCE IN FORECASTING: A FIVE-PART EXERCISE

In order to demonstrate sexual differences a female aged 9-11and a male aged 12-10 were chosen (Figs. 4-5A-L&F and 4-5B-L&F). Records were available in both patients five years later.

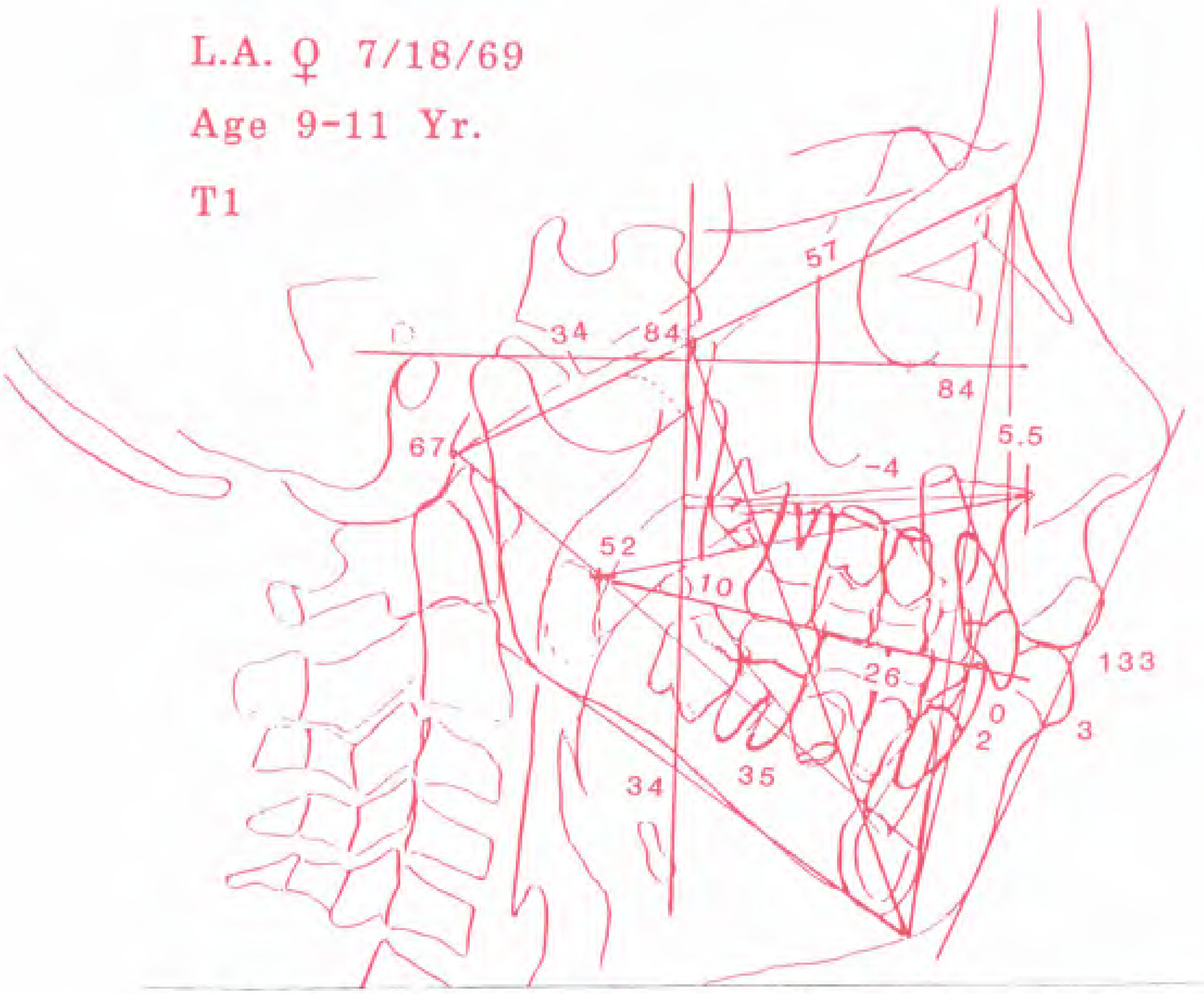


Fig. 4-5-**A-L** Lateral analysis of female patient L.A., age 9 years, 11 months, mixed dentition; T1 with values for Summary Analysis (4 mm. of lower anterior crowding). Selected to demonstrate a Long Range Forecast to age 15. Note dolichofacial type with moderate convexity.

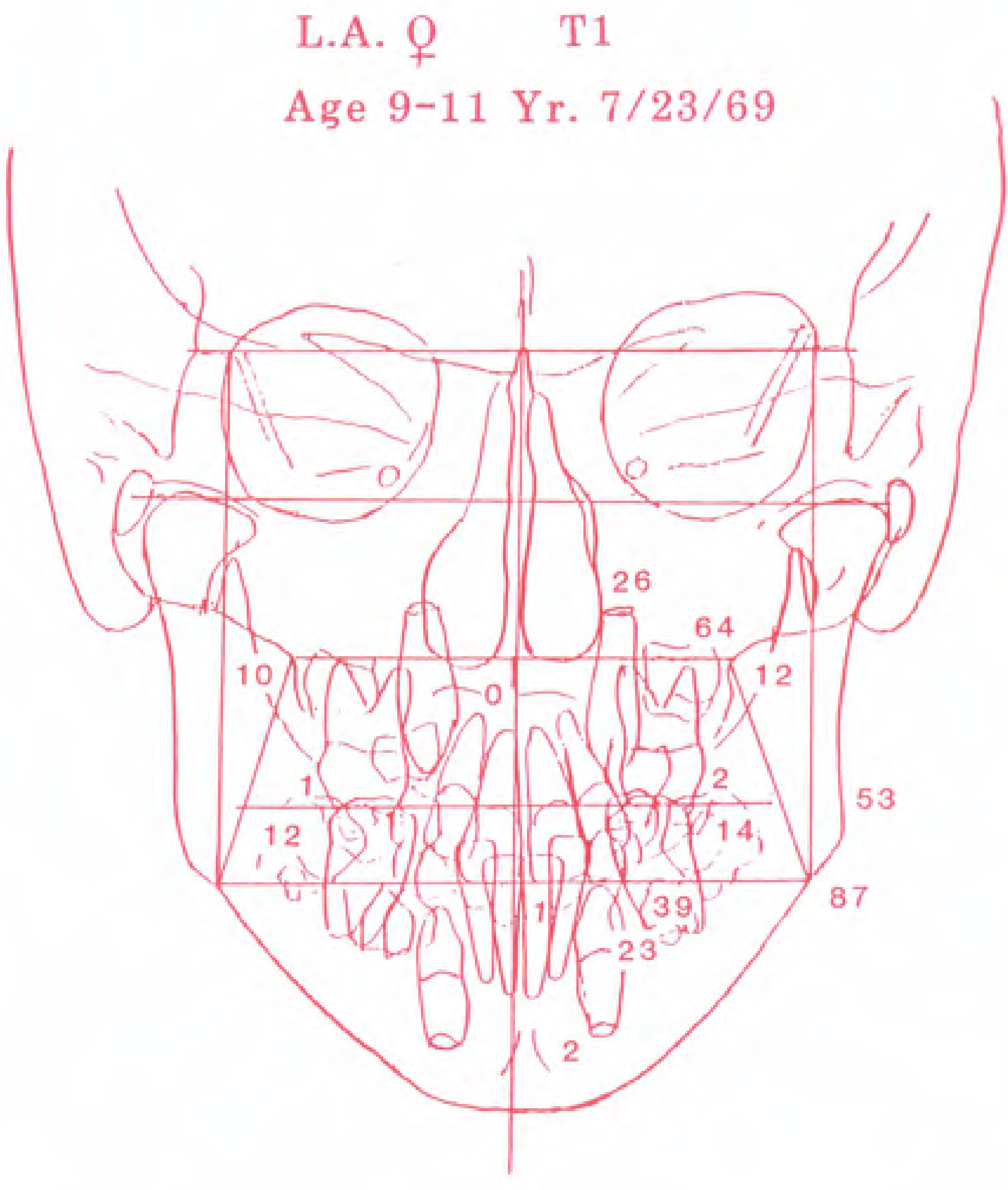


Fig. 4-5-**A-F** Frontal Summary Analysis of female patient L.A. T1 width and symmetr values are posted. Note crowded lower incisors.

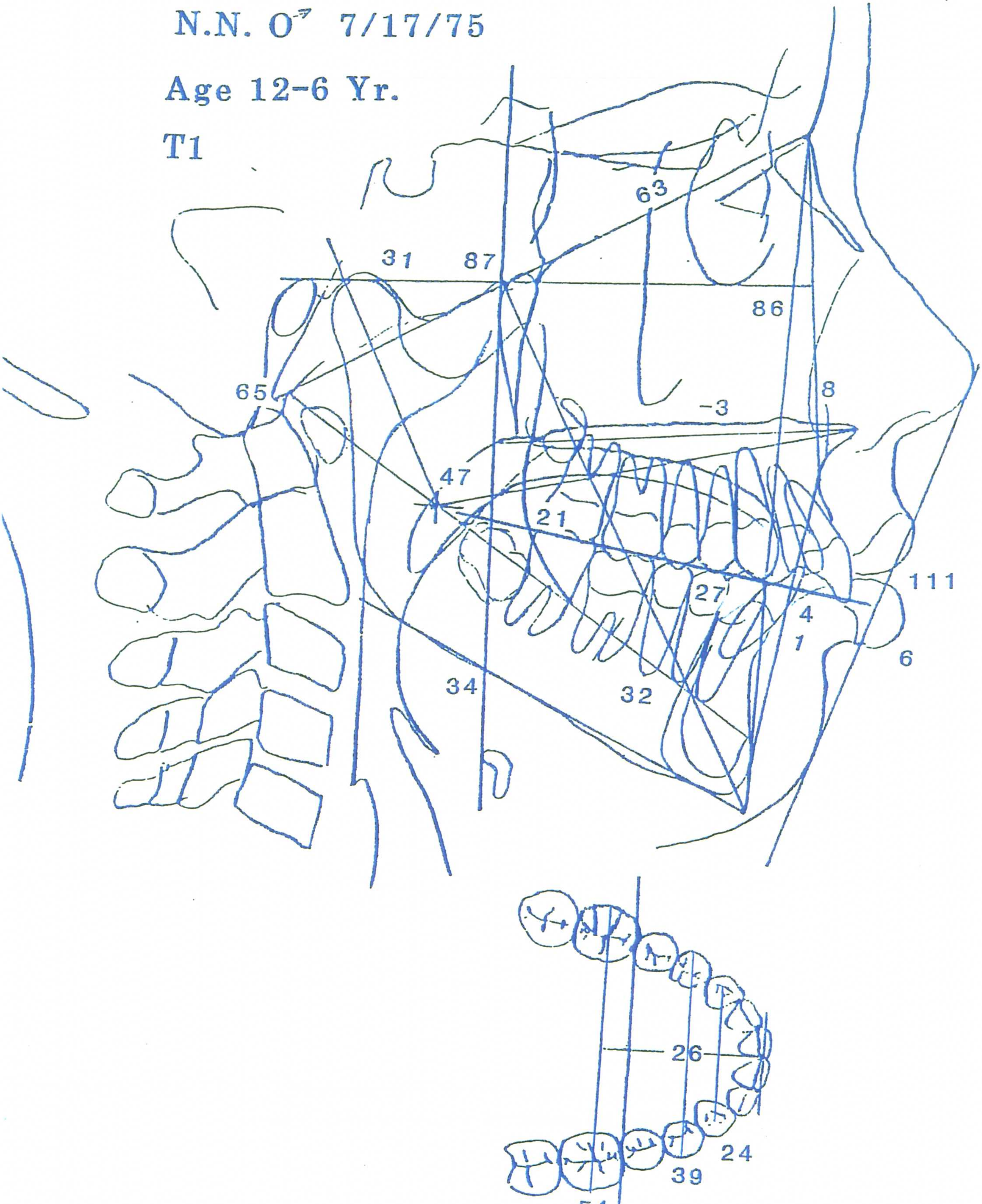


Fig. 4-5-B-L Lateral Summary Analysis of N.N. T1, Male, age 12 years, 6 months. Note extrusion of lower incisors of 4 mm. and Class II with lower lip protrusion. Used for Long Range Forecast to 17.5 years (the last available headfilm).

Below: Note narrow tapered arch form and key dimensions.

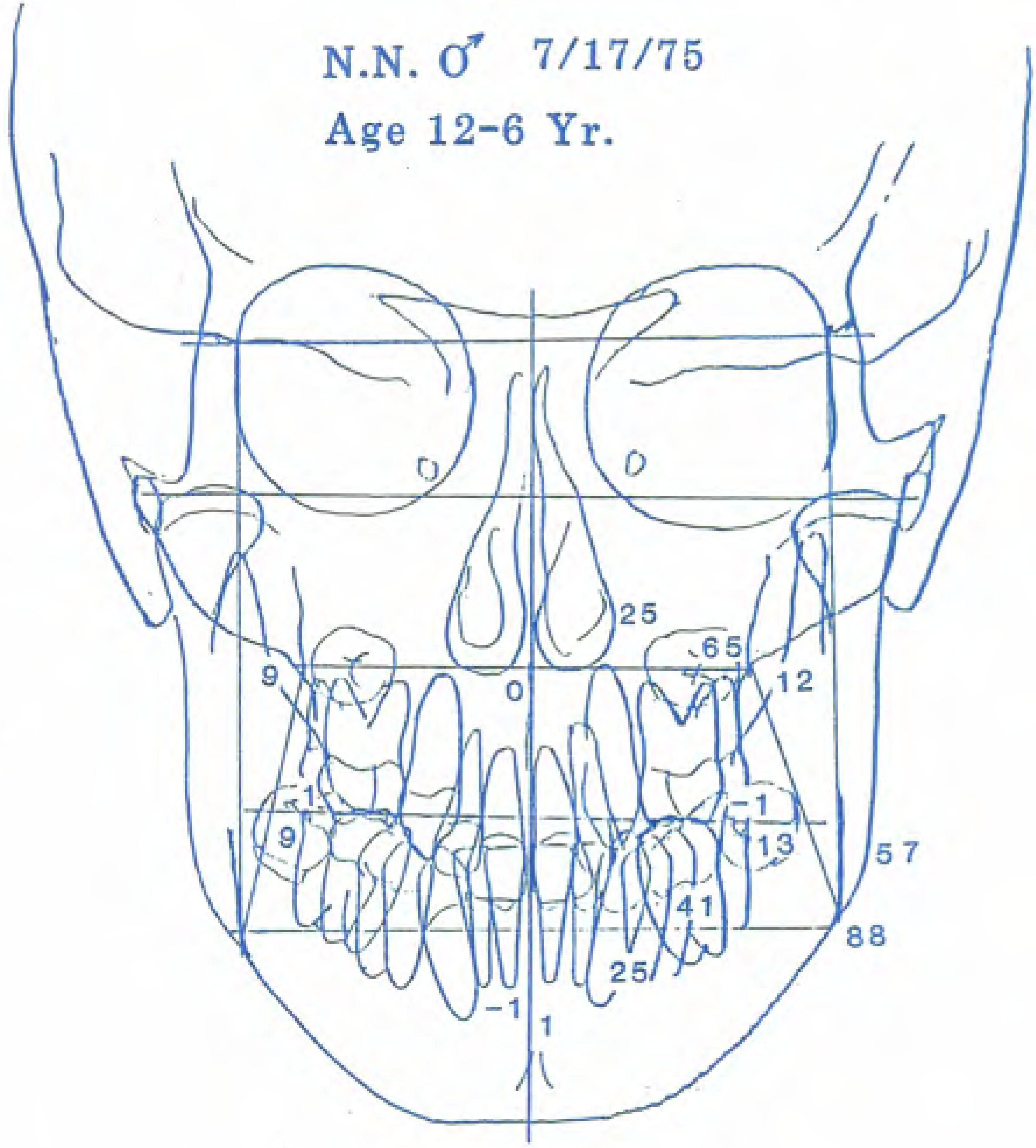


Fig. 4-5-**B-F** T1 Frontal Summary Analysis of N.N. Note cross-bite in frontal perspective often not recognized from model analysis.

Step 4: **For Nasion:** Superimpose the new (Tf) BaN plane on the original BaN plane. Register at PTV and mark Cc on the new BaN plane (Cc is where it crosses the Facial Axis). Add 0.8 mm. per year at Nasion (see Fig. 4-6A-D).

Conditional Factors: Compare the original Cc-N dimension to the data on Chart I (Cc to N = 55.4 mm. at age 8). After the factors are age-corrected and the values differ by 3 mm. or more from the mean, a 0.1 mm. per year correction is made in the prediction.

For example, a slightly larger anterior dimension typifies Class II high convexity patients. Smaller anterior dimensions typify Class III. For best performance of the forecast, both are corrected for such extremes.

* * * * *

Step 5: [Fig. 4-7A for L.A. (female) and Fig. 4-7B for N.N. (male).]
For Point A (Horizontally): Superimpose Nasion Tf on Nasion Ti and provisionally copy (by dashes) the original BaNA angle. Extend the dashed line for future reference of Point A (Figs. 4-7A, A and 4-7B, A).

Comment: Point A may move normally forward very slightly, particularly in patients with a closing type growth behavior of the mandible or a condition resulting from continued thumb habits. On average, however, Point A (in BaN)(at N) changes less than a typical tracing error.

A patient with a natural reduction of the angle BaNA is most difficult to find. It is primarily seen in long developing faces when they do occur. In fact, only one such patient has been found by the author out of the hundreds studied in long range untreated. (Long-range behavior of the palate is another research project for a student, as related to different cranial references.)

Step 6: **For Ramus reference Point:** Drop a line vertically from the original Frankfort Plane through the original Rr point (Ramus reference) (see Fig. 4-7A [B] and 4-7B [B]).
Note: As a mean behavior, according to numerous composites, the **anterior border of the ramus is the only area seen to superimpose during the complete growth process.**

Conditional Factors: It is not unusual to witness behavior in patients with deep or thick rami to move forward at the original Rr reference. Contrary-

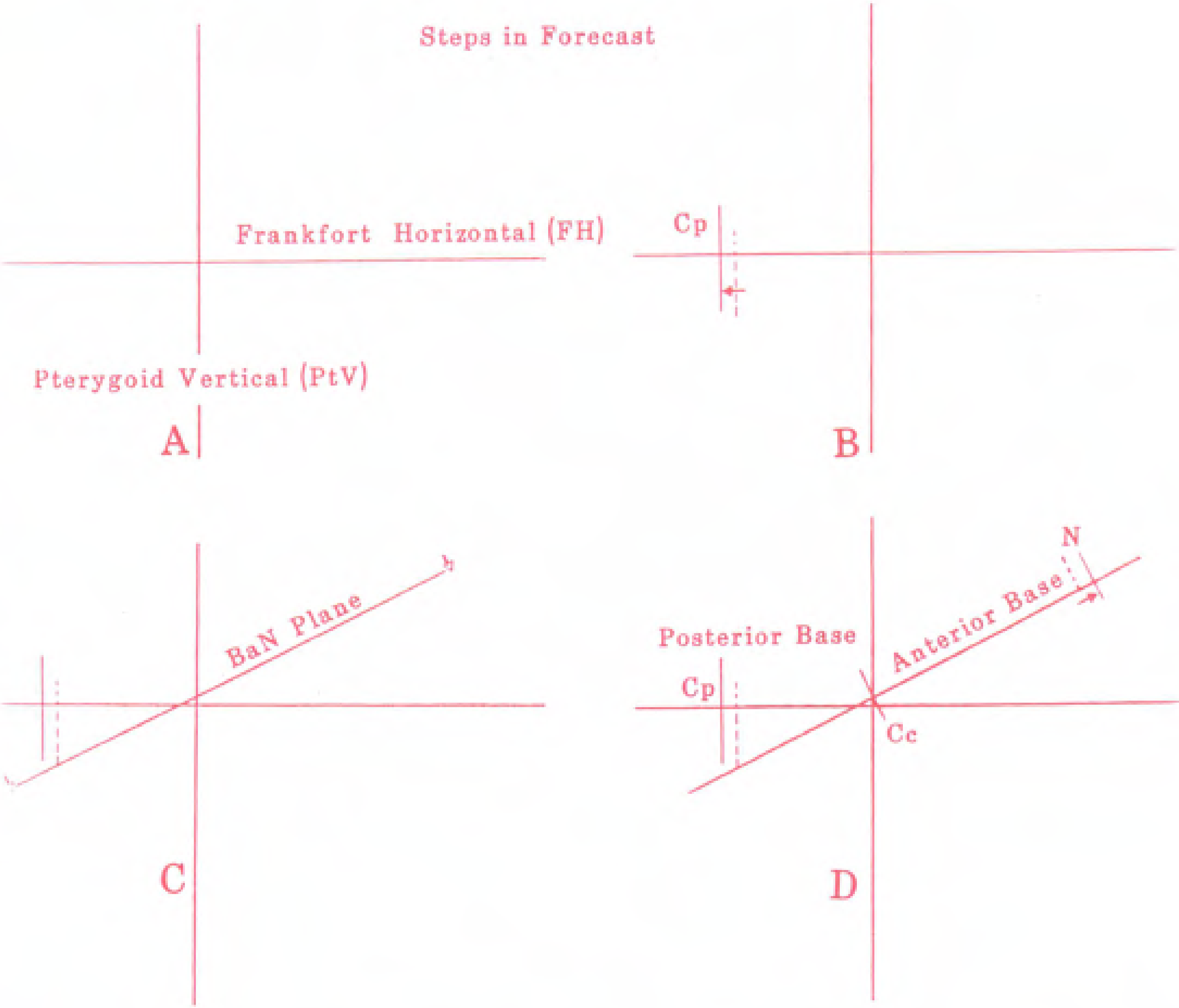


Fig. 4-6A Steps in Forecasting the Cranial Base in Patient L.A. (Female):
A. Basic starting reference (crossing of FH and PTV).
B. Forecast for backward growth of Condylion Posterior (cp).
C. Drop of BaN Plane - (1 mm. - 7 years) relative to FH.
D. Forward growth of Nasion, Register Cranial Center (Cc on BaN). Shows both cranial bases for cogent cranial forecast.

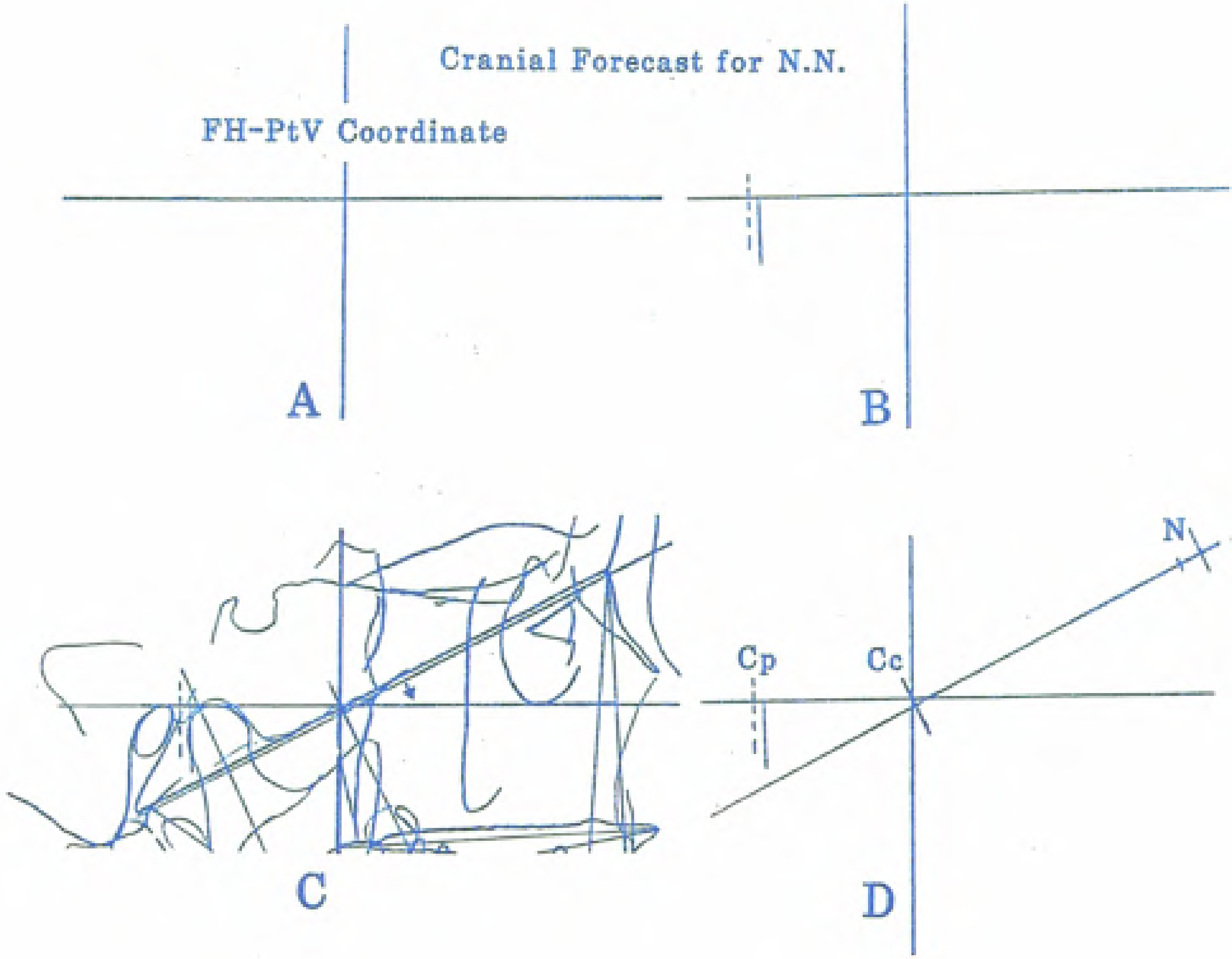


Fig. 4-6B The same type of cranial forecast seen in Fig. 4-6A, but for Patient N.N. (Male):

A. Basic starting reference (crossing).
B. Cp backward growth of Condylion Posterior.
C. Drop of BaN Plane - (1 mm. - 7 years).
D. Forward growth of Nasion, Register Cranial Center (Cc).

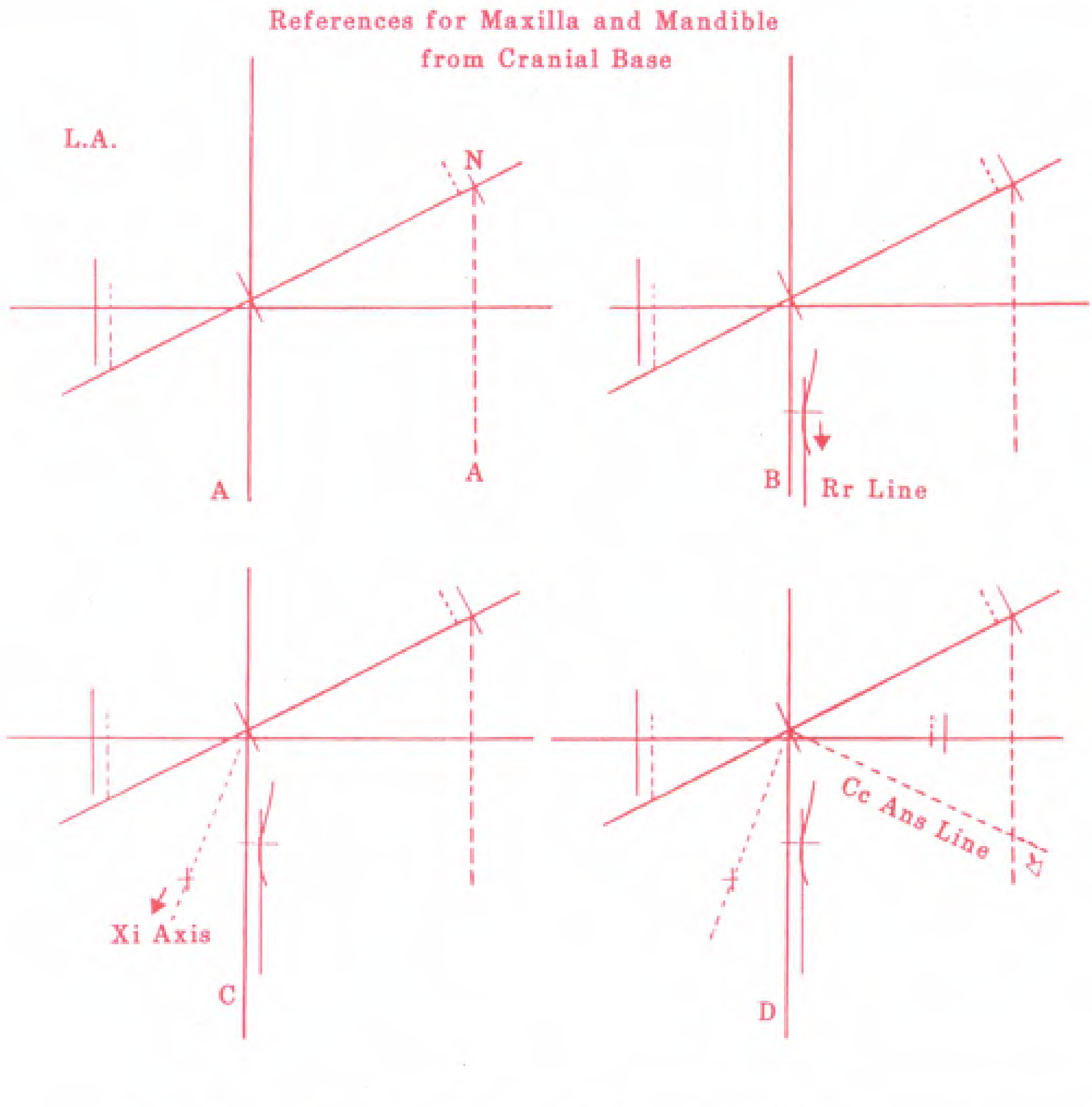


Fig. 4-7A RED for Female Patient L.A. (age 9-11) (Class I)

Shows the use of the Cranial base for reference for maxillo-mandibular forecasts.

A. The angle BaNA changes but little (NA dotted or provisional for treatment plan later).

B. A line perpendicular to FH is dropped at Ramus reference point (Rr).

C. The Xi Axis is copied from BaN at Cc.

D. The vertical drop of ANS is provisional (dotted).

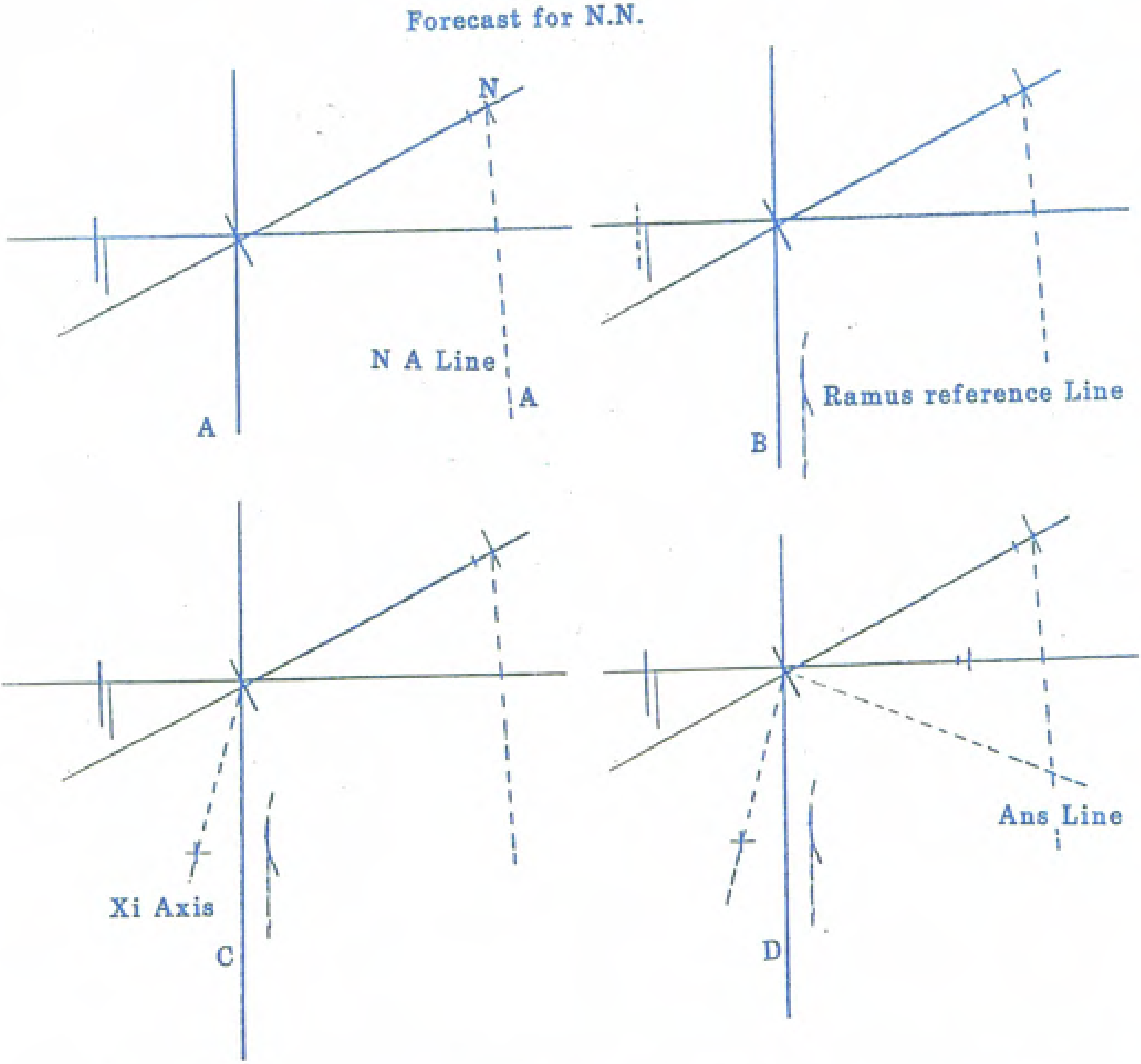


Fig. 4-7B [Blue for male.] Basic cranial reference for Patient N.N. (Class II) for Maxilla and Mandible points.

A. NA line (Nasal Plane).
B. Anterior border of Ramus.
C. Mandibular ramal centroid (Xi).
D. Downward and forward direction of Ans.

wise, very thin rami will sometimes move posteriorly slightly. The behavior is linked to condyle behavior in growth and reposturing.

Step 7: **For the Xi Axis:** From the new Cc point draw the Xi Axis provisionally forward 0.1° each year (1.0° in ten years). (See Figs. 4-7A & B [C]).

Comment: Untreated extreme Class III conditions often continue to worsen until the Xi Point may lie ahead of the pterygoid vertical reference. In cases of inhibited condyle growth the Xi Point will move backward, according to the condition or condyle arrest.

Step 8: **For Orbitale:** Mark orbitale (O) forward on FH at 0.55 mm. per year if desired, but its prediction anteriorly is not critical for clinical work.

For Ans Height: Open up the angle from Cc to Ans 0.3° each year. Make a provisional (dashed) line from Cc with the new angle(see Fig. 4-7A & B [D]).

The cranial forecast is now essentially complete on the new sheet which should be laid aside for later application (Fig. 4-7A and Fig. 4-7B).

With all the foregoing factors combined a basic cranial forecast is completed.

* * * * *

PART TWO: Technique for Forecasting the Mandible

Introduction: The Time 1 tracing may be faulty at the coronoid, the sigmoid notch, or the condylar area. Likewise, any later tracing for comparison may be of a different quality and traced differently at the thin bony areas. In the forecasting exercise the sigmoid notch tracing may not be exact; however, the amount of change to be forecasted is the critical issue.

All parts are bisected unless extreme variation or pathology is present in one or both joints (which may be missed).

Step 1: Construction of the working arc on the original tracing (T1): (Fig. 4-8, A & B).

a. Locate accurately the **Pm** Point (see previous manuals);
b. Locate **Eva**, by bisecting the base of the coronoid (by estimate). But for better detail, bisect the upper one-half of the ramus, draw a perpendicular to the anterior border, which locates **Rr** (Ramus reference); then connect Rr to R3, and, finally, bisect the line to produce the Eva reference.
c. With a compass employ the distance from Eva to Pm in order to locate a third point equidistant to both, upward and forward. This is Tr point (point of true radius).
d. From Tr construct an arc through points Eva and Pm.
e. Mark Murray point (Mu) at the crossing of the arc on the sigmoid notch (see Fig. 4-8C).

(See illustrations on following pages.)

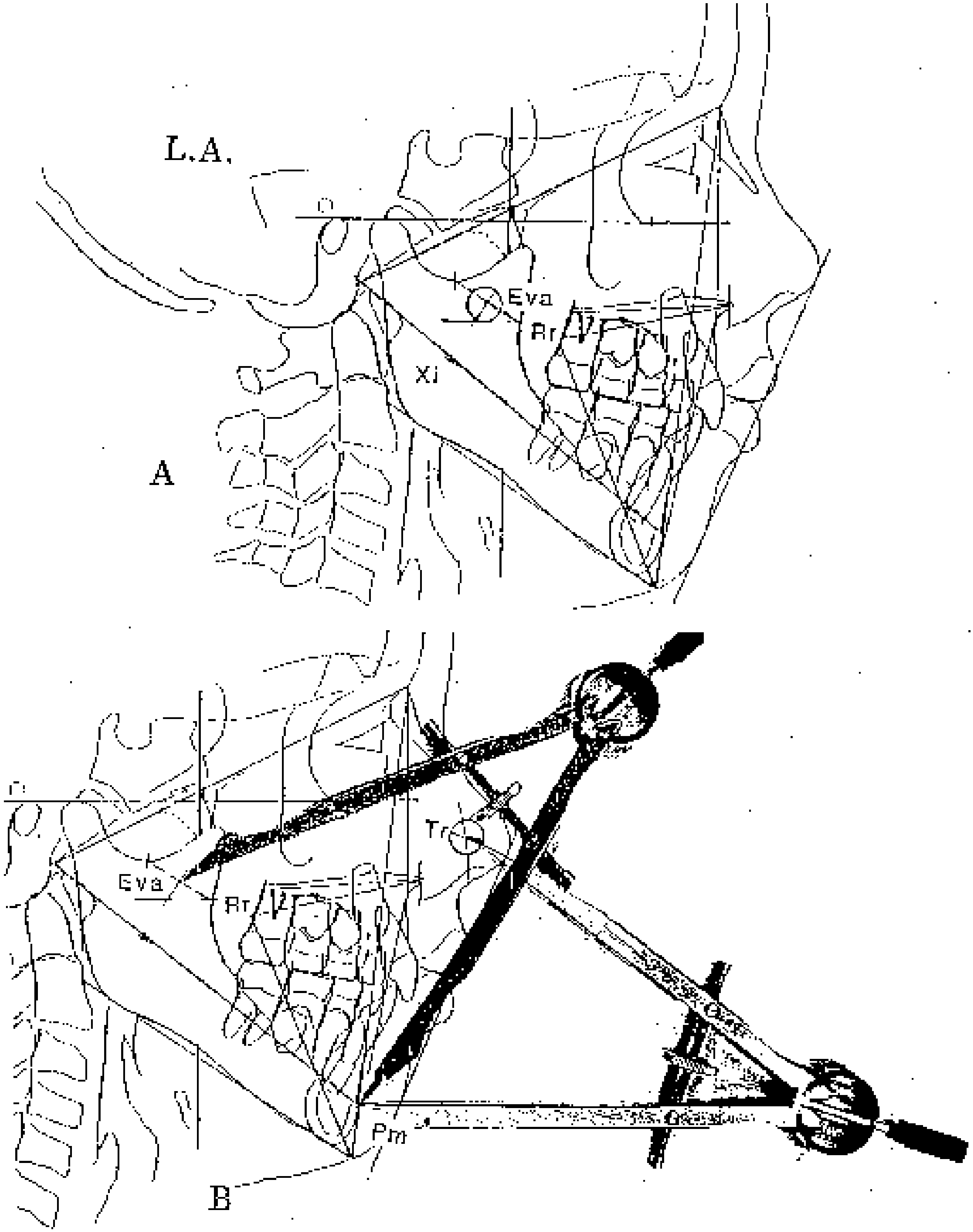


Fig. 4-8A Steps in arc construction for Patient Laurie (L.A., age 9-11 years).

A. Location of Point Eva by Bisection of line from Ramus reference [Rr] to center of Sigmoid Notch [R3] (see circle).

B. Depiction of the use of a compass using Points Eva and Pm to locate Tr (point of true radius) for arc construction (see circle).

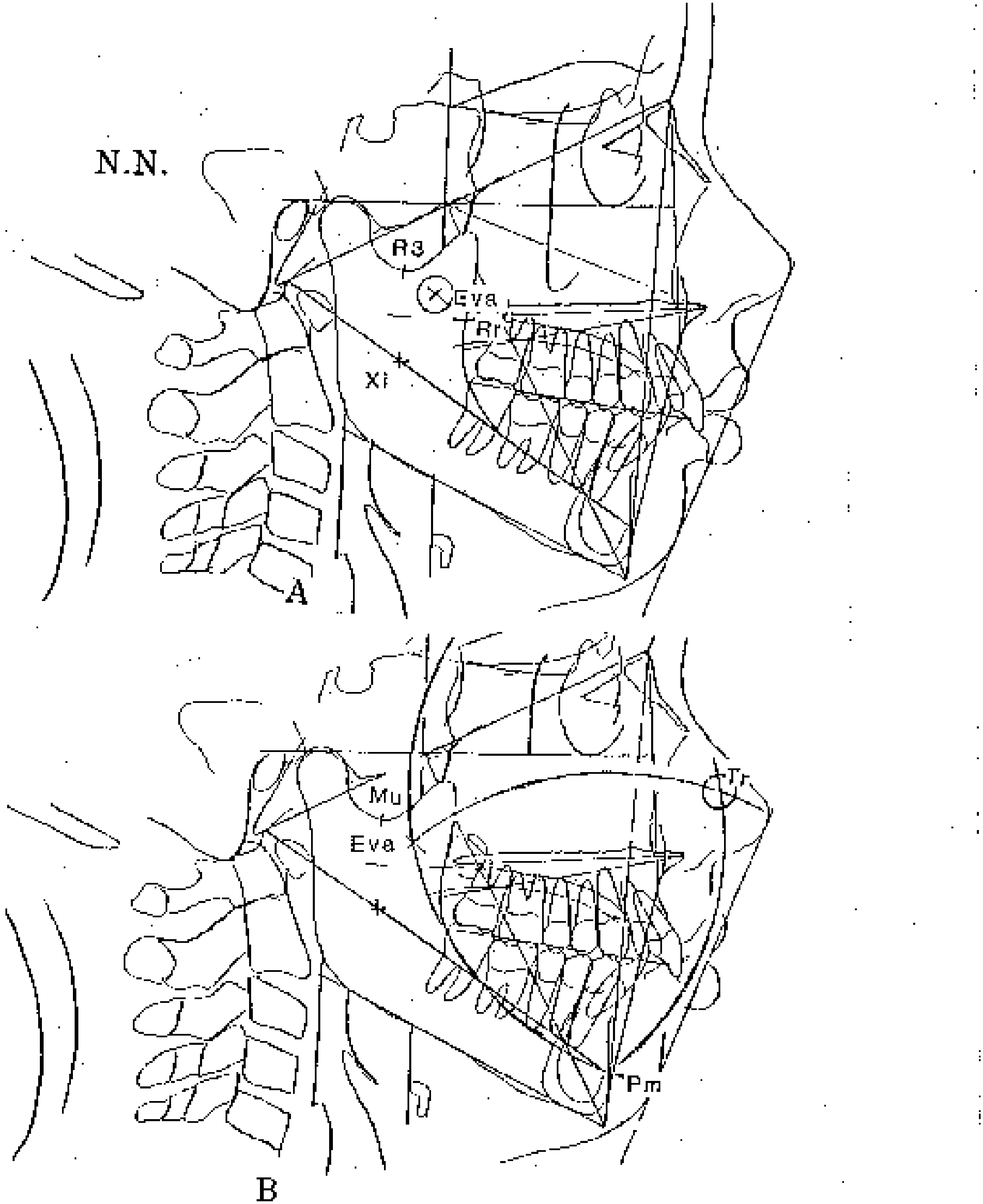


Fig. 4-8B Arc construction for Patient Nicholas (N.N.)

A. Bisect Xi to R3 and mark Rr at that level on the anterior border of the ramus. Mark Point Eva ½ the distance to R3 from Rr.

B. Use Pm and Eva for radius to find Tr; use Tr to scribe arc through Pm & Eva. Point Murray (Mu) is located at crossing of the arc with the sigmoid notch.

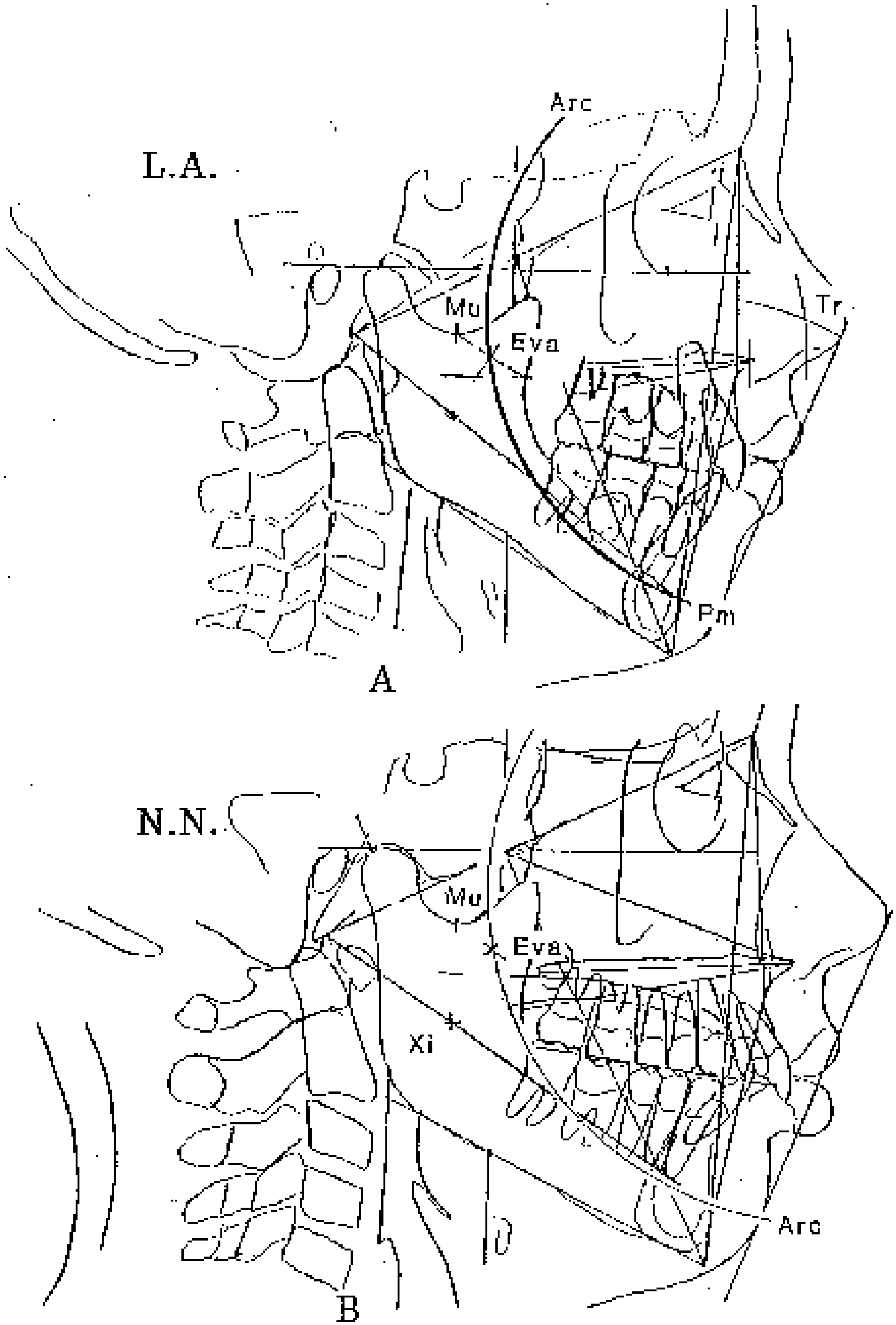


Fig. 4-8C Finished arcs for the forecasting of mandibular growth in Laurie and Nicholas

A. L.A. (Class I - Female, age 9-11)

B. N.N. (Class II - Male, age 12-6)

Step 2: **For forecasting of the symphysis:** On a new, full piece of tracing paper (for Tf), near the center of the paper, copy the arc from the original T1 tracing.

[1] Mark Pm (Fig. 4-9A&B) at the anterior limit of the arc. Add appositional changes around the circumference of the symphysis below Pm, as follows (see Fig. 4-9B):

Conditional Factors for the Symphysis:

For Females there is no appositional growth after age 6.

For Males at all ages:

Average 0.2 mm. per year completely around the lower border, feathered up to Pm point, in keeping with normal morphology (same for females only at ages before age 6) (see Fig. 4-9B).

For **a very thick symphysis** (as in extreme brachyfacial patterns in males): Add 0.25 mm. per year. These seem to be a result of bending stress in wide strong mandibles.

Step 3: **Growth on the arc:**

Calculate the amount of growth on the arc by using a factor of 2.5 mm. each year. Superimpose at Pm on the arc. [2] Mark off growth projection on the arc at Point Mu (see Fig. 4-9A).

Conditional Factors:

For Amount of Growth on the Arc:

[3] For Females -- add 2.5 mm. per year to cut-off at age 14.8 years. (The mean female growth was 2.46 mm. per year.)

For Males -- add 2.5 mm. (the average was 2.54 mm. per year) to cut off at age 19.0 years.

Note: A variation of 0.04 mm. per year means only 0.4 mm. in ten years, and that is less than a 0.7 mm. pencil line.

Wrist-plate check:

If a male or female is early or late, according to the Pyle index, the age to cut off can be corrected. (But it is truly amazing how growth averages out in 7 to 10 years' time.)

Method:

Mark off the growth amount on the chord of the arc on Tf. Bisect that total amount for future reference (1/2 Mu). [4]

* * * * *

Steps in Forecasting Mandible
(Female) L.A.

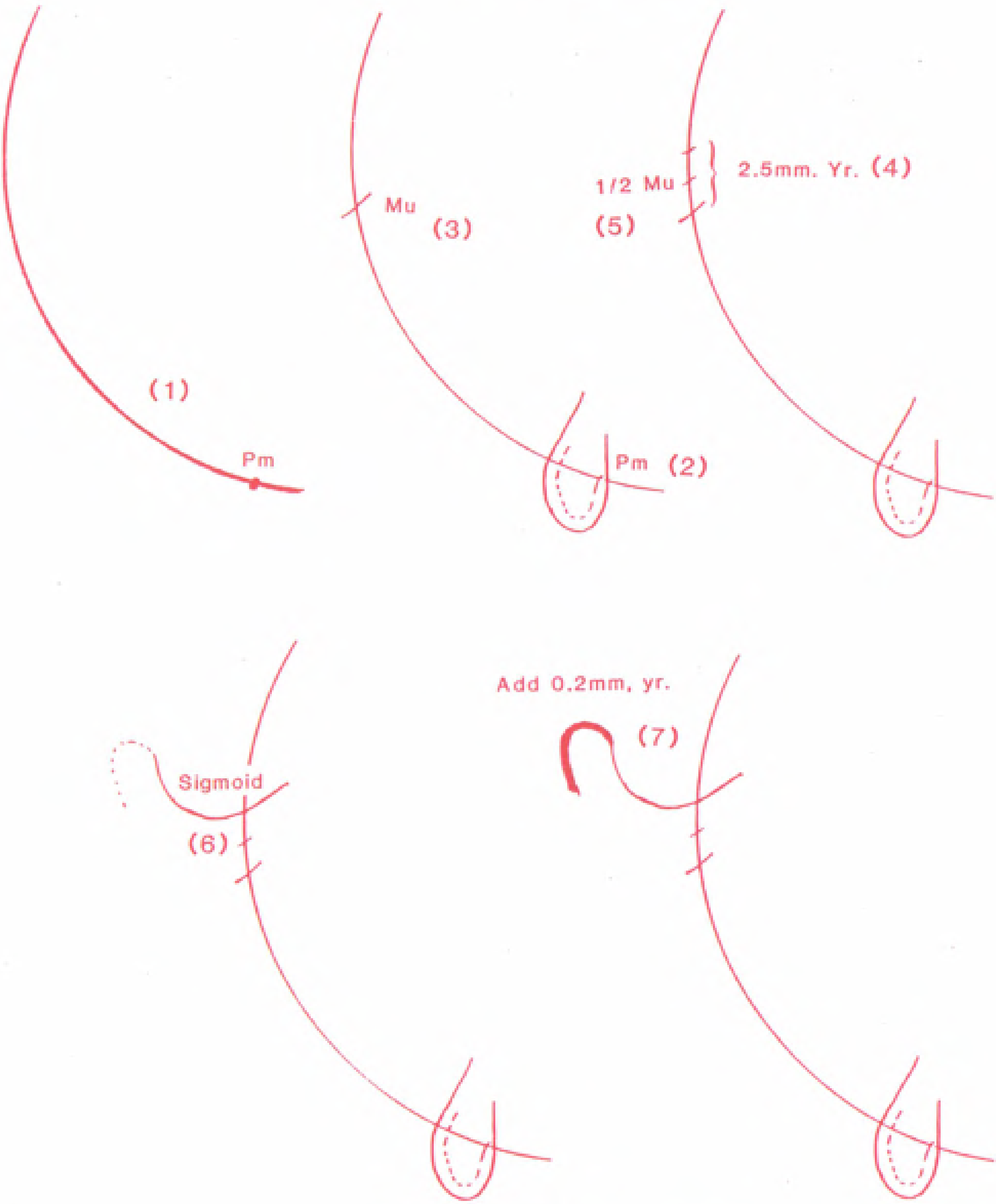


Fig. 4-9A See text.

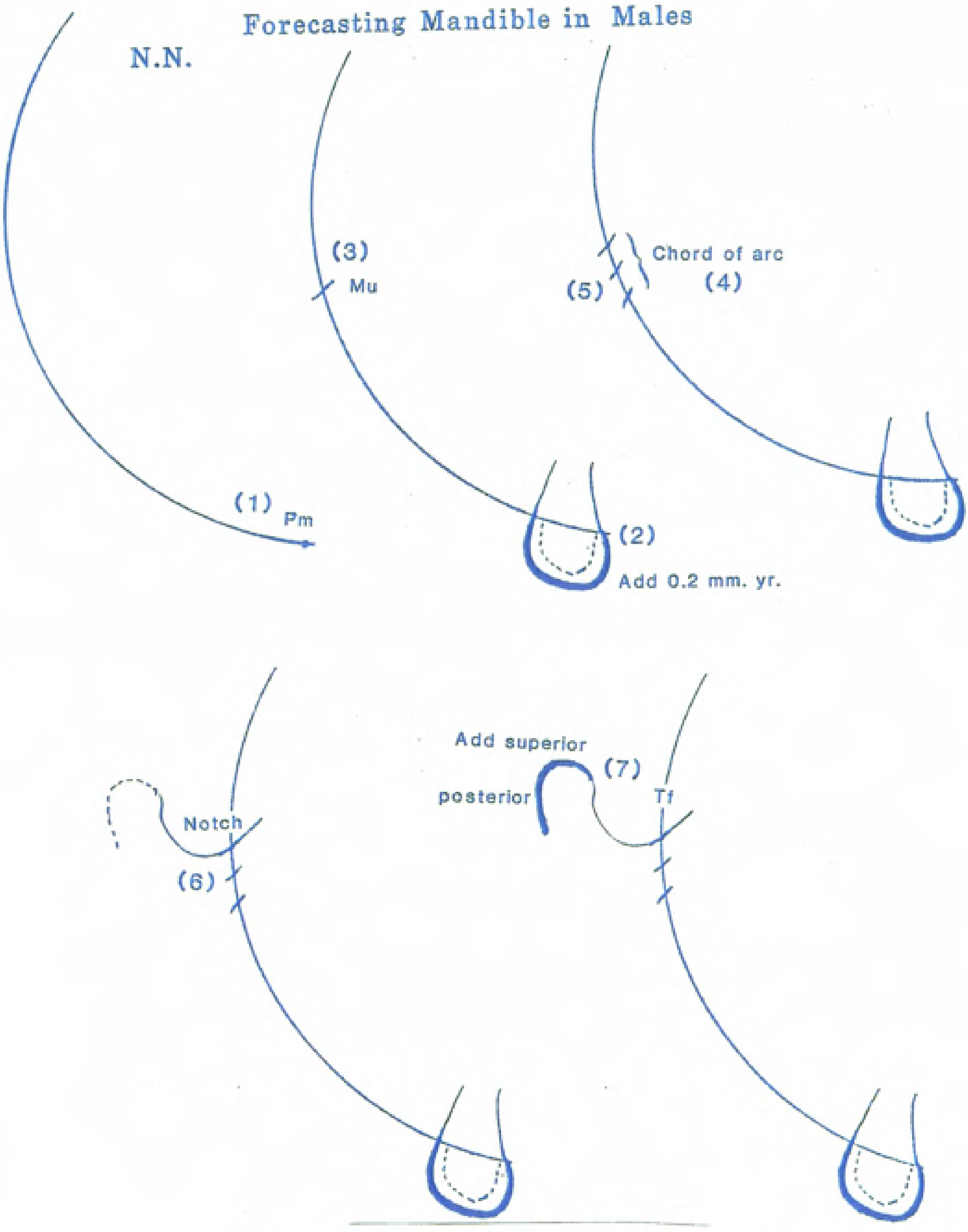


Fig. 4-9B See text.

Conditional Factors for True Prognathic Types

Seven characteristics of the **Mandible** to be recognized:

1. Long thin symphysis
2. Longer body (Corpus Axis)
3. Obtuse core angle (Condyle Axis - Corpus Axis)
4. Flatter gonial angle
5. Thin ramus (at R1 to R2)
6. Long thin condyle neck or short "stubby" condyle
7. Shorter or longer Coronoid Process

Common characteristics in **the Cranial Base** in Class III:

1. Higher than average Glenoid Fossa (relative to Frankfort Horizontal)
2. Flattened or long eminentia
3. Short Posterior Base Porion (or Cp) to PTV
4. Short Anterior Base dimension (Cc-N)
5. Xi Point near or forward of PTV

When the majority of the above are present a 3.0 growth per year on the arc for prognathism (**without treatment**) is predicted.

* * * * *

Step 4: For the sigmoid notch:

For sigmoid notch and condyle (at Mu Tf) **[5]**, copy the sigmoid notch posteriorly up to the subcondylar fovea area (see Fig. 4-9A & B).

For the condyle:

Additional condyle growth 0.2 mm. per year is made from the anterior border of the condylar head on superior and posterior margins **[6]** (about 80% of patients were found to behave very close to this behavior).

Conditional Factors: Condyle lengthening appears to **also behave on a size-gain phenomenon basis**. This occurs when the mandible (1) is not **disturbed** by treatment, (2) does not suffer a biologic insult such as trauma, or (3) reacts to a very strong opening rotational phenomenon, such as a breathing embarrassment, or (4) behaves in response to the growth of a very long cervical vertebral apparatus.

The length of the condyle neck (to the line from R2 to R3) is usually close to its base length to Xi Point (about 20 mm. and 20 mm. at age 8) (see Fig. 4-5). If the condyle length is 3 mm. to 4 mm. longer a value of 0.3 mm. per year is predicted for condyle addition. If it is 5 mm. longer than the base length a 0.4 mm. per year value is added, such as seen in mandibular prognathism.

* * * * *

In conditions of idiopathic condylar hypertrophy, the condyle when already curved forward may grow upward and forward 1.0 mm. to even 1.5 mm. per year (Fig. 4-9C). True mandibular prognathism is characterized by long narrow condyle necks.

If the condyle is very short or "asthenic", no growth or 0.0 mm. is added. In obvious disease states even condylar involution must be considered (see Fig. 4-9C). These are characteristic of osteoarthritis, rheumatoid arthritis, lupus, idiopathic aseptic necrosis, or sometimes severe trauma or other infections such as psoriasis.

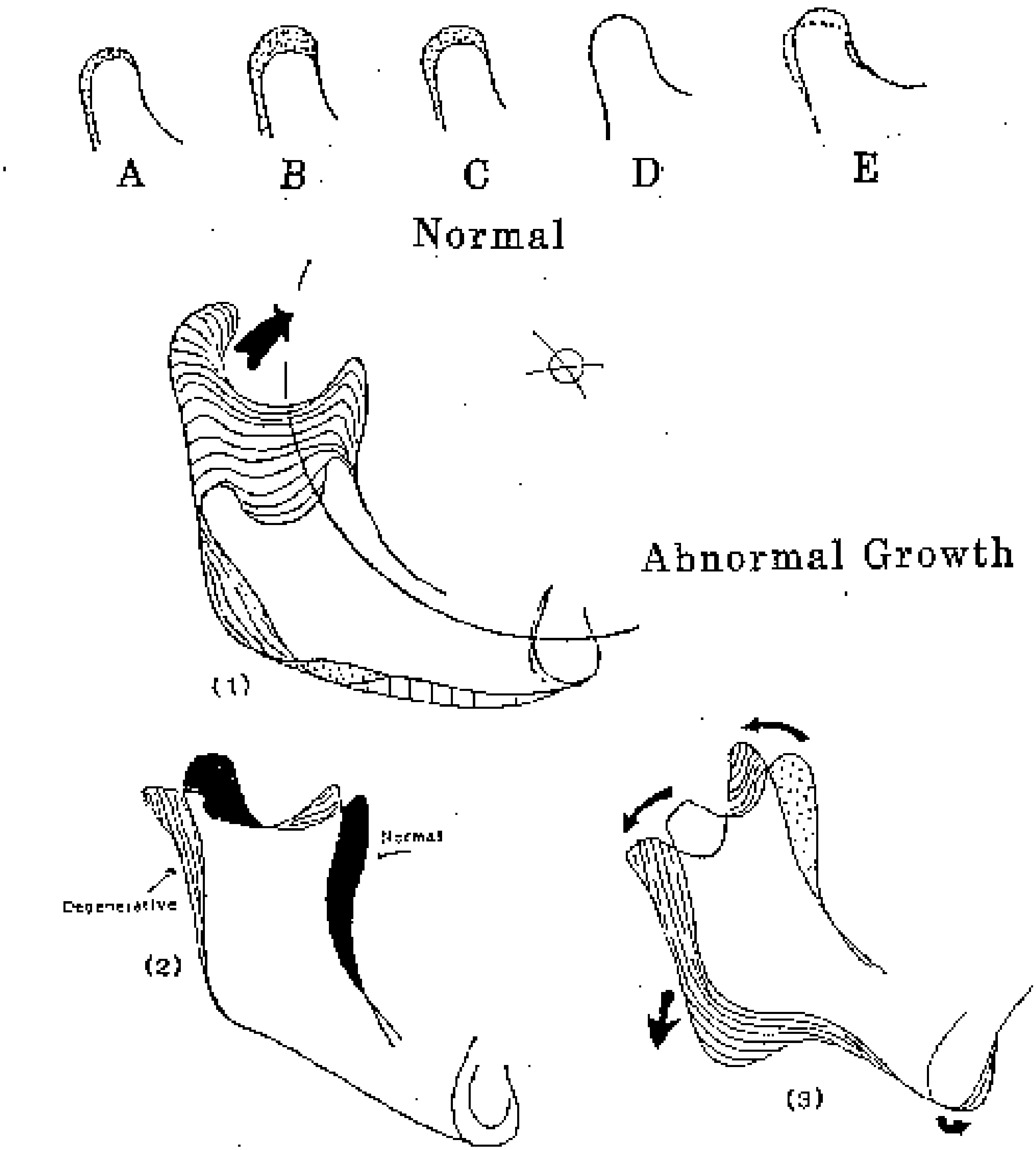


Fig. 4-9C (A) Typical condyles (and condyloid processes) as described are given 0.2 mm per year.

(B) Condylar growth in mandibular prognathism yields 0.3 to 0.6.

(C) Turgorous (strong) condyles may grow 0.3 to 0.4 a year.

(D) Asthenic (weak) condyles may not grow, period.

(E) Diseased condyles can actually involute (shorten) (see 2 & 3)

1. Idiopathic hypertrophic condyles may add up to 0.5 a year, even more has been noted.
2. Shows growth alteration in osteoarthritis (trauma).
3. Shows rheumatoid arthritis behavior. Note antegonial notch and secondary symphysis modification.

Step 5: **For Gonial Angle Drift and development:**
Superimpose at 1/2 Mu point on original Mu (Fig. 4-10A). It is ironic that the drift of the angle is almost **exactly half the total growth on the arc.**

Conditional Factors:

For Females: Copy off original gonial angle (no sexual expression is seen except in very rare androgen types).

For Males: For mean values add 0.2 mm. per year around the gonial angle to about 2 cm. above and 1.0 cm. anterior to the Gonial angle (see N.N., Fig. 4-10A).

In prominent gonial angles **in males** add 0.25 to 0.30 mm.
For Class III prognathic types with open gonial angles **no growth** at **gonion is added** for males (like the female) (see Fig. 4-10A).

Note: orthodontic treatment of prognathism has been seen to change the growth pattern of the mandible in some patients. The mechanism is still not known but probably is related to the muscle or functional phenomenon and a compression of the condyle (upward and forward). (Research project for a student.)

Mandibular Borders (see Fig. 4-10A):
Art work is conducted by superimposing on the original form first, then connecting the gonial angle to the condyle, followed by connecting the gonial angle to the symphysis.

Step 6: **For the Anterior Border of the Ramus:**
This is **an important consideration because ramal depth will have a bearing on mandibular positioning** (see Fig. 4-10A).

* Superimpose **Tf** at ½ Mu on T1.
* Mark the original **Rr** point.
* Add 0.3 mm. anteriorly per year at the external oblique ridge for the increase, and mark a point. The external oblique ridge contour is created by a backward shift of the Tf to the original tracing. The anterior coronoid incisure is carried about 1.5 cm. above Tf-Rr point and the external oblique ridge about 1 cm. below it (see Fig. 4-10A).

The forecast of the mandible is now essentially completed (Fig. 4-10B).

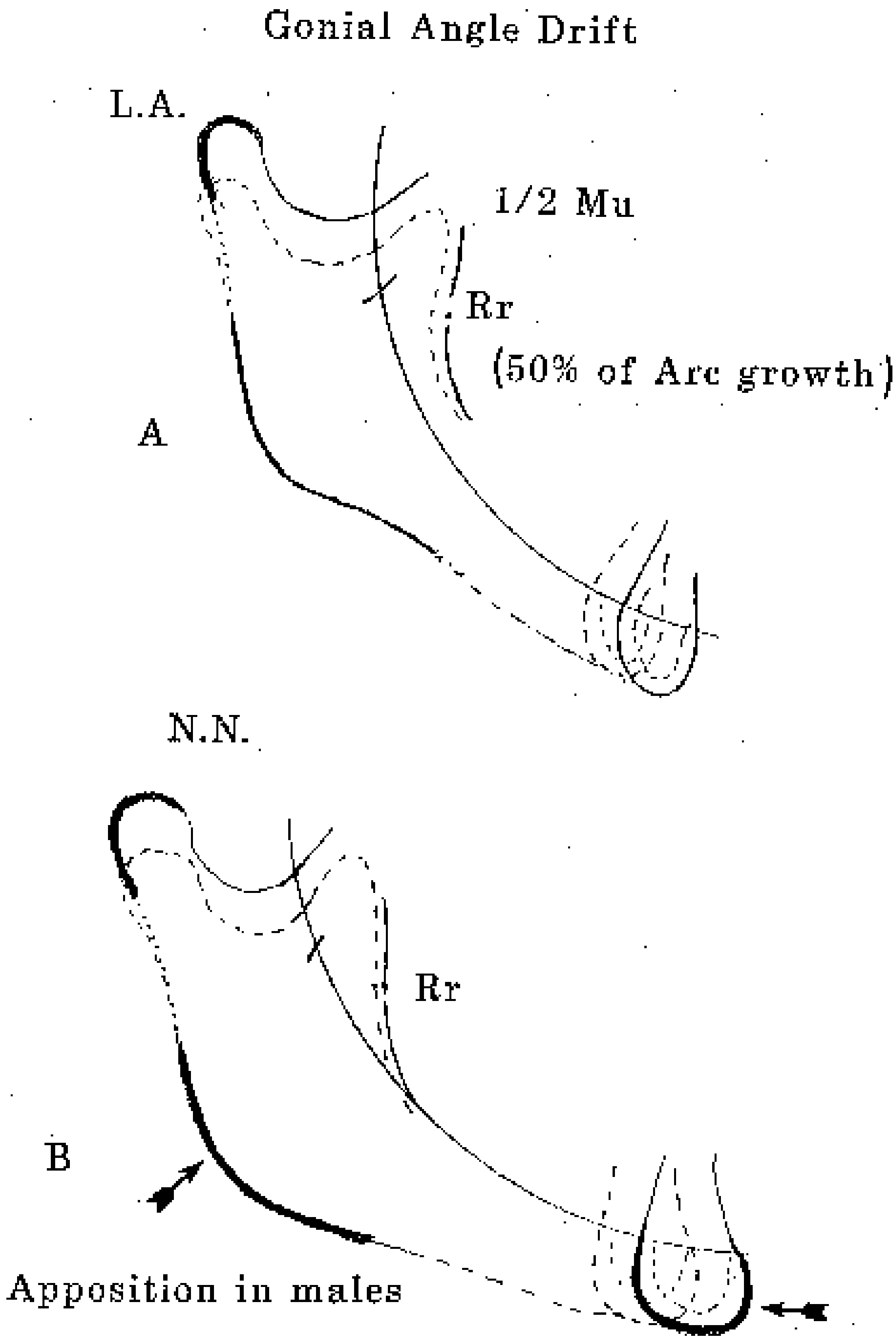


Fig. 4-10A For Gonial angle and Ramus depth. L.A. female, N.N. male. Gonial angle drift is ½ total growth. Note apposition at anterior ramal area with the technique. Note apposition of gonial angle in normal males.

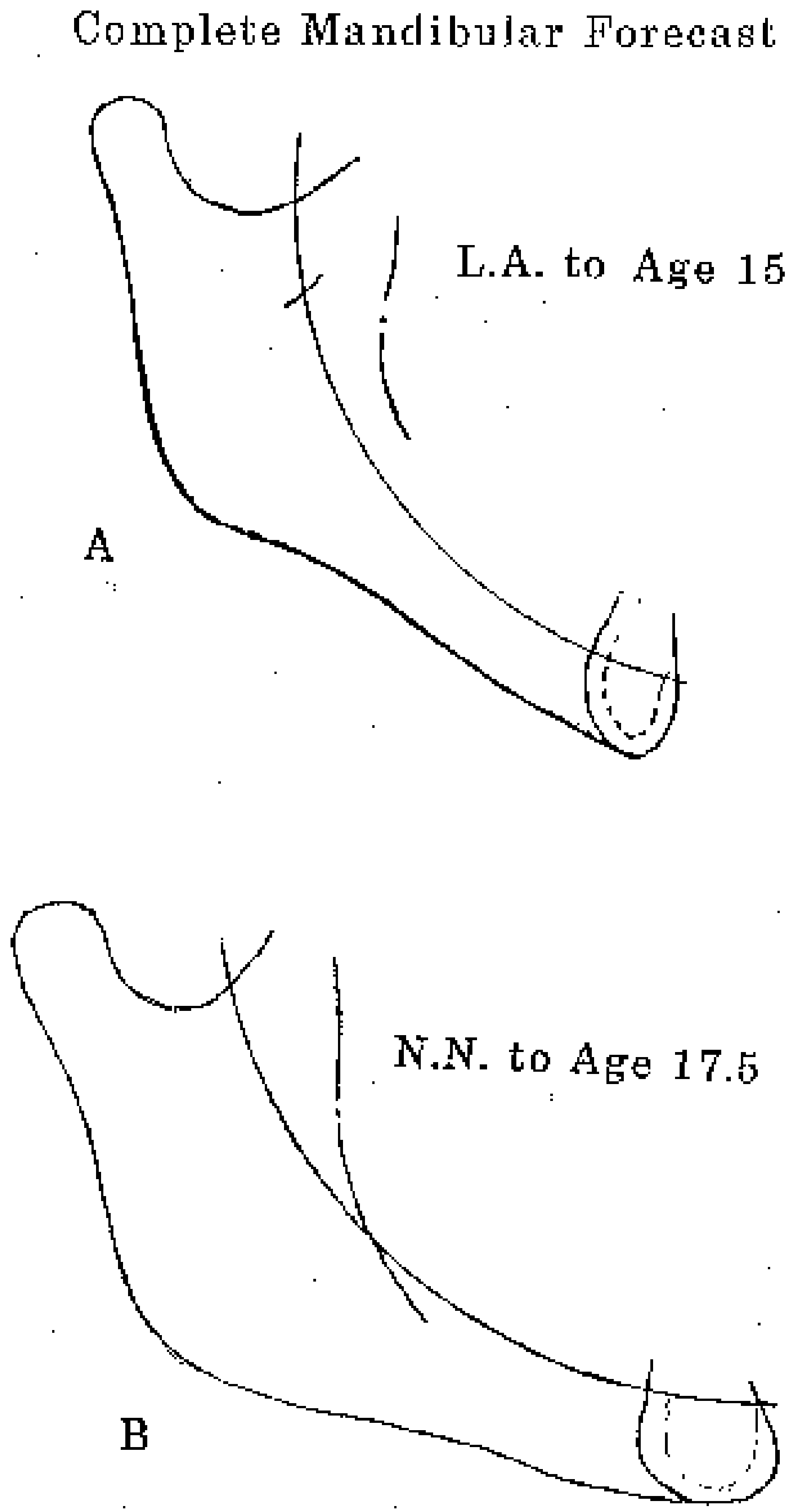


Fig. 4-10B The complete forecasts for Laurie (to age 15) and Nicholas (to age 17.5), five years for each subject.

* * * * *

Step 7: **Forecasting Gnomonic Behavior Tendencies from the mandible:**

A. Calculate a new Xi Point (Fig. 4-11A).

B. Draw a new Corpus Axis from Pm through Xi and extend it posteriorly about 5 cm. for future application (see Fig. 4-11A).

C. Establish the new Condyle Axis (bisect condyle neck at the level of the fovea) (see Fig. 4-11A).

* * * * *

D. Superimpose Xi-Tf on the original Xi Point. Copy the original true buccal occlusal plane (it may drop posteriorly 0.15 mm. per year for Curve of Spee development) (Fig. 4-11B & C).

E. With Xi registered and the Corpus Axis superimposed, draw a provisional (dotted) ORG line (Ans-Xi) (see Fig. 4-11B & C).

F. With Xi Point and the Corpus Axis superimposed, draw provisional (dotted) line through N (Nasion) for a later consideration (see Fig. 4-11B & C).

Forecasts insofar as behavior from the mandible is concerned are now completed (see Fig. 4-11C). For review, those forecasts are: the level of the denture height (the occlusal plane) and the provisional fit of the future mandible to the cranium and to the maxilla.

Now the main difficulty in forecasting arises. It is the detailed fitting (as much as possible) of the mandible to the cranium.

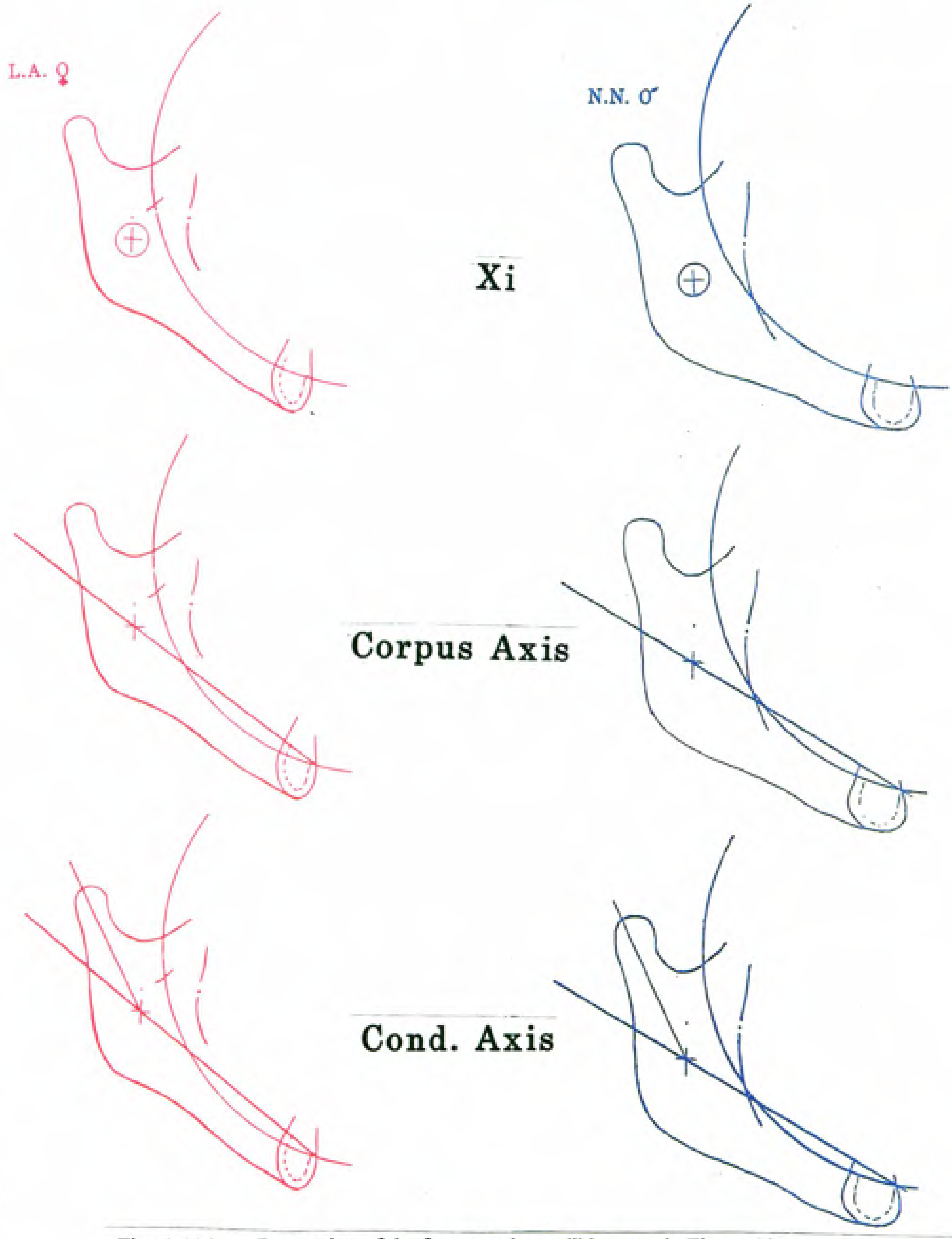


Fig. 4-11A Processing of the forecasted mandibles seen in Figure 10.

A. Measure and locate Xi.

B. Draw line from Pm through Xi for the Corpus Axis.

C. Draw line from Xi through center of the condyle neck (at the level of the fossae) for the condyle axis.

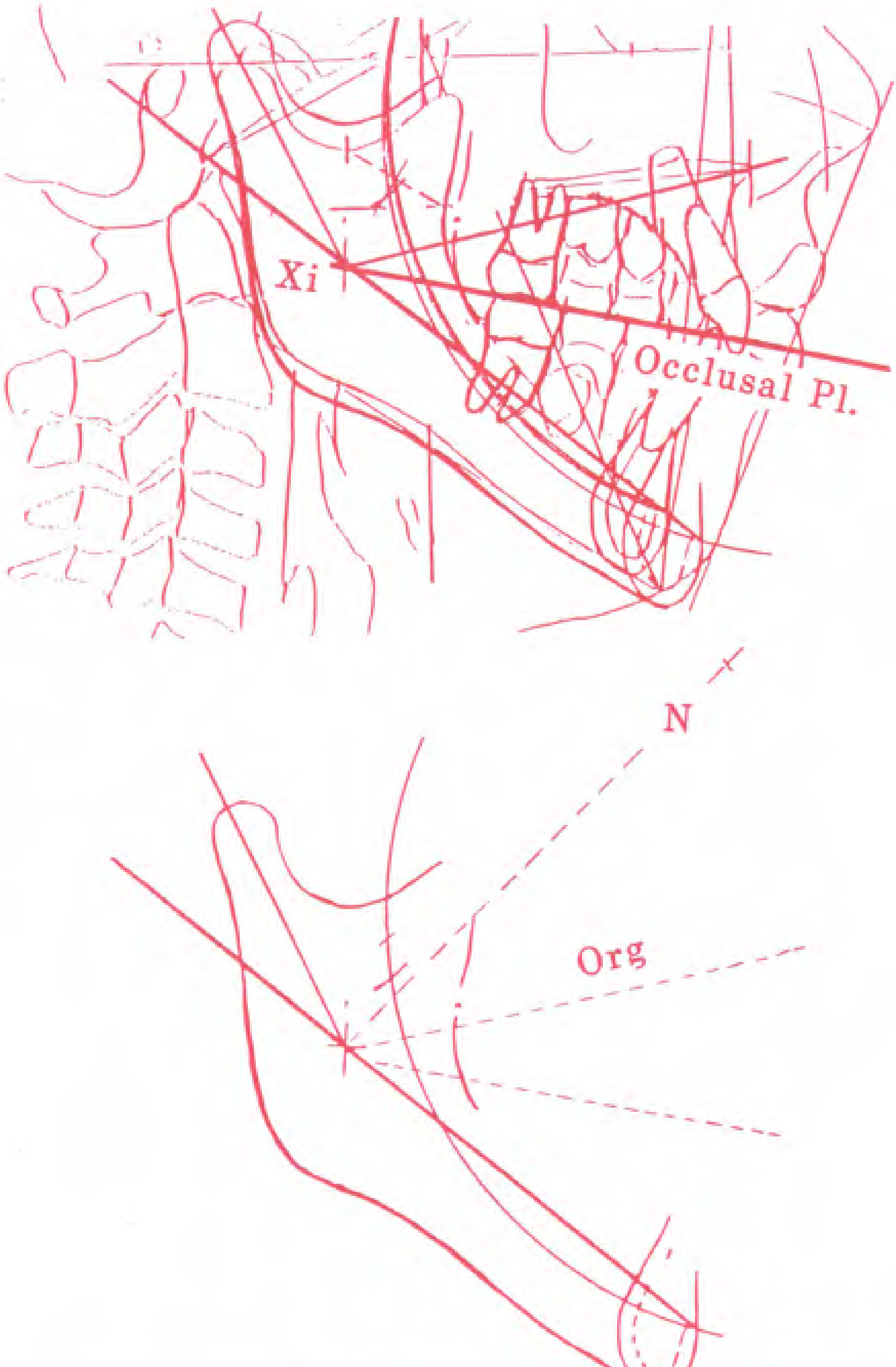


Fig. 4-11B **Above:** The forecasted mandible is superimposed on the original tracing at Xi to predetermine the occlusal plane. **Below:** the org line (Ans-Xi) and Nasion

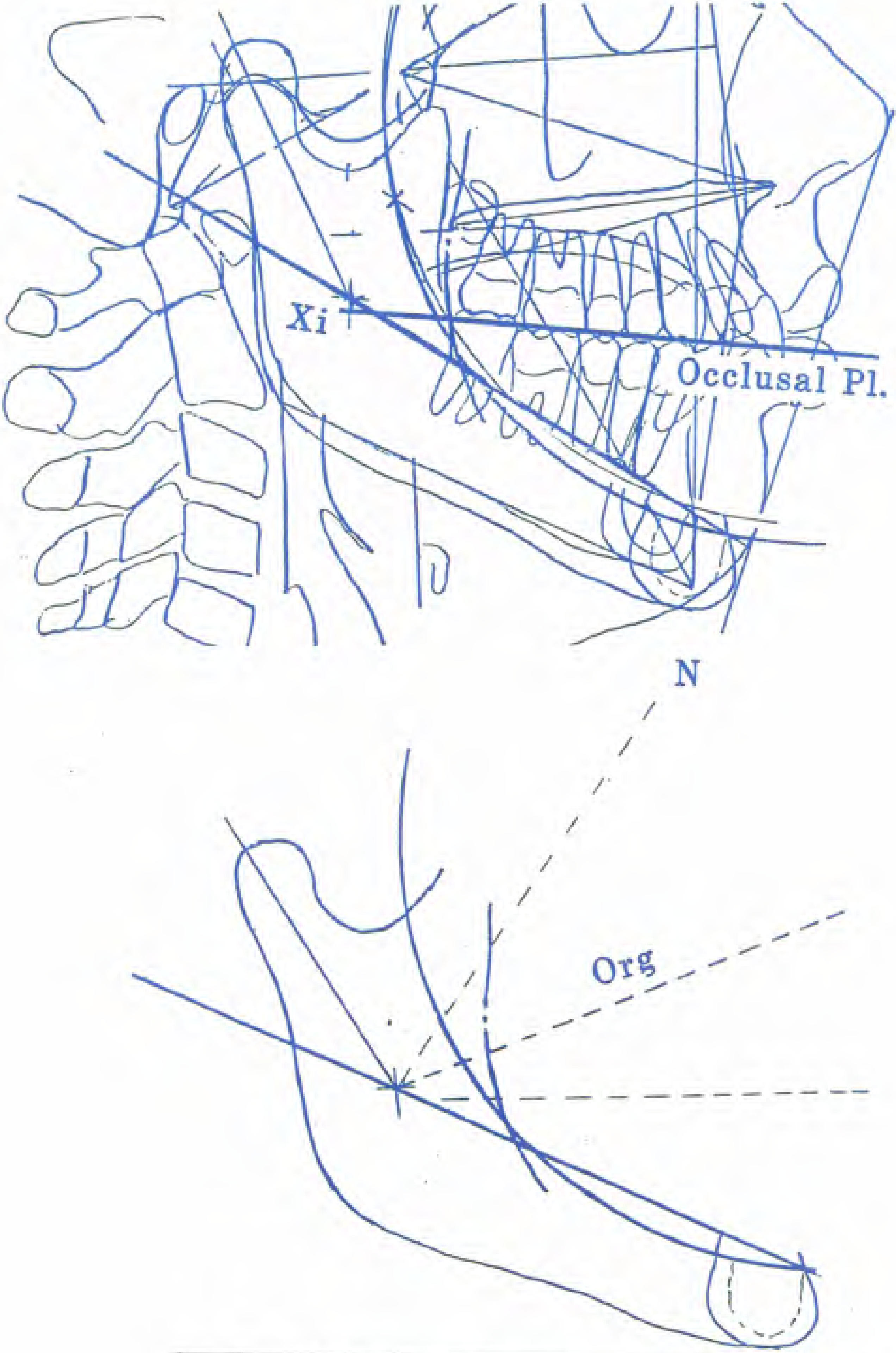


Fig. 4-11C Technique for forecasting the occlusal plane point, Ans, and Nasion.

PART THREE: Fitting the Mandible to the Cranium and the Upper Face

Technique for Matching the Mandible to the Cranium

Two tracing sheets are employed thus far for this teaching exercise. One is for the cranial forecast, the other is for that of the mandible. These two separate productions now must be rectified, or put together. **(It should be understood that the forecast could also be done on the T1 tracing if desired.)** The Cranial Base and the mandible are shown in Figure 4-12A & B.

Step 1: Superimpose the Tf mandible on the Tf Cranial Base and the condyle (Cp and Cs) in the same or the corrected position to the Frankfort Plane (Fig. 4-12C & D)).

Step 2: With the central morphology being anything but atypical, the ramus is now trial-positioned in three ways.

The new **Xi** is placed on the original Xi axis (see Fig. 4-12C & D). A second check is made for alignment of **Rr** on the Rr line.

A third check is made with an orientation from Xi to **Nasion.** It will miss on average, the mean behavior opening about one degree to the Corpus Axis in 7 years. Again, this reflects condyle turgor behavior.

Now, with the condyle held in place, if the lines and references, particularly the Xi Axis and **Rr** line, are in agreement the new Basion-Nasion Plane can be copied with better confidence as originally rendered in the cranial forecast.

Conditional Factors: If the condyle is short or weak and no extra growth was forecast for it, – then **the Xi Point will move distally** and the face may be lengthened or the chin retracted. Conversely, if the condyle is large, strong, and inclined forward, the Xi Point may move forward slightly. If a Class III is unchecked with treatment, the Xi Point may move forward significantly, particularly in closed bite Class III.

Thus the position of the chin is directed by the ramus! This is the most delicate part of the whole procedure (see Fig. 4-12C & D).

Step 3: **The Cranial Base**

Superimpose the cranial and arcial mandibular forecasts and copy the cranial forecast onto the mandibular forecast (Fig. 4-12E & F).

To repeat the sequence: (1) the condyle is positioned in a new position, (2) the mandible is rotated via the ramus by orienting to the

Xi axis, Rr line and Nasion, and (3) the cranial components are copied onto the mandibular forecast (significantly the BaN).

Step 4: Completion of Facial Lines

* Draw the mandibular plane (Subgonion to Menton).
* Draw the Facial Plane (N to Po).
* Draw the New Facial Axis (Cc to Gn) (Fig. 4-12E & F).

Now the direction of facial growth, or the behavior of the chin, can be visualized by comparison to the T1 tracing.

The oral gnomon will be adjusted later according to the type of facial behavior.

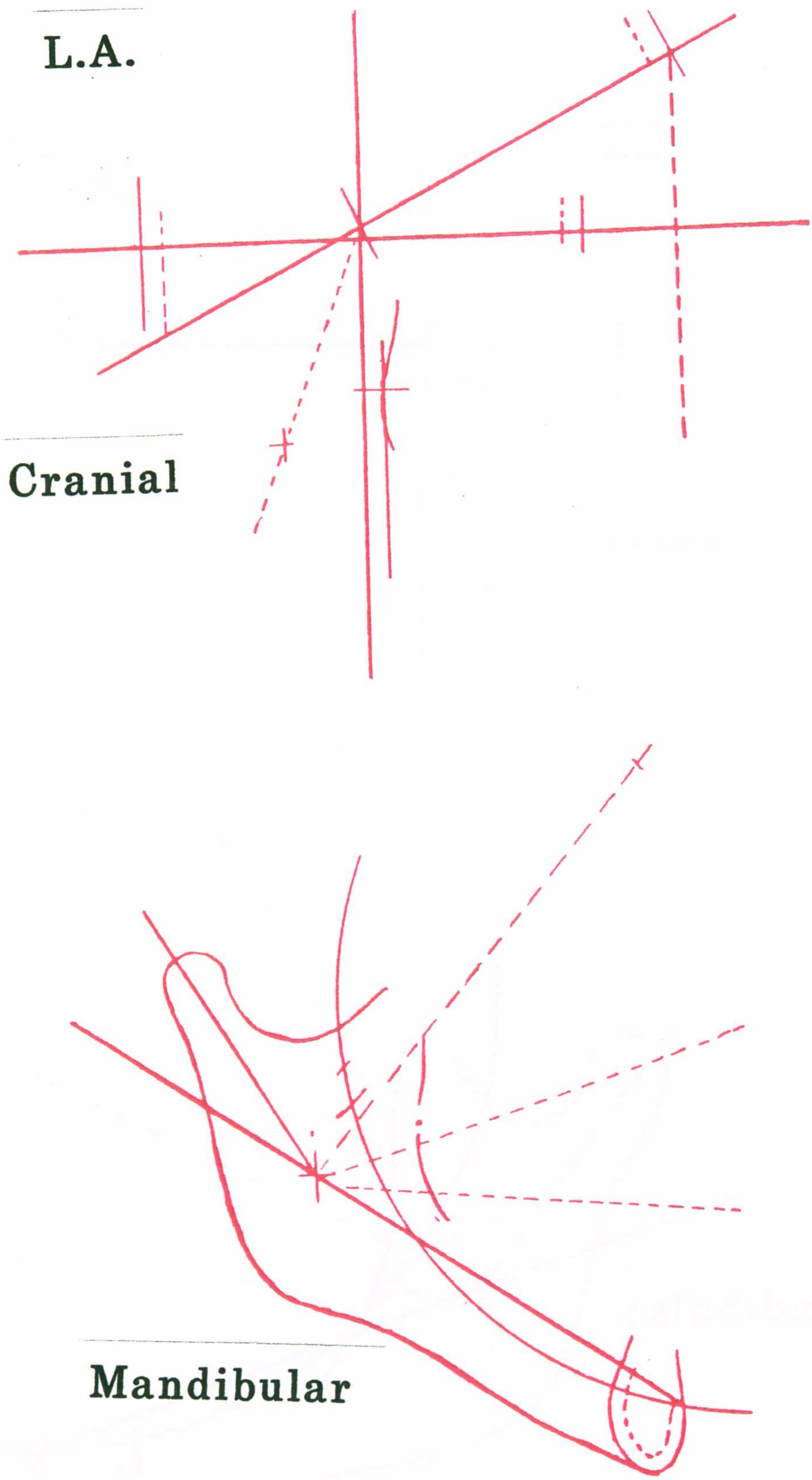


Fig. 4-12A Independent cranial and mandibular forecasts for L.A. (female). (Now fitting of the two is the challenge.)

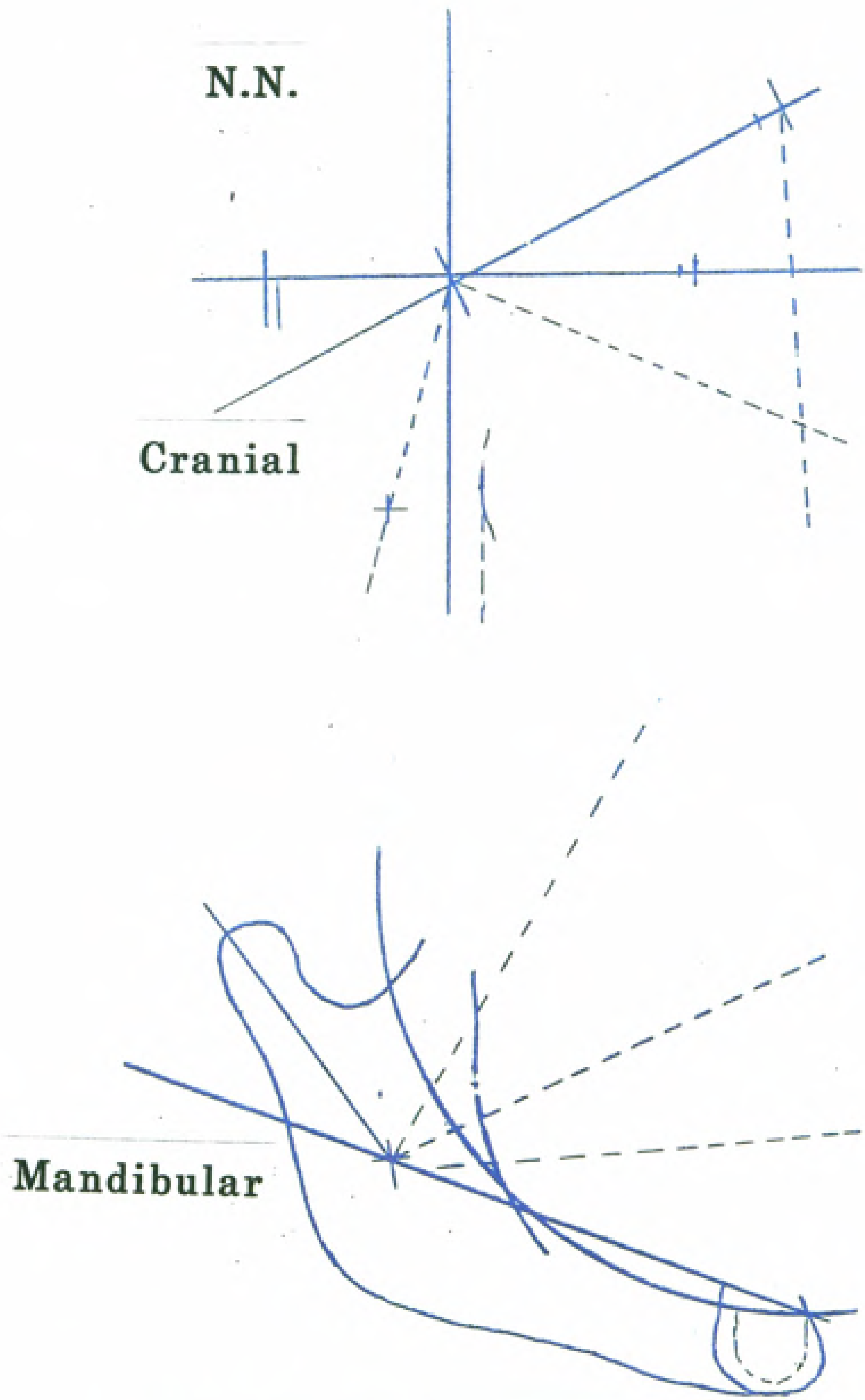


Fig. 4-12B Independent cranial and mandibular forecasts for N.N. (male). (Fitting of the two is the most difficult step.)

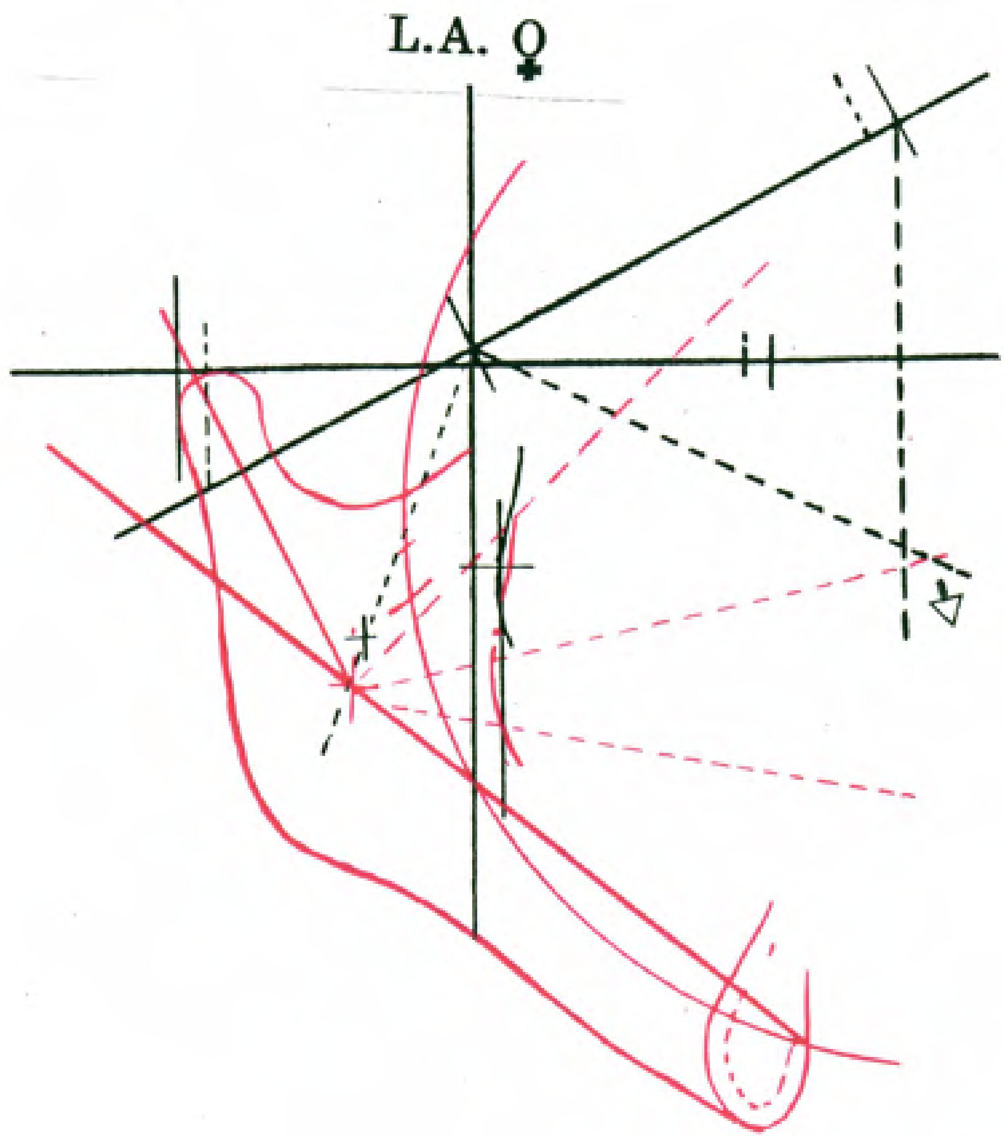


Fig. 4-12C Fitting for female L.A.: The mandible (in red) is adjusted to the cranial base (in black).

Step 1: Place condyle at predicted Cp position on the Frankfort Plane.

Step 2: Rotate the mandible by evaluation for the Xi Axis, the Rr line, and the Xi Nasion line.

Step 3: Copy the basic cranial reference onto the mandibular forecast.

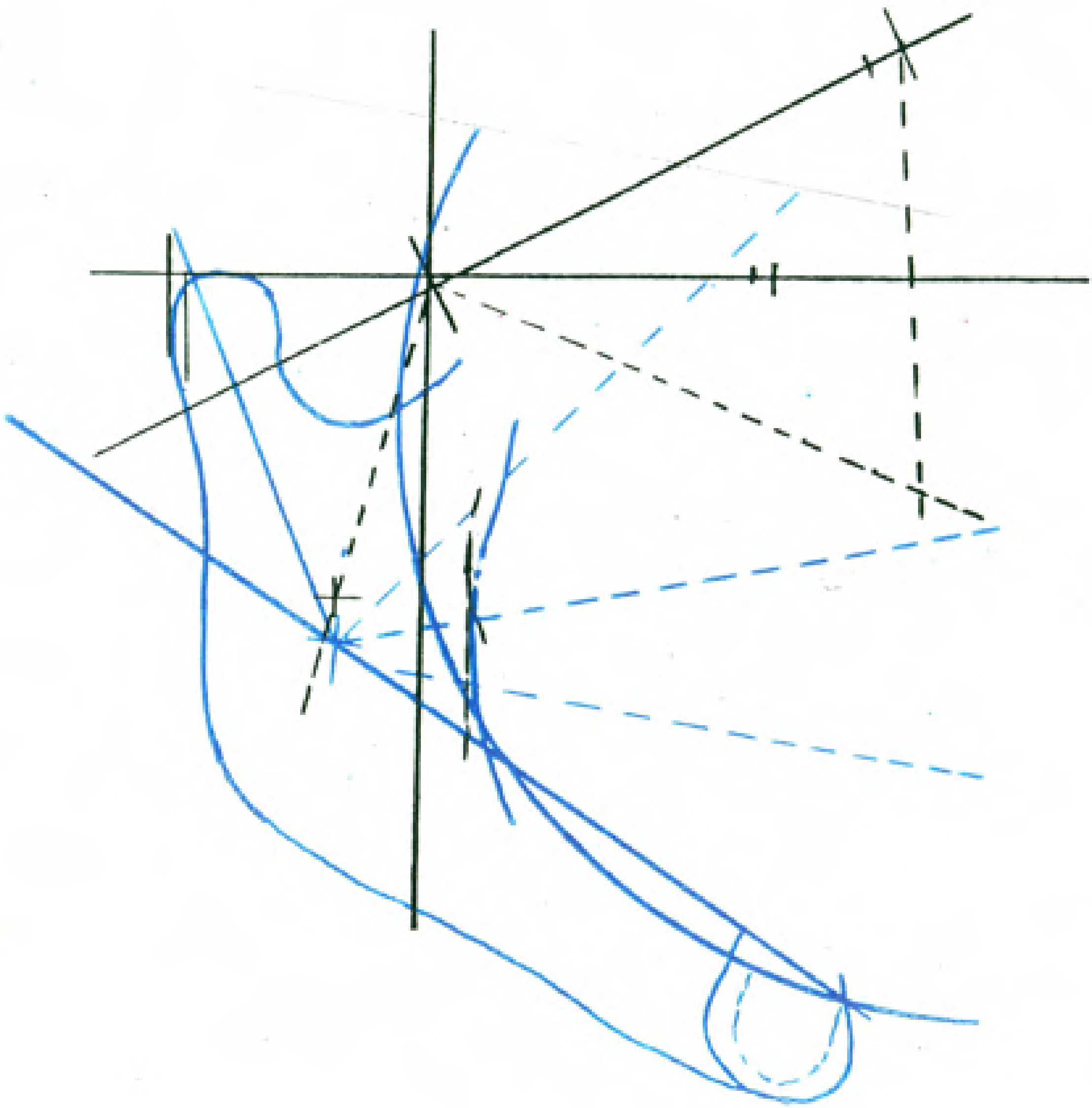


Fig. 4-12D Fitting the two basic forecasts for N.N. (male). The male mandible is in blue. (See Fig. 4-12C and text.)

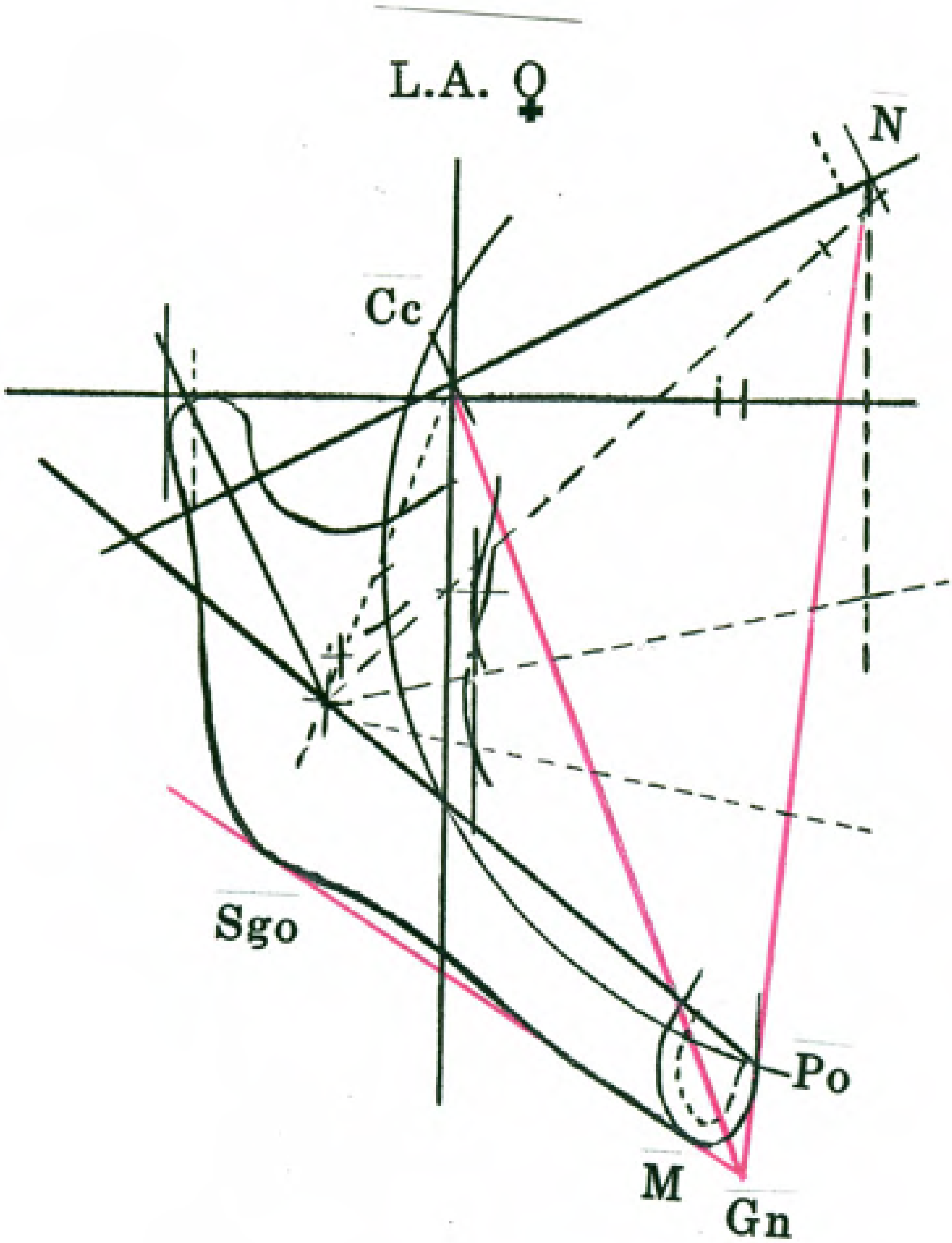


Fig. 4-12E Facial Planes for L.A. [Red]
Step 4 of the fitting procedure:

The Facial Plane	N-Po
The Facial Axis	Pt (Cc) Gn
The Mandibular Plane	Sgo-M

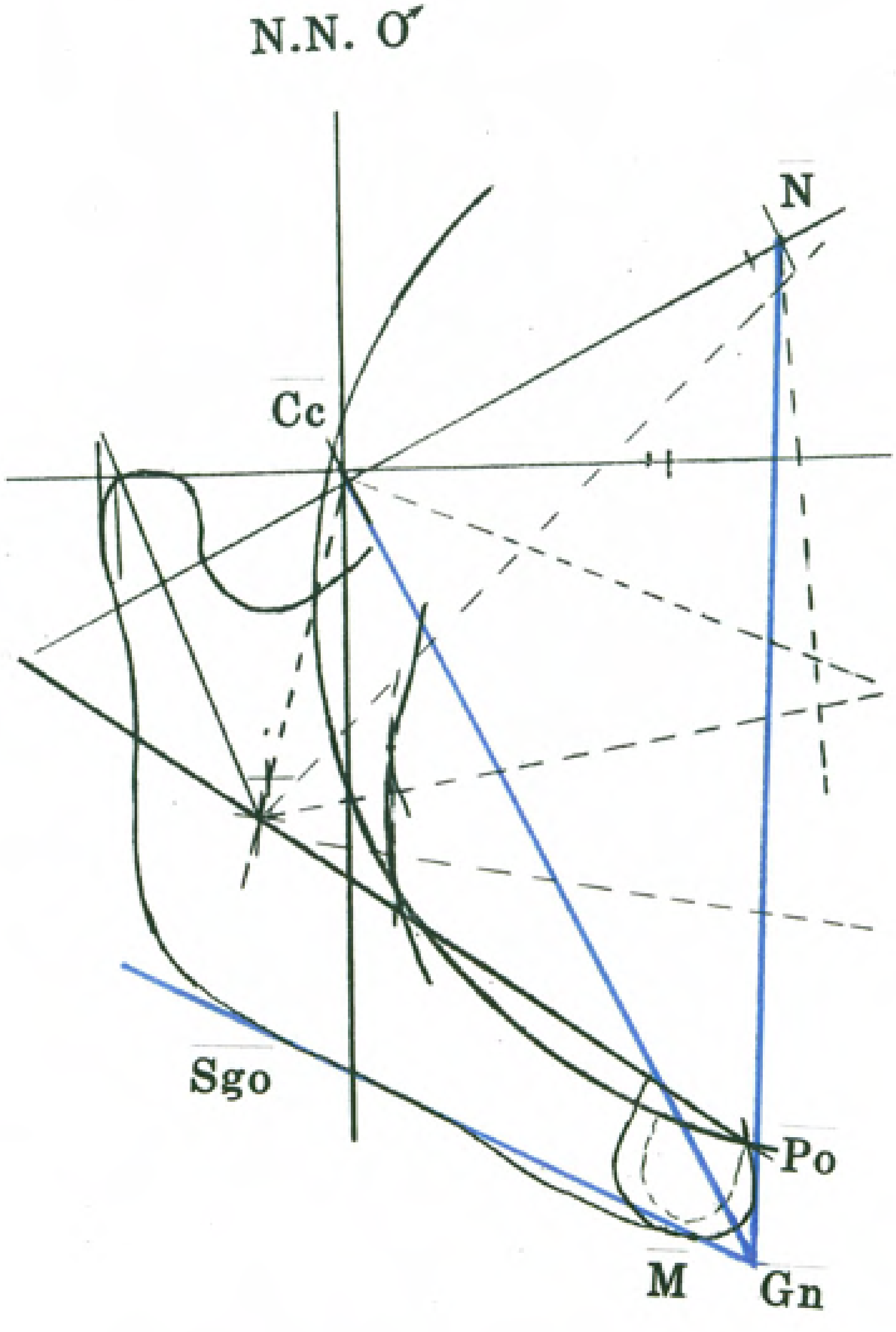


Fig. 4-12F Skeletal Planes for N.N. [Blue]:
Facial Planes
Facial Axis
Mandibular Plane

Step 5: **Prediction of the Maxilla** (Palatal Elements)

A. For Midface Depth:

1. The provisional angle BaN-Point-A was described in Step 5 of the cranial base forecast (see Fig. 4-7). Therefore, copy (without treatment) that provisional N-A line (see also Fig. 4-12C & D).

Note: This angle (BaNA) in the Caucasian population is 63°±3° and averages more in high convexity Class II, less in Class III.

Conditional Factors: Without treatment the N-A line angle to BaN is quite stable. One study showed that it changed about 1° forward in ten years, which is little more than a tracing error. Thus, with growth the forward development of Nasion and Point A behave at almost exactly equal rates. In addition, the angle formed by the N-A line (also called the Nasal Plane) to Frankfort Plane does not usually change. The average angle, in normal Caucasians, is almost a perfect 90°, but varies ±2.3°. In some brachyfacial faces the angle will increase, but rarely in long faces it will decrease.

B. Forecasting Maxillary Height

1. The height for Ans was provisionally dashed in at Step 9 of the Cranial Base. It was accomplished thusly:
   - (a) Observe a point at the intersection of the Nasal plane (NA) with the Org line (Ans-Xi). This is called Ip, or Intersection Point. See original tracing (T1) and the forecast (Tf). Orientation revealed the crossing of the two dashed lines at a new Ip point.
   - (b) Superimpose the Ip of Tf on the original Ip of T1 (Fig. 4-13A & B).
   - (c) Recompose the anatomy of the anterior nasal spine, and
   - (d) Reform Point A as a function of height of the oral gnomon (Fig. 4-13C & D).
   - (e) With the Ans superimposed, copy the original angle of the Palatal plane to the BaN plane. (The dearth of change is remarkable in the angle of the palate to BaN without treatment.)

2. The oral gnomon is adjusted to Facial Axis behavior, i.e., opened in an increased vertical facial expression (see Fig. 4-13A).

3. With the agreement between the org line and the Cc-Ans line by keeping the palatal plane parallel to the BaN Plane, the palate can be formed (see Fig. 4-13C & D).

Discussion:

The Vertical

The forecast of the vertical behavior for the maxilla as expressed from the anterior nasal spine can be confusing.

A first clue for the vertical position of the anterior nasal spine is made from the angle N-Cc-Ans (see Step 4 - Cranial Base). This height angle starts, at age 3, at 47° (almost equal to the oral gnomon) but increases at a mean rate of 0.3° per year.

The height of the maxilla (Ans) is secondly forecast from the mandibular Corpus Axis. This is due to the regularity of the angle of the oral gnomon which is 46°±3° in the normal. If the facial axis is constant without treatment, the angle tends to be constant.

The mandible is positioned in the forecast by the ramus position; Xi Axis and Rr position are a statement of muscle conditions.

A third clue for the midface vertical is the palatal plane to BaN. Findings revealed that the original palatal plane at age 6 was 26° and reduced only 1° in ten years. Therefore, from a practical point of view it can be considered almost a tracing error in change.

The Posterior Nasal Spine remains, on average, the same distance from PTV horizontally throughout the growth experience.

Conditional Factors:

If the Facial Axis has opened, the oral gnomon may open one degree for each opening of the Facial Axis. If the Facial Axis closes, the oral gnomon (denture height) may close in a ratio of about 50%. Greater extremes are to be considered (see Fig. 4-13). In other words, depending upon change of the facial axis, the "denture height" angle is adjusted.

* * * * *

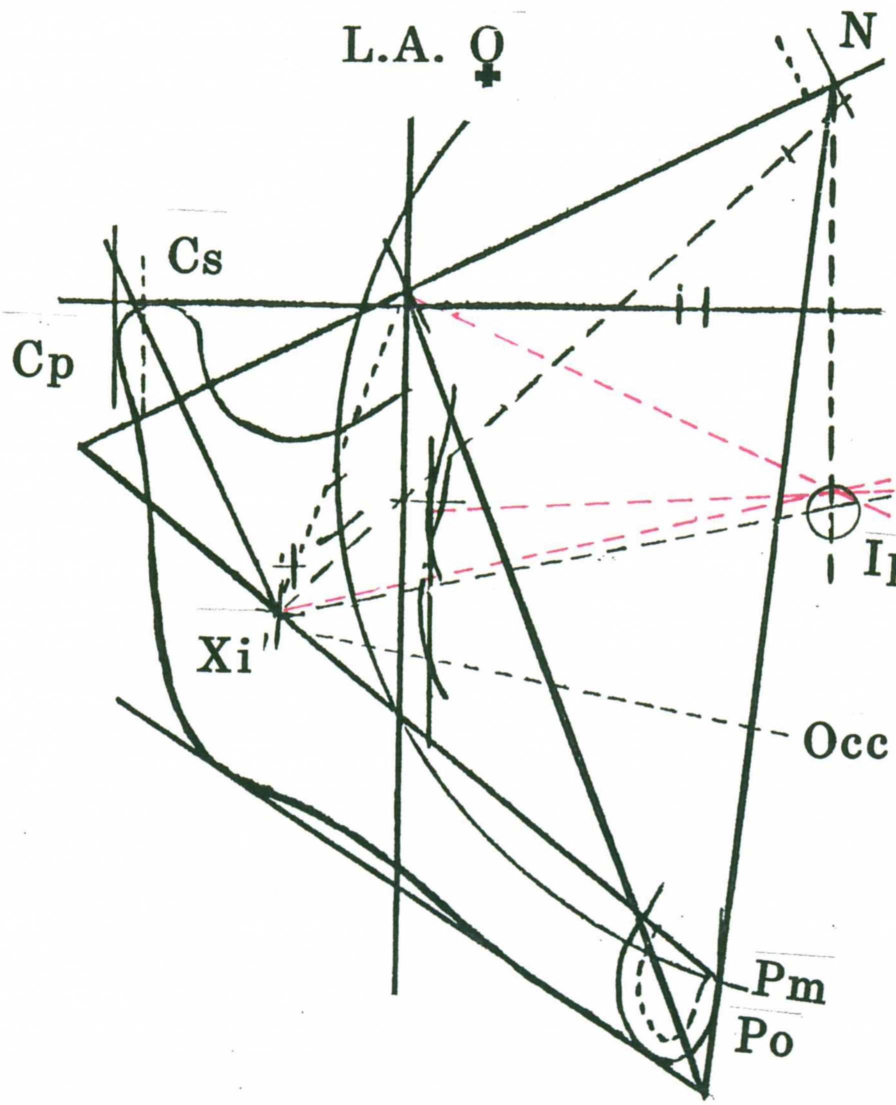


Fig. 4-13A Maxillary Forecast for L.A.
The crossing of the line N-A with the org line (Xi-Ans) is called the Intersection point for the maxilla (Ip). The oral gnomon (Ans-Xi-Pm) is adjusted depending upon the predicted behavior of the Facial Axis. Arbitrarily each degree of change in the Facial Axis effects a 0.5° change in the oral gnomon. The vertical is assessed by line Cc-Ans. Illustration is without treatment, as treatment can affect the midface.

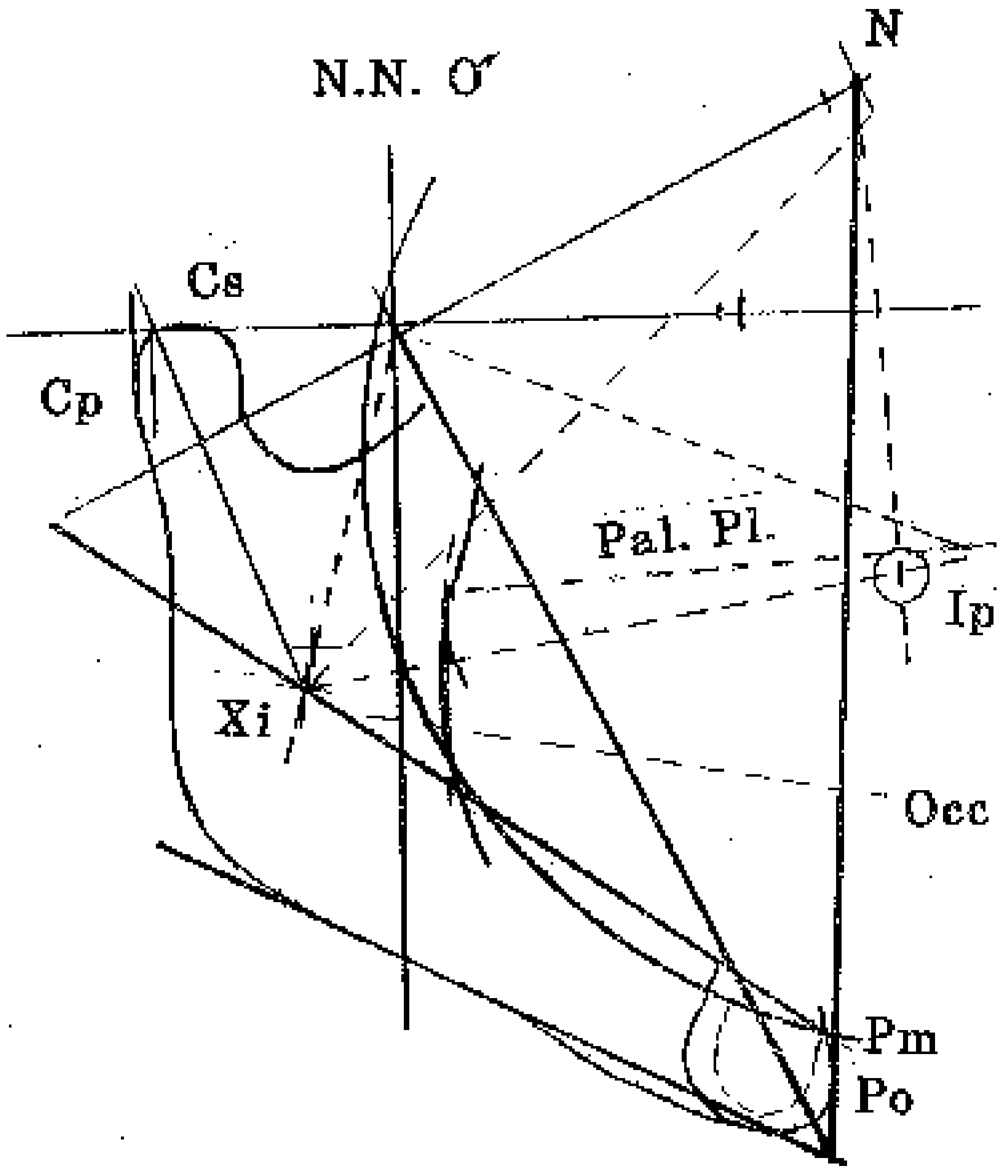


Fig. 4-13B Maxillary Forecast for N.N.
Intersection point (Ip) is employed as reference for positions of the maxilla. The palatal plane without treatment is maintained at the same angle to BaN. (See legend for Fig. 4-13A and text.)

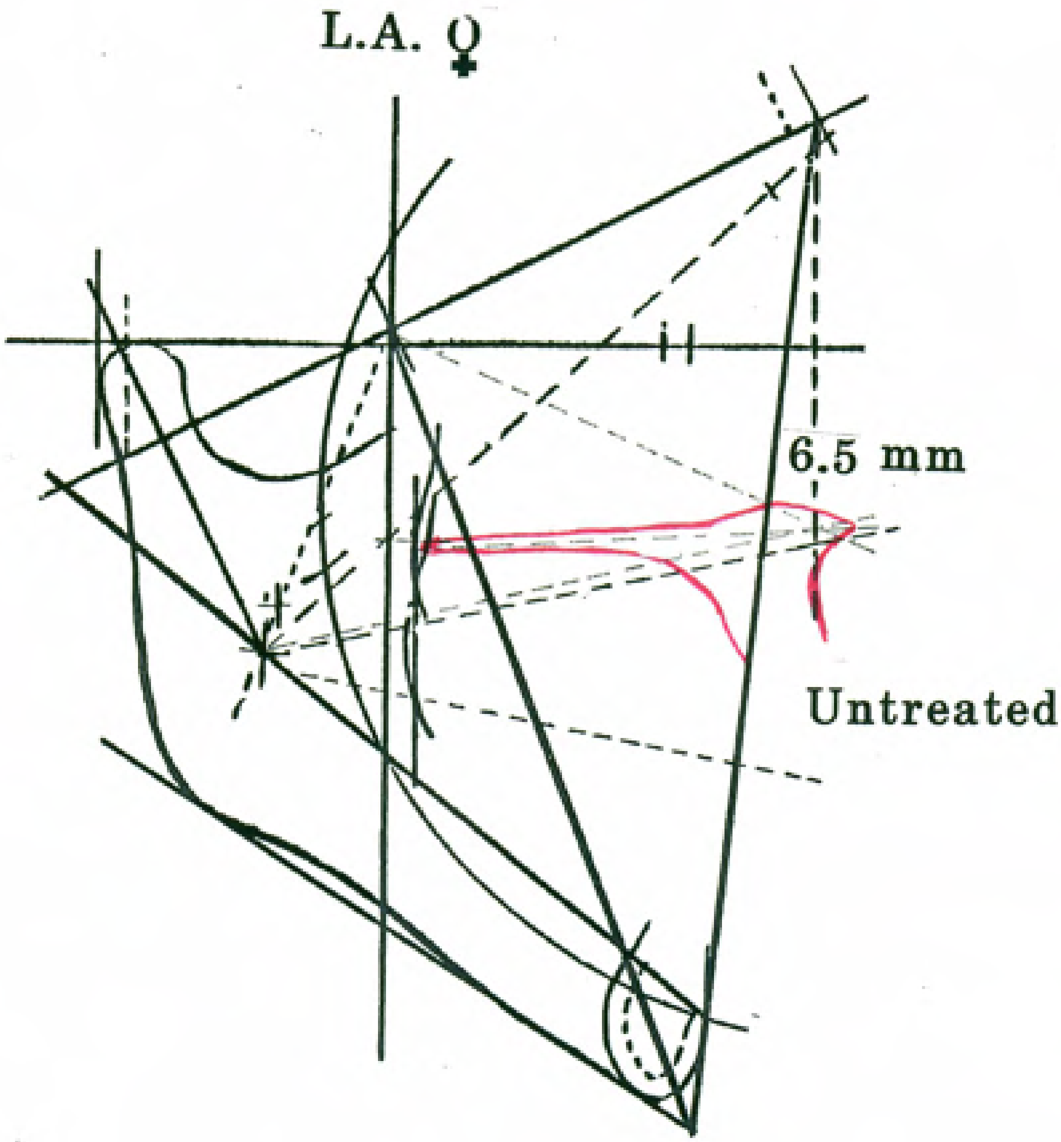


Fig. 4-13C Predicted maxilla [red] for female patient L.A. (without treatment).

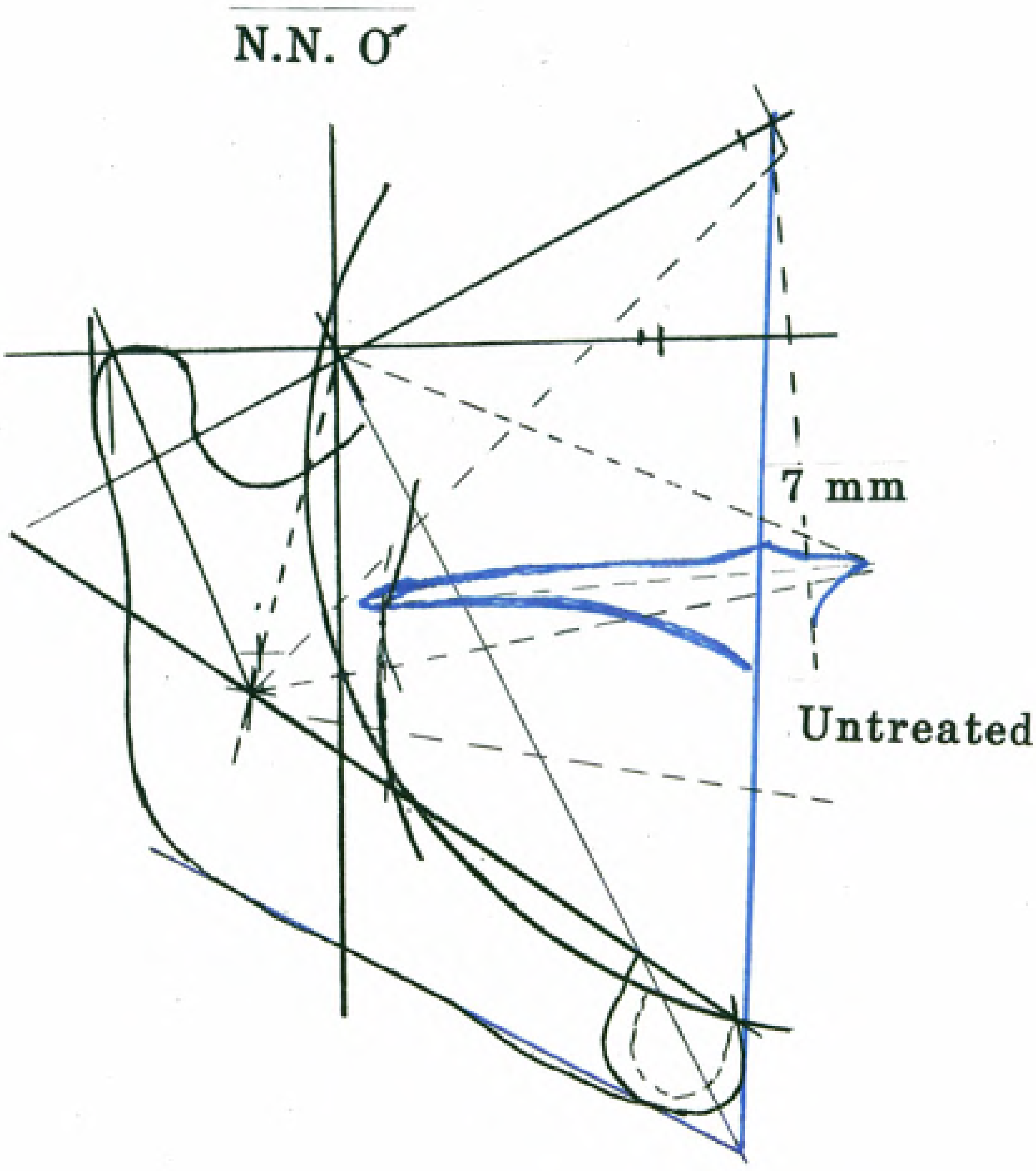


Fig. 4-13D Forecast of maxilla for male N.N. [in blue] (without treatment).

The Skeletal Reference Lines

With Point A determined (see Fig. 13), the new APo plane for the forecast (Tf) can be drawn. **The relative reduction, or change, in convexity without treatment can be evaluated.** This is accomplished by measuring the position of Point A relative to the Point A at T1 and Tf, which provides valuable information for clinical work (Fig. 4-14A & B).

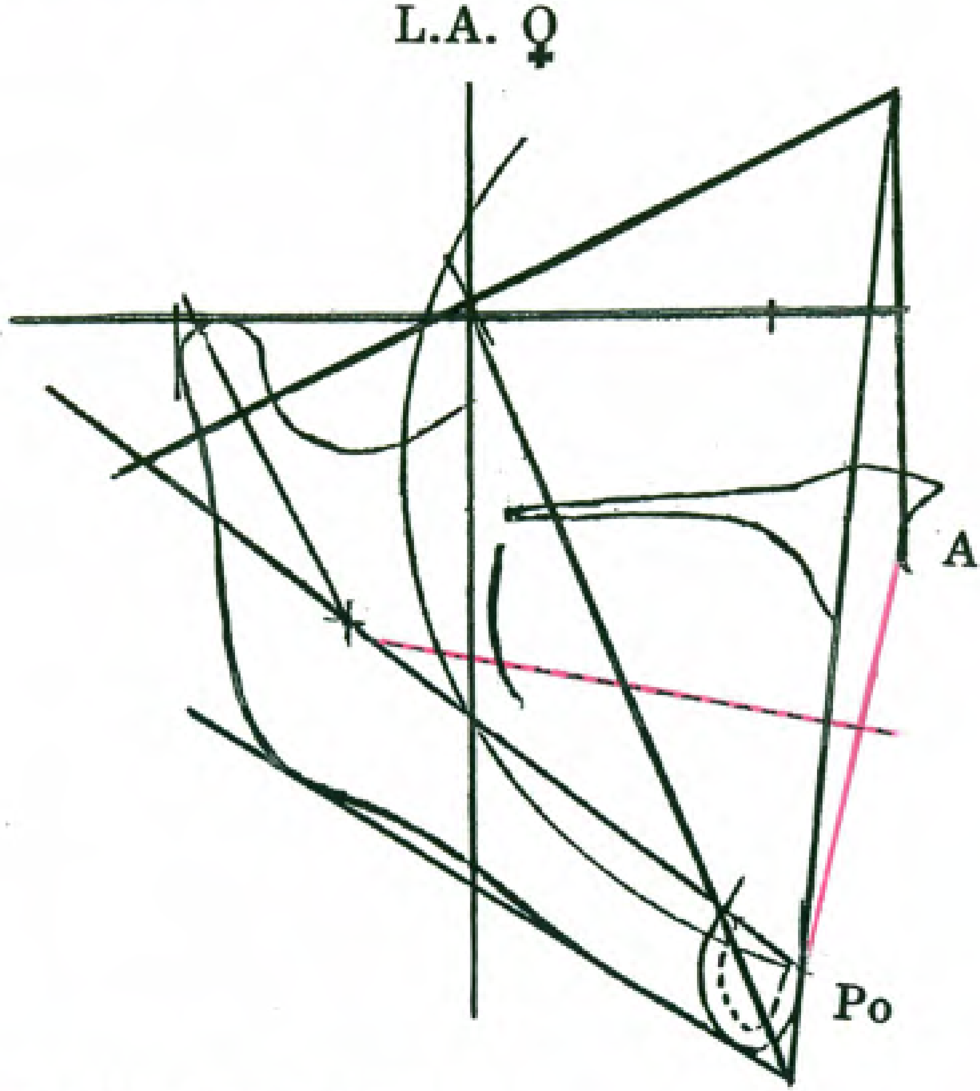


Fig. 4-14A Denture References for L.A.
The new point A suggests probable convexity change (A to Facial Plane) in mm.
The APo Plane and occlusal plane serve as references for tooth positions.

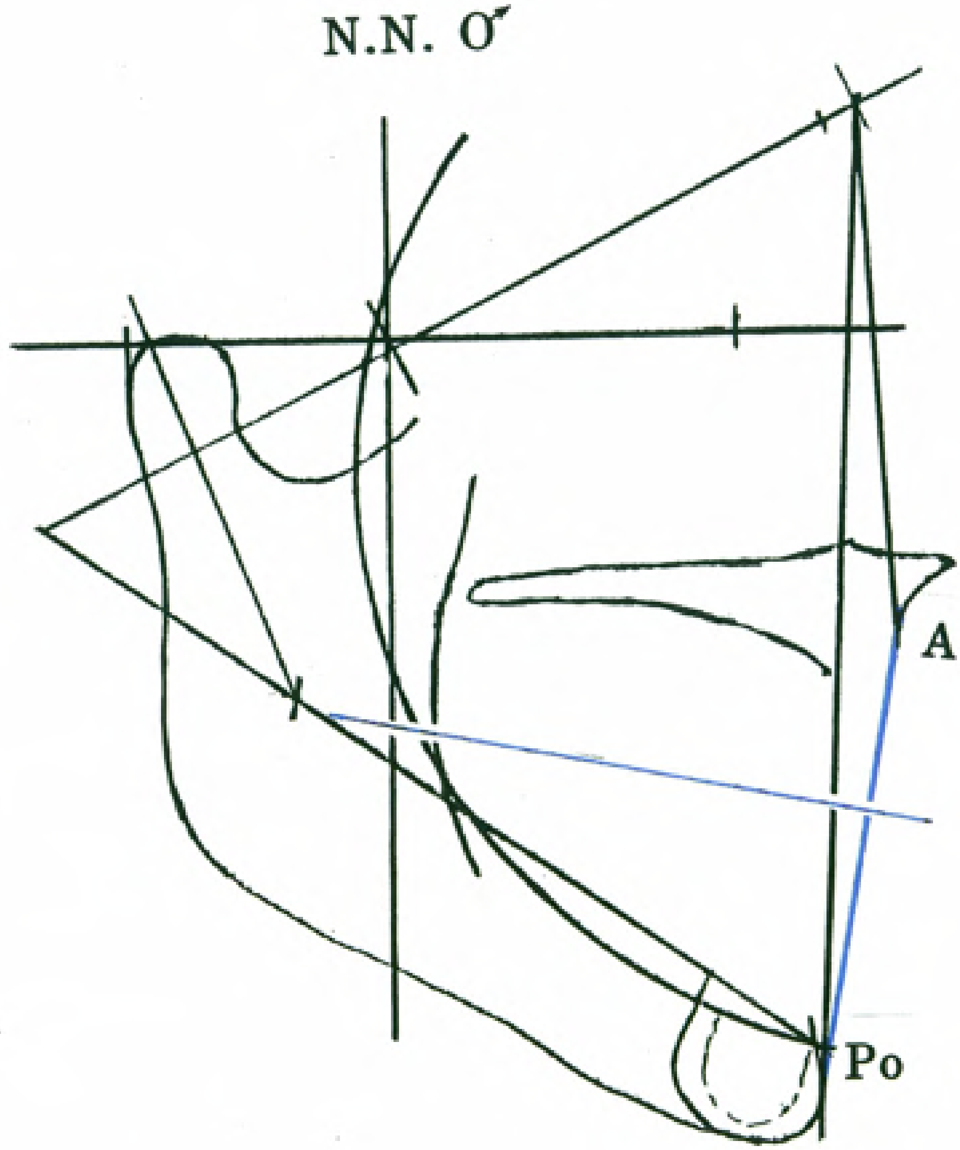


Fig. 4-14B Predicted convexity change with untreated natural growth in patient N.N. Note APo Plane and occlusal plane for basic orientation of the teeth.

PART FOUR: Teeth

Occlusal Plane Behavior (Dental)

Discussion: Study of the computer composites revealed that the eruption of height of the upper molar was determined by the growth of the mandible. This is because the occlusal plane behaved almost precisely with Xi Point. Therefore, the development of the plane of occlusion or eruption of the upper molar is determined by the growth behavior of the mandible.

If a patient exhibits asymmetrical ramus growth, the differences in the height of the ramus at the subgonial areas are dramatically evident. In asymmetry the occlusal plane will differ from the opposite side half as much as the differences the mandibular plane or lower border will exhibit. That finding is unequivocal without treatment in the author's experience.

With the order established relative to the corpus axis and the occlusal plane, the eruption of the lower arch is contingent upon the elevation of Xi Point. This information was a breakthrough! It is still not well known by the mainstream of the profession as of this writing.

Technique for Occlusal Plane

1. Superimpose on the Corpus at Xi (see Fig. 4-14).
2. Lower the occlusal plane posteriorly 1 mm. for each 5 years for the development of the Curve of Spee.
3. Copy the occlusal plane.

Discussion

With the technique up to this point, the True Buccal Occlusal Plane and APo Plane are now available for reference.

For forecasting the problem becomes one of positioning of the teeth relative to those planes. It can start either with the lower incisor or the lower first molar.

* * * * *

Denture Emplacement

In the past orthodontists reacted to the position of the upper first molar by assuming it to be the most permanent and the most logical reference to "reason about" in diagnosis and the planning of treatment.

But whether a forecast is being made without treatment or with treatment, the primary interest lies in the position of the lower incisor as a starting point. The predicted behavior of the lower incisor, without treatment, is deduced through the clinician's method of superpositioning. This accounts for much of the controversy.

Method of Superimposing (Fig. 4-15)

If the traditional **mandibular plane** and the symphysis is used, long-term growth shows that typically the lower incisor moves lingually with natural development. If the **corpus axis** is used, the lower incisor moves bodily upward and backward relative to the symphysis while the molar moves straight upward at 90° to the Corpus Axis.

But if the superpositioning is made on the **mandibular** arc (or essentially on Pm and the anterior border of the external oblique ridge, as is very close to biologic truth), **the complete lower denture moves upward and forward.**

Compensation

It has been observed from the beginning with the use of the APo plane that the lower incisor is influenced by (1) the **oral functional condition** and (2) by the status of the **change in maxillo-mandibular relationship with growth**. In fact, this is where the word "compensation" originated (Fig. 4-16). Compensation meant a positioning of teeth in response to concavity or convexity in the facial pattern when the teeth occupied normal arrangement with each other.

From a functional standpoint the lip muscles are connected to the jaw bases. The drape of the lips, even at repose, is displayed with the upper lip being restricted more in the concave face relative to a mandibular prognathism. The opposite is true if the skeletal base or the upper jaw (Point A) is forward. Theoretically as the profile straightens with natural development both the upper and lower incisors are **contained by the lower lip**. In addition, lip-sucking, tongue-thrusting and oral habits may be continued or discontinued in the child. Without knowing behavior in advance, the prediction of anterior tooth positions is speculative and fraught with contingencies. However, adults still retaining a thumb-sucking habit may be estimated to be as high as 2% of those having the habit as a child.

The fact remains, however, that on average with essentially normal conditions the lower incisor relation to the APo plane tends to be sustained throughout the growth experience (see Fig. 4-16). Whatever the prediction of the profile may be, the lower incisor tends **somewhat to follow** the **APo plane**. Further, it tends strongly to maintain its vertical relationship to the true buccal occlusal plane without treatment. The exception to that rule is that open bites, on average, tend to close somewhat with long-term development. Findings show that closed bites tend generally to increase with continued development.

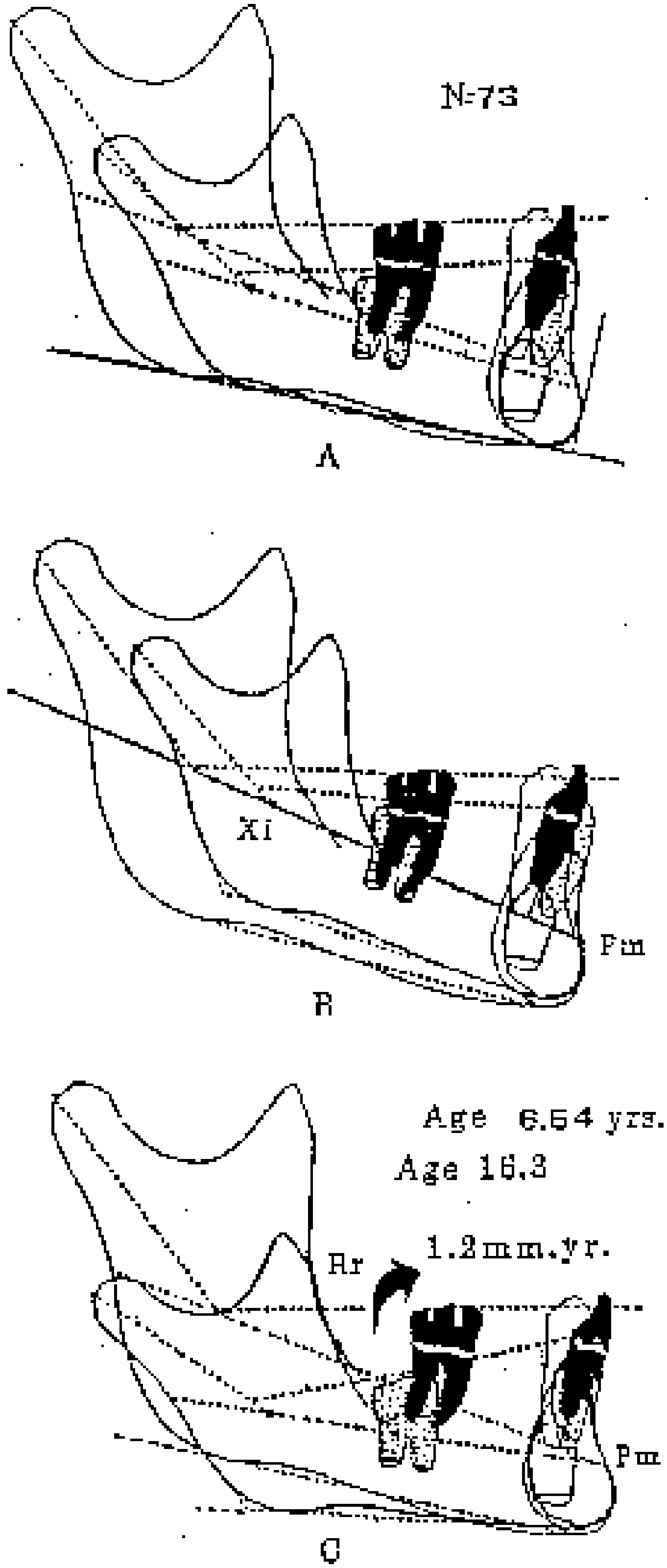


Fig. 4-15 The controversy over mandibular superpositioning as revealed by 10-year untreated composites.

A. View of the mandibular plane at the symphysis. Note molar movement upward and forward, and incisor movement backward.

B. On Corpus Axis (Pm-Xi) note straight upward behavior of molar and lingual position of incisor.

C. On the arc the whole lower denture moves forward as the molar moves 1.2 mm. each year.

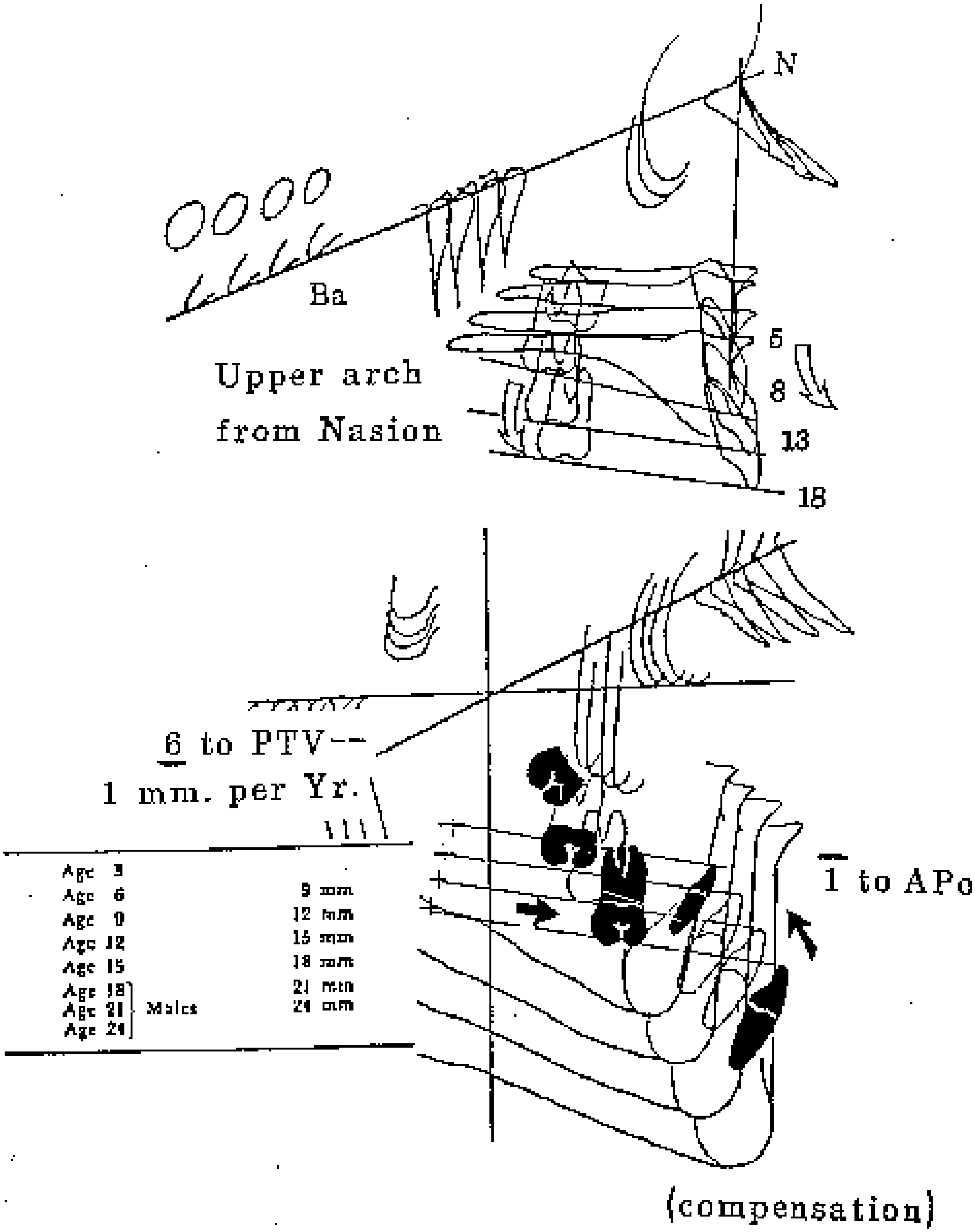


Fig. 4-16 Compensational behavior.
Note the uprighting of the lower incisor with the change in convexity. Note the forward drift of the upper arch in compensation to mandibular growth.

Development of Lower Arch Depth -- The Basic Lower Molar

Two findings have been of great interest and serve for practical utility. The first is the factor of arch depth from the mesial of the first molar to the center of the incisor tip. Normal arches have a **cephalometric** arch depth of 23.5 mm. on average (Fig. 4-17). However, in the **mixed** dentition, the depth is 25 to 26 mm. Because the lower molar when analyzed from the Corpus Axis erupts at 90°, it does not move forward, but erupts perpendicularly when analyzed with the Corpus Axis orientation.

In addition, from the Corpus Axis position the lower molar is found, without malocclusion and without loss of teeth, at an average distance of 31 mm. from a vertical to Point Pm (see Fig. 4-17). However, with this orientation the incisor moves **backward** 3 mm. from age 6 to maturity (from 9 mm. distance to 12 mm. from the Pm vertical). This is accounted for by loss of space at the second deciduous molar (mean of 2.8 mm.) plus a natural widening of the arch about 2 mm. in the premolar area. This measurement helps to assess mesial drift of the denture.

The forecasting exercises will, therefore, be conducted from the **lower first molar as a basis** first as a basis for the final position of the incisor.

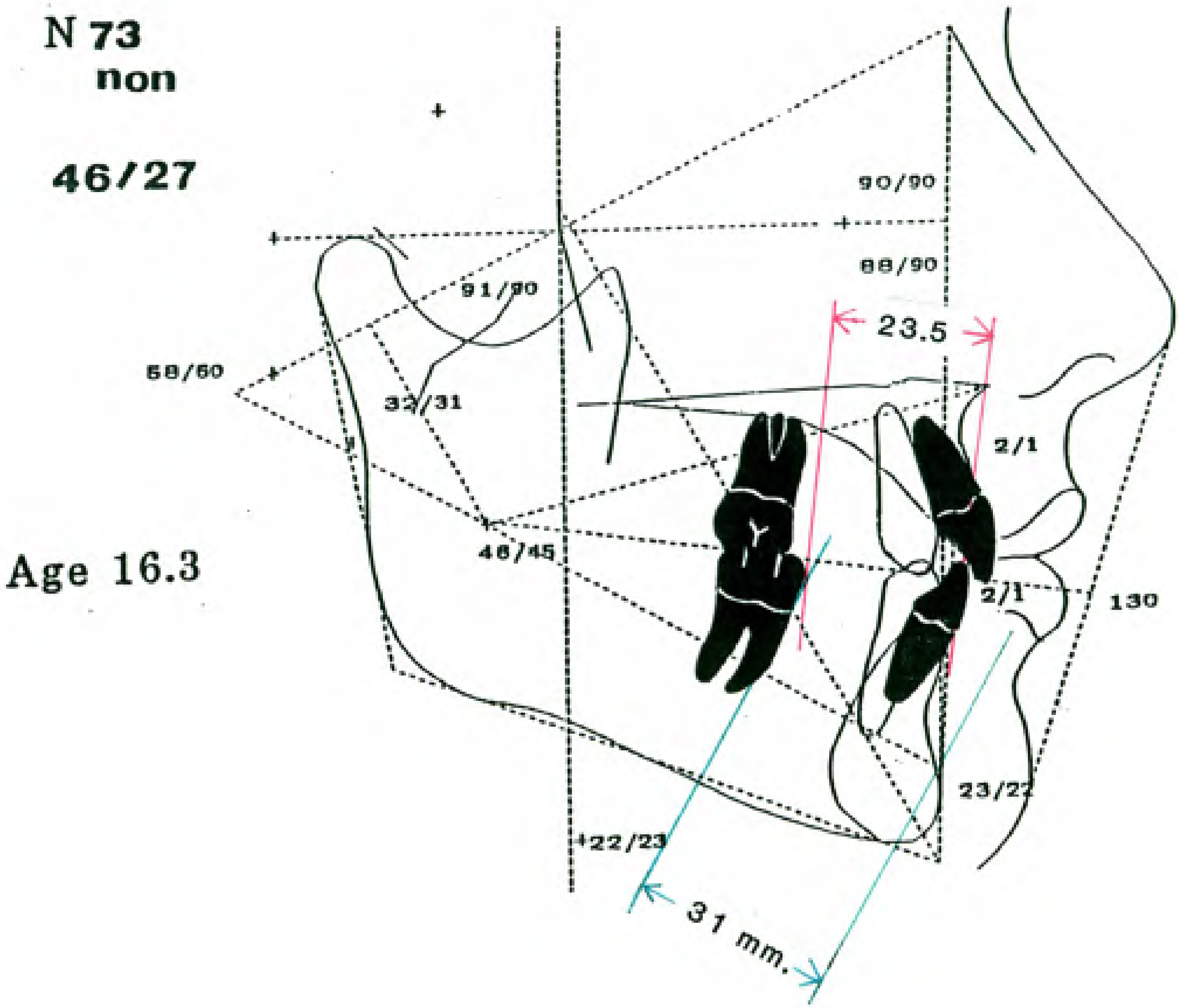


Fig. 4-17 Critical factors in evaluation of denture emplacement:
[Red] Arch depth cephalometrically is a mean of 23.5 mm. from the mesial of the lower molar to the center of the lower central incisor edge.

Relative to the Corpus Axis at Pm, the lower molar in Caucasian samples shows a mean of 31 mm., which tends to maintain itself during growth.

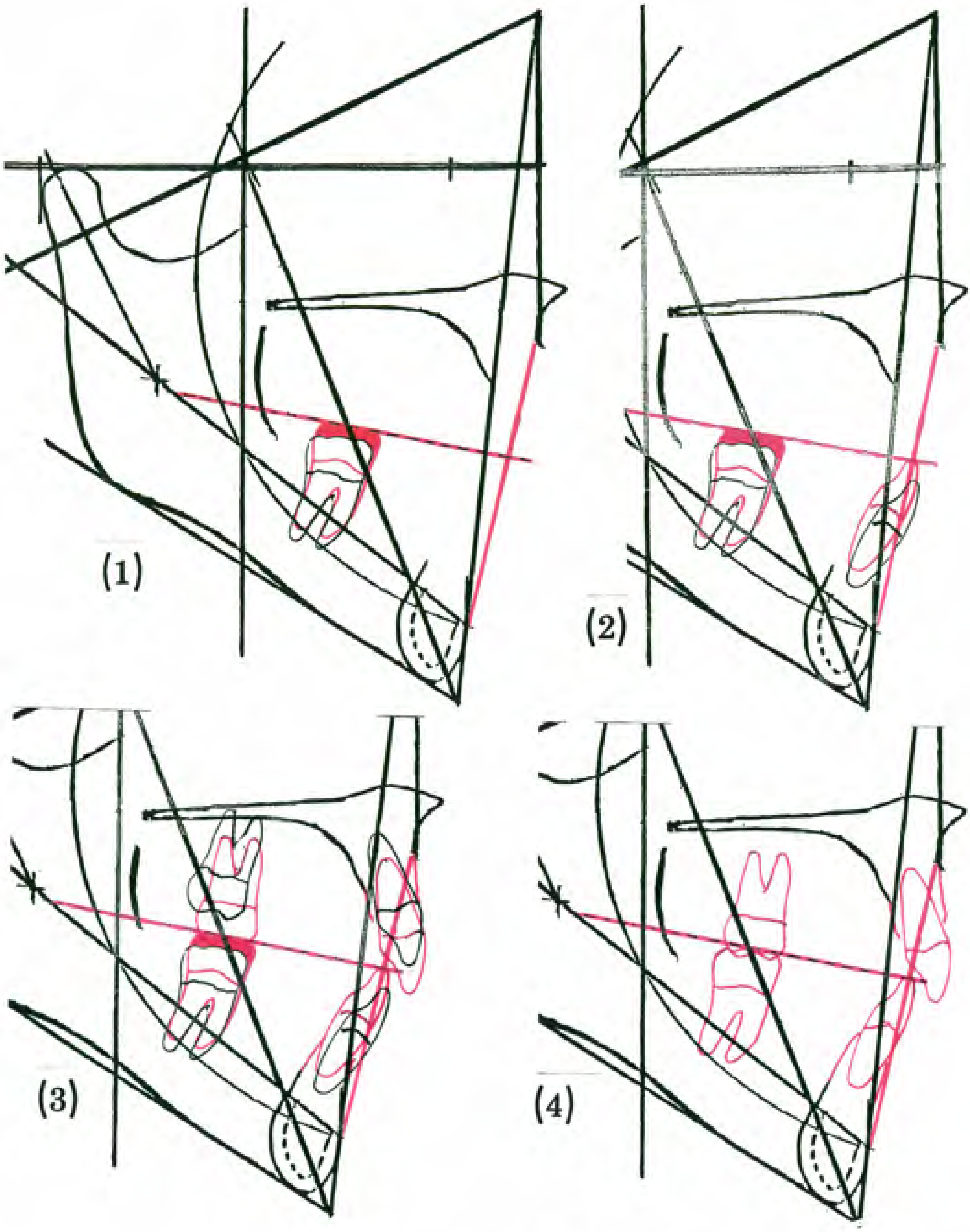


Fig. 4-18A Steps in forecasting molar position (see text).

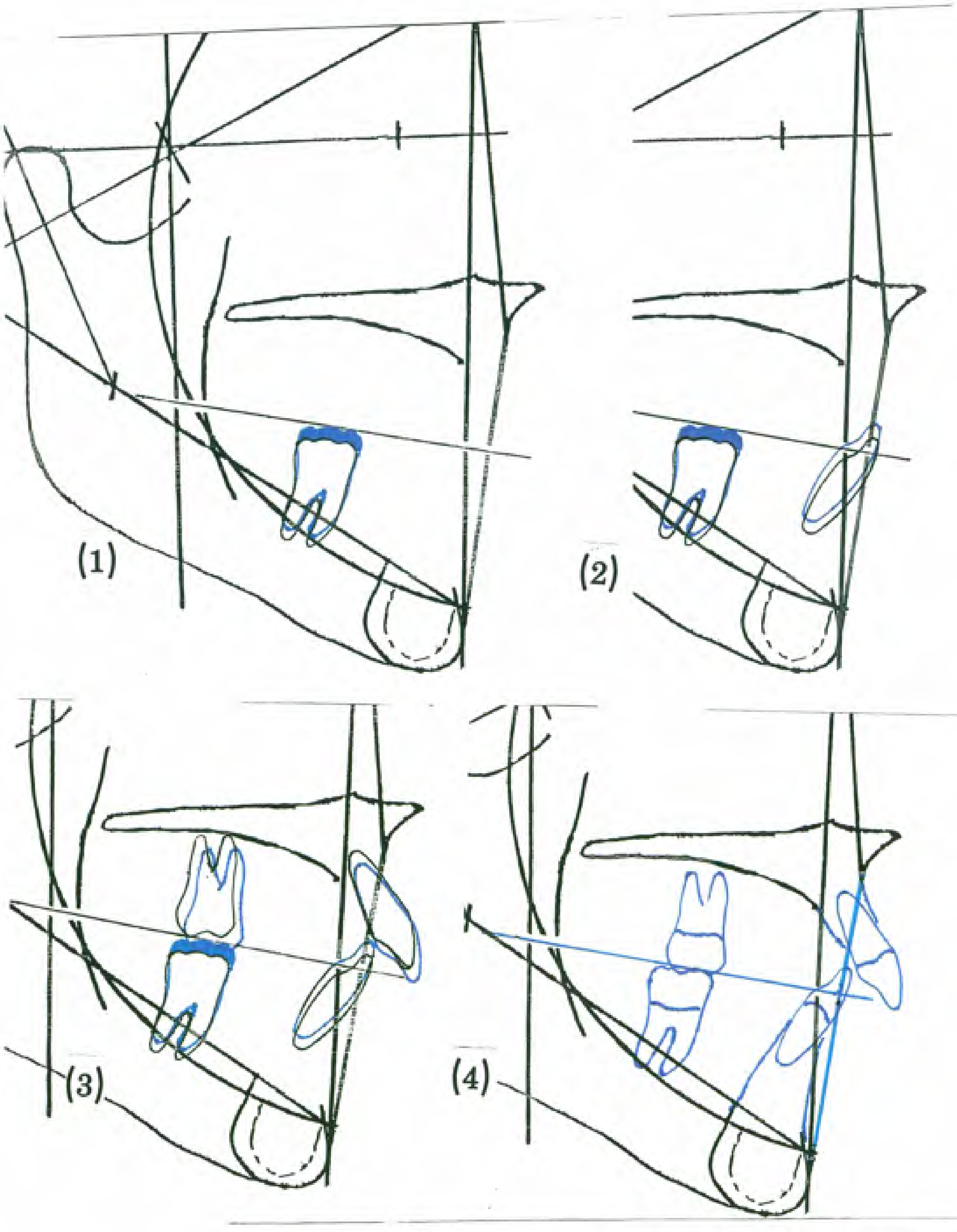


Fig. 4-18B Forecasting the denture (untreated) in patient N.N. (see text).

Step 1: **Technique for the Basic Lower Molar, Without Treatment:**

- **A.** Superimpose the Corpus Axis at Pm.
- **B.** Erupt the lower molar to the projected occlusal plane (at a right angle to the Corpus Axis T1) (Figs. 4-18A & B[1]).

Conditional Factors: It is emphasized that the true Buccal Occlusal Plane is employed. Some patients with large tongues and loose, flaccid lips display continued mesial drift. Tight lips, on the other hand, particularly the lower, contain the forward development of the arch, as witnessed by retruded lower dentures often in Class II malocclusions.

Step 2: The Lower Incisor

- **A.** Superimpose on the APo plane at the occlusal plane (Figs. 4-18A & B[2]).
- **B.** **Check** the change in arch depth as revealed from the molar.
- **C.** Check the pattern of facial development.
- **D.** Copy the lower incisor relative to the APo plane and buccal occlusal plane. [**Conditional Factors** were explained in the discussion of occlusal development.]

Step 3: The Upper Incisor

- A. Place the upper incisor in a similar overbite and overjet to the lower if normal (Figs. 4-18A & B[3]).

Conditional Factors: For a prediction of the inter-incisor relationship or the placement of the upper incisor, its position prior to the forecasting is first taken into account. In most situations, where the lower lip is trapped under the upper incisor, and the lower incisor functions against the rugae of the palate, the condition rarely corrects with growth. But in a few children with deep bite and Class II, growth will be of such magnitude that improvement in the occlusion, even to a Class I, will occur, but not often in complete closed bite. Therefore, for the predicting of the upper incisor, the behavior of the mandible is reviewed. In cases of Class II, Division 2, or deep overbite, the anterior teeth tend to worsen.

Step 4: **The Upper Molar:**

A. Copy off the same first molar relationship if the teeth are in a firm, locked position (Figs. 4-18A & B[4]).

Conditional Factors:

Under the influences of excellent mandibular development, the molars have been seen to change from Class II to Class I. Other patients have been noted to change from Class I to Class II, particularly with very tight lower lip and bands of buccinator muscles. Further, individuals have been seen to change from Class I to Class III. These dental changes in arch relationship should be realized as possibility without orthodontic intervention.

Another bit of irony is the aforementioned tendency for the upper molar to maintain a developmental cycle by moving forward a mean of 1 mm. per year as related to the Pterygoid Vertical Plane until growth is completed. This is due to two factors: first, a 0.7 mm. forward growth per year of the maxilla, and second a 0.3 mm. drift per year of the upper denture. Thus, the prediction of the upper arch relative to the lower arch has a dependency on both (1) the behavior of the mandible and (2) the conditions of the oral muscles. Once these possibilities are taken into account the final arrangement is forecast.

In subjects demonstrating dramatic change in the Facial Axis, or with great velocity of growth, some change in the occlusal relationship can be anticipated. But under normal or usual conditions, once the first molars are locked into a Class I, Class II or Class III, future behavior can be predicted as the arch relationship essentially does not change.

As a summary: the convexity of the face reduces, a compensation occurs as the upper denture migrates forward, while in the profile the lower incisor moves backward as the uprighting of the APo plane takes place (see Fig. 4-16).

Calculations for Third Molar Space

The Lower Third Molar

Once the forecasting exercise has been conducted, a prediction of the demise of the lower third molar can be made on the basis of available space. Patients in whom space is available, but who undergo a distal tipping of the lower second molar, during treatment may experience a third molar being entrapped. In this event, the third molar often will be removed even in the presence of enough space. However, many such third molars can be saved if the dentist and orthodontist make the effort.

On the other hand, when space restrictions are obvious from the forecasts, the third molar can be enucleated at age 8 to 10 years. The evaluation is made from the space available because without space the prognosis is nil. Space is assessed by relating to the external oblique ridge and the predicted Xi Point (Fig. 4-19). Articles have been published on this phenomenon.

The Upper

The upper first molar interestingly is usually located at a position corresponding to the patient's age + 3 mm. to the Pterygoid Vertical Plane to the growth cutoff period. A 15-year-old girl who has 18 mm. of space is on the borderline of having enough space for the upper third molar. Reduction of that space usually spells a poor prognosis for the eruption of the upper third molars, particularly if the teeth are large. In patient L.A. the forecasted space is only 13 mm.

SUMMARY FOR CHAPTERS TWO, THREE AND FOUR

Forecasting of facial growth and development has been argued for the past century. Until three-dimensional computer research was accomplished, practically all ideas regarding growth forecasting in long term were negative. However, after 25 years of cephalometric experience, and from the study of treatment influences, together with the advent of the computer, discoveries were made which marked quite positive progress by 1970.

Prior to the computer findings, forecasts consisted of a short-term matrix over which treatment objectives and treatment influences were superimposed. **The VTO thus became a target for the selection of mechanics in order to produce the objectives or hit the target.**

The mandibular ramus was noted to consistently bend upward and forward with normal growth when analysed from medial or internal stress lines. This

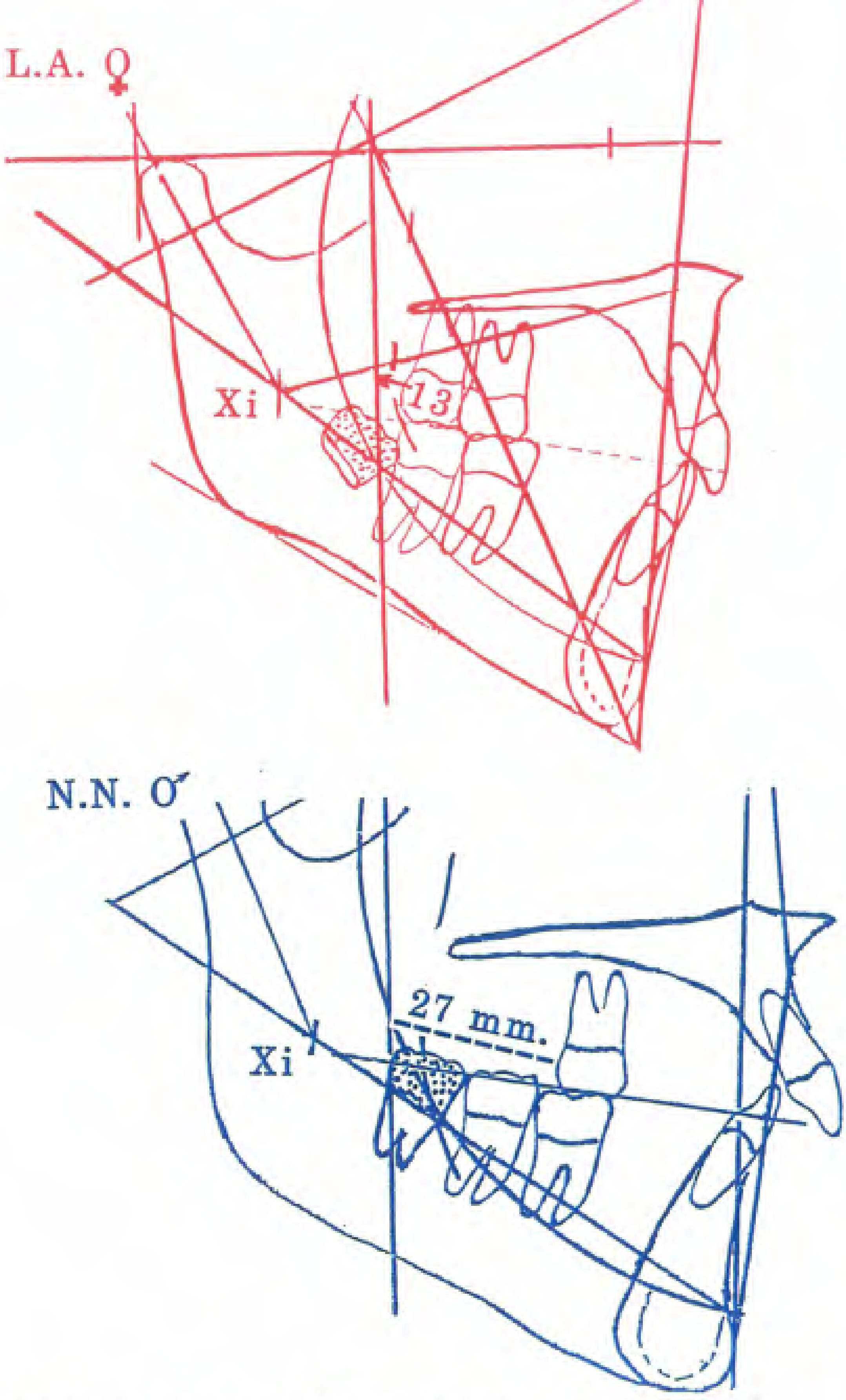


Fig. 4-19 Forecasting of third molar space.

L.A. The forecast without treatment shows only about a 10% chance of adequate eruption of the lower third molar and about 30% chance for the upper.

N.N. In patient N.N. the space is about 75%, and the prognosis is good.

indicated that a **growth curve was operative**. For working purposes a curve was located from the chin (Pm) through point Eva (located centrally at the base of the Coronoid Process using the dimension between the two points as a radius for construction). Most interest previously had been focused on the condyle and on the outside of the mandible. Thus with the discovery of a mandibular arcial growth method (thought to be the long leg of a logarithmic spiral) **long-range projections to maturity became practical**. It was subsequently noted that a polar phenomenon, gnomonic behavior and Divine Proportions characterized natural development.

As the arc became confirmed, further studies were made for appositional changes occurring on the processes as measured from the basic arc "core". The true buccal occlusal plane was dramatically associated with Xi Point. This "centroid" point on the ramus represented the mandibular foramen for the mandibular nerve, veins and arteries. It also was located at an area for insertion of the spheno-mandibular ligament which is almost tendinous in nature.

In order to apply the arcial process, further research was conducted on the the facial and the cranial scaffolding. Contrary to adding the mandible onto the skull as originally practiced, for simplicity the cranial base and face were constructed on the predicted mandible. This meant reverse thinking and was confusing to teach the inexperienced. Therefore, the technique was changed for teaching purposes to a prediction of the cranial base on the original tracing schema, or on a separate sheet of tracing paper, and a matching procedure was then rendered.

The posterior cranial base (for the condyle) was related to the Pterygoid Vertical Plane (perpendicular to Frankfort Plane). The anterior base (for Nasion) was measured from the Facial Axis (Cc) to Nasion on the BaN plane. The Xi Axis from Pt was formed with connection to traditional Gnathion. It was found to be a better reference than S-Gn. In all, eight steps were described to prepare the original tracing to receive the new predicted mandible.

Four checkpoints were employed to set the predicted mandible into the new cranial matrix. These were Concylion (superior and posterior), Xi Point (the Xi Axis) and the Ramus reference (Rr) line and the Xi relation to Nasion. Certain mandibular types behave differently, resulting in conditional factors which were learned with experience and described.

Once the mandibular forecast was completed the predicted points on the original tracings were copied onto the mandibular projection. The Facial Plane, Mandibular Plane and Facial Axis were drawn. The maxilla was located and constructed from the oral gnomon and from the anterior cranial base. With this base accomplished, the skeletal components were predicted.

For the teeth the Buccal Occlusal Plane and APo Plane were employed for reference. The lower molar and lower incisor were set first. These were followed by the upper incisor and molar in that sequence.

The soft tissue forecast will be addressed later.

For the VTG (long-term treatment goals or objectives), also to be taken up later, modifications are made for the symphysis position and Point A. Mandibular rotation as influenced by treatment is a problem. The teeth are either to be "idealized" or **placed according to feasible solutions for the given patient.** The adjustment and growth of the soft tissue is changed as contingent on the correction.

The long-range forecast to maturity has numerous functions. It has led to changes in viewpoints on treatment possibility. No orthodontist can look at a young child's malocclusion in the same light once a long-range forecast is made available.

Robert M. Ricketts, D.D.S, M.S., N.M.D

Director

American Institute for Bioprogressive Education

9106 E La Posada Court

Scottsdale, Arizona 85255

Tel (480) 948-4799

Fax (480) 367-0933